



Planning & Development Services

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Public Comments on 2nd Critical Areas Ordinance Update

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4	Kristine M Johnson	16936 Lake View Blvd Mount Vernon, WA 98274	Email	07/24/2025	78
5	Celia Miller	17201 West Big Lake Blvd Mount Vernon, WA 98274	Email	07/24/2025	80
6	Dave Rekevics	17143 West Big Lake Blvd Mount Vernon, WA 98274	Email	07/24/2025	81
7	Janet Schuirman	23170 Mosier Rd Sedro Woolley, WA 98284	Email	07/24/2025	82
8	Jenna Friebel	Skagit Drainage & Irrigation Districts Consortium LLC 2017 Continental Place, Suite 4 Mount Vernon, WA 98273	Email	07/25/2025	83
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10	Ellen Bynum	Friends of Skagit County PO Box 2632 Mount Vernon, WA 98273	Email	07/28/2025	89
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18	Marlene Finley	Evergreen Islands PO Box 223 Anacortes, WA 98221	Email	07/28/2025	581
19	Jake Koopmans	23904 N West View Rd Mount Vernon, WA 98274	Email	07/28/2025	614
20	Alison Studley	PO Box 2497 Mount Vernon, WA 98273	Email	07/28/2025	619
21	Kim Matthews	Western Washington Agricultural Association	Email	07/28/2025	621
22	Jovian Nordgren	111 Woodworth Street #301 Sedro Woolley, WA 98284	Email	07/28/2025	629
23	Lora Claus	Skagitonians to Preserve Farmland	Email	07/28/2025	633
24	Kirk Johnson	Skagit Land Trust 1020 S. Third Street Mount Vernon, WA 98273	Drop-Off	07/28/2025	638
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Robby Eckroth

From: Jan Edelstein <jmeten@comcast.net>
Sent: Sunday, July 20, 2025 12:09 PM
To: Lisa Janicki; Peter Browning; Ron Wesen
Cc: Jack Moore; Robby Eckroth; Andy Wargo
Subject: CAO Update - 200' restriction - Public Comments
Attachments: JME Comments 7.20.25 - CAO Update before BOCC .pdf;
Dr.HornerOpinionBigLakeDegraded.pdf

Dear Commissioners,

I submit herewith public comments on CAO Update/200' with attached expert report. These comments address the staff and consultant remarks at the work session, which argued for using the draft language which would eliminate the Director's ability to require a site assessment for expected off-site impacts of new development on critical areas beyond 200' from the project boundary (300' in the case of wetlands.)

In summary:

1. 200' is NOT a buffer.
2. 200' does NOT remove pollutants.
3. Distance is irrelevant for polluted stormwater sent in ditches from the development to the critical area.
See BAS Review pg. 55 which notes that stormwater sent through ditches "by passes" the buffer and "receives little water quality treatment via biofiltration."
4. Stormwater Code principally manages flow, no measurement of pollutants or requirement to reduce or eliminate them.
Stormwater Code does not "protect functions and values of critical areas" as required by the GMA, and confirmed in Stevens County v. EW GMHB.
5. 200' restriction precludes consideration of the cumulative impact on the critical area from diverse projects.
6. Includes imbedded images which demonstrate the failure of the Skagit Stormwater Code to protect Big Lake from stormwater pollutants.

Please protect all critical areas adversely affected by new development, not just those critical areas within 200' of the project boundary.

Thank you for your consideration,
Jan Edelstein

Jan M. Edelstein
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July 20, 2025

Skagit County Commissioners

Via e-mail.

cc: Jack Moore, Robby Eckroth, Andy Wargo

Dear Commissioners:

Please - Fix the Critical Areas Ordinance – Remove the 200’ limitation on the requirement for critical area site assessments for new development. Please protect all critical areas adversely affected by new development, not just those critical areas within 200’ of the project boundary.

SUMMARY:

1. Reliance on a 200’ zone incorrectly assumes the zone is a well vegetated buffer that is capable of filtering out all stormwater pollutants, including phosphorus, sediment, and 6PPD.
2. The 200’ restriction ignores that stormwater is managed through a drainage system which delivers runoff to critical areas more than 200’ from the project boundary.
3. Reliance on County Stormwater Code incorrectly assumes that compliance with the Code is sufficient to protect the functions and values of anadromous fisheries and other critical areas from stormwater pollution.
4. The 200’ restriction prevents consideration of cumulative impact on the critical area from diverse projects.

SCIENCE:

1. *“Polluted stormwater runoff is the leading pollution threat to our lakes, rivers, streams, and Puget Sound.”* Dept. of Ecology¹
2. *“Despite using some or all of the practices identified in the manual, some degradation of receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development.”* Dept. of Ecology, 2024 Stormwater Manual, pg. 60.
3. Once a riparian buffer becomes saturated with phosphorus, its capacity can be severely limited, to the point of having *“no net effect on phosphorus.”* BAS Review, February 24, 2025 pg. 43.
4. *“Stormwater runoff that is conveyed through stream buffers in pipes or ditch-like channels and discharged directly to stream channels “short circuits” or bypasses buffer areas and receives little water quality treatment via biofiltration.”* BAS Review, pg. 55.

¹<https://apps.ecology.wa.gov/publications/documents/1103060.pdf>

DISCUSSION

1. Reliance on a 200' zone incorrectly assumes it is a well vegetated buffer that is capable of filtering out all stormwater pollutants.
 - a. No factual basis for the assumption that the 200' around the project's perimeter provides a well vegetated buffer.
 - b. No factual basis for the assumption that even if there is a well vegetated 200' riparian buffer, it is capable of filtering out the toxic soup of stormwater pollutants before they reach the receiving water.² For example, the BAS Review dated February 24, 2025, observes that once a riparian buffer becomes saturated with phosphorus, its capacity can be severely limited, to the point of having *"no net effect on phosphorus."* BAS pg. 43.
 - c. The BAS Review, when describing Functions and Values of Streams Lakes and Ponds, and Riparian areas, concentrates on high flow impacts that come with the addition of impervious surfaces (pg. 35). While it acknowledges pollutants in stormwater, it focuses on buffering processes to strain out some portion of some of the pollutants with no consideration of cumulative impacts on any individual areas critical to anadromous fish. The BAS Review acknowledges that slope and type of soil exacerbate pollutant loading in stormwater runoff (pg. 41), yet the Gap Analysis does not identify the County Code's failure to address this important condition.³
 - d. Finally, the BAS Review does acknowledge that riparian buffers offer no water quality protection when stormwater is delivered by conveyances such as ditches and culverts.
"Stormwater runoff that is conveyed through stream buffers in pipes or ditch-like channels and discharged directly to stream channels "short circuits" or bypasses buffer areas and receives little water quality treatment via biofiltration." (Pg. 55).
 - e. The description of the impact of "contaminants" that come with the flow is brief and dated (pg. 39).
 - f. Much has been learned about the impact of stormwater pollutants on Puget Sound and its tributaries in recent years.
 - i. The Department of Ecology states:
"Polluted stormwater runoff is the leading pollution threat to our lakes, rivers, streams, and Puget Sound."
 - ii. See 2024 Ecology Stormwater Manual, pdf pages 55-61, 65-71, for a listing of various pollutants carried in municipal stormwater.
 - iii. See also Dr. Richard Horner's November 19, 2024, report on stormwater pollutants, and management thereof, as it impacts Big Lake. Includes discussion of the impact of slope and soil erosivity on pollutant loading in stormwater runoff. Pgs 5-12, 16-18, 23-26. (NOTE: This Report was submitted to the Planning Department and Ordinance Consultant by e-mail dated December 10, 2024.)
 - iv. 2024 County NPDES Permit – Appendix 7 - Determining Construction Site Sediment Damage Potential. At a minimum, this assessment tool could be used

² Dept. of Ecology 2024 Stormwater Manual: See pages 55-61, 65-71.

to always require Critical Area Site Assessment when the construction site sediment damage potential is rated high.⁴

2. 200' restriction ignores that stormwater is managed through a drainage system. The goal of the County's drainage system is to protect adjacent properties and roads from flooding by delivering stormwater runoff directly to the receiving water by way of ditches, culverts and other structures, rather than by infiltration and dispersion.

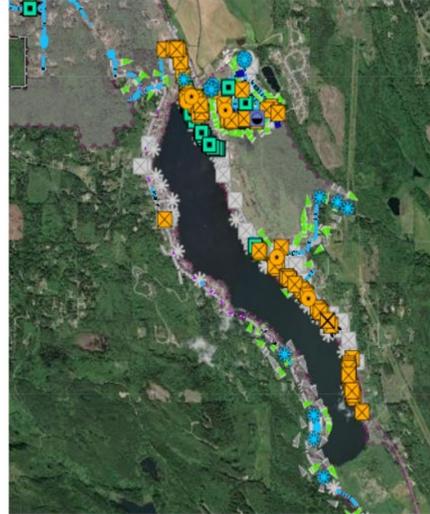
WHERE IS THE BUFFER?

“Polluted stormwater runoff is the leading pollution threat to our lakes, rivers, streams, and Puget Sound.”

Dept. of Ecology
Washington State



NW Big Lake
Drainage Facility



Skagit GIS map
NPDES Drainage Facilities

3. Reliance on County Stormwater Code to address pollution is misplaced. The stormwater code with its reliance on Ecology's 2024 Stormwater Manual does not restrict pollution. The Code and the Manual focus primarily on rate of flow, with recommendations for treatment. Significantly, the Manual does not measure pollutants, nor does it require the reduction or elimination of stormwater pollutants before the runoff reaches critical fish habitat. Finally, it does not assess or consider the impact of the proposed polluted stormwater drainage on the function and value of the critical areas through which the stormwater passes or is ultimately discharged.

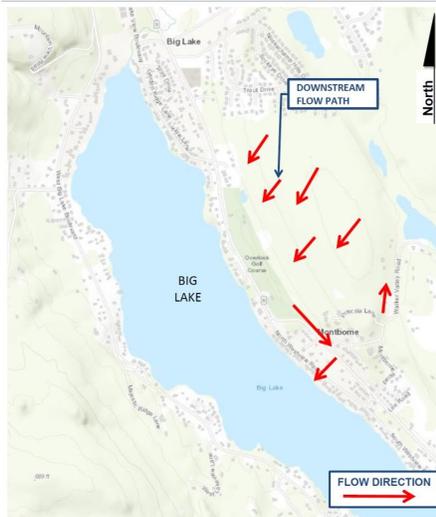
- a. Instead, the Manual simply encourages 'best management practices.' For example, the project pictured below was approved by the Planning Department in 2024 as

⁴ Excerpt:

Step 1 is to determine if there is a sediment/erosion sensitive feature downstream of the development site. If there is such a site downstream, complete Step 2, assessment of hydraulic nearness. If there is a sediment/erosion sensitive feature and it is hydraulically near the site, go to Step 3 to determine the construction site sediment transport potential.

complying with the stormwater code with its proposed direct discharge to Big Lake of stormwater runoff generated by 18+ new acres of impervious area with no Minimum Requirement #5 Low Impact Development BMPs, and no on-site treatment.

**4 SEPA Reviews over 20 Years
No Assessment of Impact on Big Lake of Stormwater Pollutants from 18+
acres new impervious area**



No LID BMPs
**Runoff going in
one big pipe to Big
Lake.**
**Certified by P.E. to
comply with
Stormwater
Manual.**



- b. In the words of the Department of Ecology (Ecology) from the 2024 Stormwater Manual⁵:
- i. *“Although the ‘best management practices’ advocated by the 2024 manual and other stormwater manuals can reduce the impacts from new development to water quality, these systems cannot remove enough pollutants to replicate the water quality of pre-development conditions”, and*
 - ii. *“Despite using some or all of the practices identified in the manual, some degradation of receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development.Unless land use development methods are adopted that cause significantly less disruption of the hydrologic cycle, new development followed by degradation of ‘swimmable, fishable’ surface waters will continue.”*

⁵ 2024 Stormwater Management Manual for Western Washington, pg. 60.
<https://apps.ecology.wa.gov/publications/documents/2410013.pdf>



“Prepared in full compliance 2024 stormwater manual”

...runoff discharging from the detention ponds... [through] wetland” to a series of ditches and culverts with “capacity and erosion issues” to Big Lake.

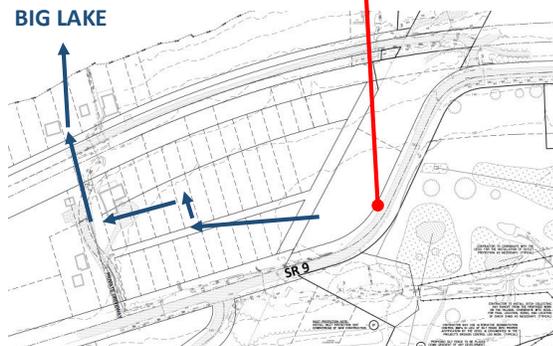
Nick Palewicz, PE for Overlook Crest, LLC.

Approved Stormwater Site Plan: DETENTION PONDS DRAIN TO BIG LAKE

**See 2025 Stormwater Site Plan, page 9. Stormwater runoff from detention ponds goes through wetland to Big Lake through a series of ditches and culverts.*



Photo taken on February 1, 2025. Overlook Crest golf course ponds transporting sediment-laden water into PCA Tract 2 which transports sediments to Big Lake.



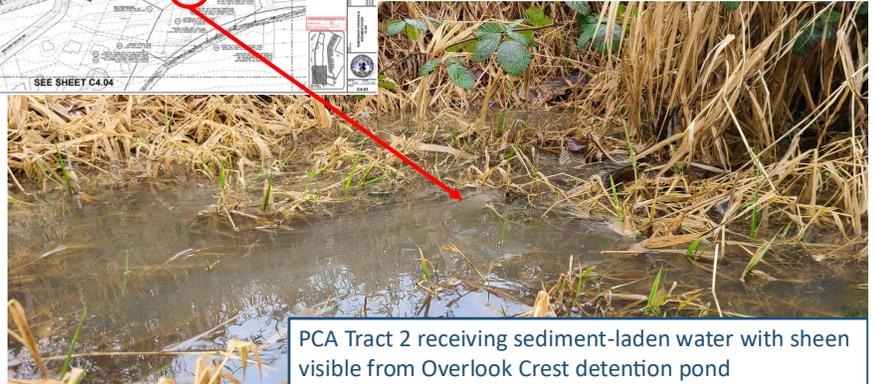
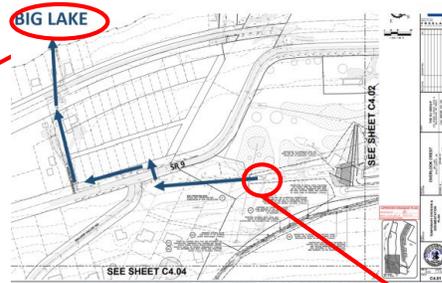
Reference: BP21-0785
2025 Approved Civil Plans, Sheet 4.01.
(Exhibit 10)

SEDIMENT-LADEN WATER RUNS TO BIG LAKE



Big Lake Outfall receiving sediment-laden water from Overlook Crest

Photos taken 2/1/2025



PCA Tract 2 receiving sediment-laden water with sheen visible from Overlook Crest detention pond

- c. Big Lake's water quality has deteriorated since Skagit planning under GMA⁶.
- i. 1999: Department of Ecology reports measured mean in 1999 was 18.7 ug/L. Sets 20 ug/L Total Phosphorus as maximum water quality criteria for Big Lake, "pending a more thorough study."
 - ii. 2004 – Ecology ranks it Level 2 – Water of Concern
 - iii. 2006- Ecology reports a 2001 study which says "shallow depths, dense residential development, and a location in a relatively large watershed may render Big Lake particularly susceptible to (and may have already caused) human-caused eutrophication. Future studies may likely recommend lowering the total phosphorus criterion."
 - iv. 2004 – 2022 – In the absence of current information in their data base, Ecology 'carries forward' "Level 2 – Water of Concern". Ignores Skagit County identification of Big Lake as "sensitive to phosphorous."
 - v. 2004 -2024: Skagit County Water Quality Data documents water leaving Big Lake at Nookachamps Creek with Total Phosphorous levels averaging in excess of 50 ug/l. (That is, 2 ½ times the maximum water quality criteria.)
 - vi. See attached November 19, 2024, Opinion of Richard R. Horner, PhD, pgs 5-9, 16-18, 23-26, for current status of Big Lake Water Quality and discussion of stormwater pollutants.

⁶ This writer acknowledges that there are actions other than new development that can adversely affect water quality, such as condition of stormwater water infrastructure and lakeside resident landscaping choices. Nevertheless, the focus today is compliance with the Growth Management Act's requirement to adopt development regulations that protect the functions and values of critical areas.

4. The 200' restriction prevents consideration of cumulative impact on the critical area. By restricting the review to within 200' of project boundary, the cumulative impact of multiple projects sending stormwater pollution to a single receiving body (e.g. Big Lake), is never considered.
5. GAP Analysis ignores BAS that stormwater runoff conveyed in ditches *“short circuits” or by passes buffer areas and receives little water quality treatment via biofiltration.* BAS Review pg. 55. The GAP Analysis erroneously recommends the review distance for critical areas other than wetlands be continued at 200'. Noting that the 200' distance applies to high land use intensity projects, the GAP Analysis goes on to make things worse: “Varying distance depending on low, moderate or high land use or risk is recommended.” (Pg. 4).

This analysis ignores the science documented in the 2024 Dept. of Ecology Stormwater Manual, Dr. Richard Horner's report, and elsewhere, regarding the harm caused to anadromous fisheries by the pollutants in stormwater runoff.

Significantly, the Gap Analysis ignores the 2.24.2025 BAS finding at page 55:

“ Stormwater runoff that is conveyed through stream buffers in pipes or ditch-like channels and discharged directly to stream channels “short circuits” or bypasses buffer areas and receives little water quality treatment via biofiltration.”

Given the BAS acknowledgement of the result of stormwater conveyed by ditch, one would expect the GAP Analysis to recommend removing the 200' limitation altogether for off-site impacts that are not rendered harmless by a particular distance.

The GAP analysis silence on the impact of polluted stormwater on surface water quality from residential development around our lakes is notable, especially in view of the increased risk of sedimentation identified by the BAS that comes with increase in slopes.

There is little doubt that there will be increased pressure to develop lake view properties in Skagit County. Critical areas site assessments are essential to provide critical information to assure protection of Big Lake and other critical areas from stormwater runoff or other wide ranging off-site impacts.

6. Current and proposed revisions contrary to GMA.
 - a. GMA requires the County to adopt development regulations to protect Critical Areas likely to be affected by development. WAC 365-196-830 makes clear that the requirement to protect Critical Areas is not limited to critical areas located on the development site or within 200' of the development project.

“(6) functions and values must be evaluated at a scale appropriate to the function being evaluated.... Some critical areas, such as wetlands and fish and wildlife habitat conservation areas, may constitute ecosystems or parts of ecosystems that transcend the boundaries of individual parcels and jurisdictions, so that protection of their function, and values should be considered on a larger scale.”

- b. The Skagit County Comp Plan calls for the protection of all Critical Areas, not just those within 200’ of the development boundary:

“to prevent the continued loss and degradation of Critical Areas (Comp. Plan Goal 5A-5) with

“...special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries.” (policy 5A-5.1(d)(viii)

- c. Although current Skagit County Code requires the Director to look beyond the 200’, the Planning Department uses a CAO Checklist that asks for information only within 200’ of the project:

“ ...Administrative Official shall determine whether critical areas or their required buffers are within 200 feet or a distance otherwise specified in this Chapter or may be affected by the proposed activity. SCC 14.24.080(2)

- d. In spite of state law and the Skagit Comprehensive Plan, the proposed CAO update would make the County Code worse by removing the requirement that the Administrative Official (now Director) look beyond the 200’ distance. Instead, it gives the developer a guarantee that no site assessment may be required for impact to critical areas, whether fishery, flood zone, or geological hazardous area, if it is more than 200’ – 300’ from the project boundary depending on type of critical area.

“If a site inspection does not indicate a critical area on or within 200 feet of the subject property, no additional critical area assessment will be required.” SCC 24.080(4)(a)(ii). [Wetlands-300’, Property in Special Flood Hazard Area -250’, all others – 200’]

- e. Over 20 years of development under the County’s CAO, with its 200’ restriction on Critical Area review, has failed to “preserve the existing functions and values of critical areas” such as Big Lake, which provides core summer salmonid habitat. (See 9 below).
- f. The Court of Appeals of Washington, Division Three No. 29191-0-III in Stevens County v. E. Wash. Growth Mgmt. Hearings Bd., affirming the decision of the EWGMHB rejected Stevens County development regulations that required only minimizing stormwater impacts, saying: “The words “minimize the effects” do not mean the same thing as “protect.” Specifically, the Board had concluded:

“Stevens County has failed to enact legislation which complies with the Growth Management Act’s requirements to protect the functions and values of critical areas as set forth in RCW. 36.07A.020(10), .060(2), and .172.”

In other words, development regulations (either land use or CAO) that only minimize or reduce the effect of impervious surfaces and stormwater runoff on critical areas as the County's Stormwater Code does, do NOT meet the GMA mandate. The measure of compliance requires looking at the impact on the critical area. That is, does the development regulation protect the functions and values of the critical area at risk from the proposed new development.

Big Lake deserves the additional protection that would be provided by requiring Critical Areas site assessment of the impact of new polluted stormwater runoff on the lake from development projects. Please fix the ordinance by removing the current limitation of 200' on assessment of adverse off-site impacts on critical areas.

For the record, I incorporate by reference the comments I filed during the Planning and Zoning Commission's consideration of possible revisions to the Critical Areas Ordinance.

Very truly yours,
s/

Jan M. Edelstein

Attached: Dr. Horner Nov. 19, 2024 Report

RICHARD R. HORNER, PH.D.

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November 19, 2024

Friends of Skagit County
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skye@cnw.com

To Whom It May Concern:

I reviewed the Stormwater Site Plan Overlook Crest Plat, Skagit County, Washington, July 2022 (the Stormwater Plan) submitted by the proponent of the Overlook Crest Plat development (Overlook Crest, the development, or the project) in the Skagit County (the County). I focused on the proposed system to manage the stormwater runoff from the development and its potential effects on the waters that would regularly receive the stormwater discharge (Big Lake and its outlet stream). In addition to the Stormwater Plan, I relied on sources from the literature of the stormwater management field and internet resources, all cited in footnotes. This letter presents the conclusions I reached.

In evaluating the Overlook Crest documents, I applied the experience of my 47 years of work in the stormwater management field and 11 additional years of engineering practice. During this period, I have performed research, taught, and offered consulting services on all aspects of the subject, including investigating the sources of pollutants and other causes of aquatic ecological damage, impacts on organisms in waters receiving urban stormwater drainage, and the full range of methods of avoiding or reducing these impacts. Attachment A to this letter presents a more complete description of my background and experience, and Attachment B contains my full *curriculum vitae*. The following Table of Contents is a directory of the topics in this letter.

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ATTACHMENT B: <i>CURRICULUM VITAE</i>	

SUMMARY OF MY CONCLUSIONS AND OPINIONS

Based on my assessment, I have drawn conclusions and formulated opinions as follows:

- Big Lake provides habitat for salmonid and other fish and qualifies as a Critical Area under the County's Critical Areas Ordinance. Despite this status, it is listed as impaired by several water pollutants and is in a eutrophic (relatively highly phosphorus-enriched) condition, with excessive algal and aquatic plant growths degrading its beneficial uses.
- The construction phase of the Overlook Crest project poses substantial risk to Big Lake through soil erosion and the transport of sediments and the phosphorus they carry. This risk is amplified by the steep slopes on the site and the resulting elevated erosion tendency.
- The Stormwater Plan offers almost no detail on how this construction-phase risk will be countered. There must be a thorough analysis of all the factors contributing to it and, before development approval, a comprehensive plan presented to employ a range of source control practices and implement advanced construction runoff treatment to protect the lake.
- Based on extensive data collected in the stormwater management field, the finished and occupied development will generate higher runoff volumes and concentrations and mass loadings of a number of water pollutants, some not previously of concern, compared to the current open land. It is my opinion that the Overlook Crest development stormwater management plan as proposed will result in substantial increase in the discharge of phosphorus and other pollutants to, and degradation of, Big Lake.
- To counter this threat, the Stormwater Plan offers only sketchy pollutant source controls without commitments. It further proposes to manage runoff in adjacent, downslope golf course ponds modified to serve both as a detention basin for flow control and a wet pond for pollutant capture. Based on extensive data collected on wet ponds, it will not sufficiently reduce phosphorus in the discharge to prevent further eutrophication of Big Lake. It is my opinion that, given the deficiencies of the construction and post-construction stormwater management plans proposed for Overlook Crest, the development will aggravate the already eutrophic and degraded state of Big Lake.
- I recommend that, before development approval, the Stormwater Plan be extensively upgraded to specify and commit to a broad suite of pollutant source controls and supplement the golf course ponds with either: (1) comprehensive stormwater infiltration based on additional geotechnical work to identify any localized opportunities for runoff dispersion and assess deep infiltration via wells; or (2) bioretention units to collect and treat runoff from the road through the development and any runoff draining onto the road from residential properties. It is feasible in my opinion to construct these units without underdrains, except in locations where lateral drainage across the glacial till would cause some problem.

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- It is my opinion that the success of any upgraded stormwater management plan for the Overlook Crest development will require significant inspection, maintenance and repair efforts which will need a secure funding source.
- The potential environmental harm associated with the development as proposed warrants a full environmental impact assessment.

The remainder of my letter elaborates on these points and justifies my conclusions and opinions.

THE PROPOSED DEVELOPMENT

The Site and Development Proposal

According to the Stormwater Plan, the proposed development would cover an area of approximately 180 acres east of Big Lake and north and east of the Overlook Golf Course located downslope from the project site. The project includes phased development of up to 105 residential lots with associated open space, utilities, and roadways. There will be approximately 59 acres of cluster development and 118 acres of open space with access via streets dedicated to the public. The residential lots will be along the slope east of the golf course and range in size from 1/3 acre to 1 acre.

Access will be via an existing private road to be improved to Skagit County standards and made public. The proposed roadway within the plat will also be public, encompassing approximately 13 acres and to be constructed to Skagit County Road standards within a 60-foot-wide right-of-way. A second emergency access to the development will be constructed along the northern property line.

The site is currently vegetated with grass, brush, and scattered tree cover. Topography of most of the site slopes down to the west towards the flat-lying golf course. Site topography at the east end of the site slopes downward in all directions from a hilltop feature. Site slopes range between 3 percent and 35 percent, with an average slope of approximately 13 percent.¹

The Proposed Stormwater Management System

The Stormwater Plan states that the finished development will have two stormwater catchment areas, which it refers to as Threshold Discharge Areas (TDAs). TDA 1 is the much larger, encompassing the majority of the area producing stormwater runoff. It also receives run-on drainage entering from off the site. TDA 1 stormwater will drain to ponds on the golf course. The access road and associated sidewalk will comprise TDA 2, the runoff from which will disperse through existing vegetation.

Stormwater flow control and treatment for TDA 1 will be managed in the existing golf course Ponds 1-4. Pond 1 is the largest and farthest downstream. The ponds will function as both a detention basin for flow control and wet pond for water quality treatment. They will operate as a

¹ The Stormwater Plan is inconsistent regarding the average slope, with page 5 citing 13 percent and page 30, under the Stormwater Modeling Overview, stating 8 percent.

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single system, since they all have the same bottom elevation. Aqua-Swirl hydrodynamic separators will be installed at two inlets to the pond system for pre-treatment. The ponds will be expanded, interconnected, and have a flow control structure added to Pond 1. Berms will be constructed on the north and south ends of the ponds to create the necessary detention volume.

Water discharging from the golf course pond system travels through a smaller pond that turns into a channel as it leaves the site. From there it passes through a series of channel, culvert, and pipe conveyances to Big Lake. This downstream system will be upgraded as part of the project to handle additional flow. The Stormwater Plan implies that increased flow would result from failure of the pond control structure and that the upgrades will be designed for the 100-year peak storm discharge.

The Stormwater Plan fails to describe how the drainage at the east end of the site sloping downward from a hilltop feature will be managed. It is also vague on the dispersal of runoff from TDA 2. Although these flows may not affect Big Lake, the plan should cover their disposition.

THE BIG LAKE AQUATIC ECOSYSTEM

General Description

Big Lake, at 536 acres in size, is the largest lake in Skagit County. It provides important wildlife habitat, and offers recreational opportunities, including swimming, fishing, boating, and shoreline-related activities. The lake has a Washington Department of Fish and Wildlife boat ramp and is heavily used by both lake residents and the public for recreation. Beneficial uses of the lake have been severely impacted from dense, prolific growth of invasive aquatic plants.² Big Lake is listed as an impaired water body for the parameters in Table 1 in the Washington Department of Ecology (Ecology) Water Quality Assessment under Clean Water Act section 303(d).

Big Lake has existing or potential habitat for the salmonids coastal cutthroat trout, coho salmon,³ bull trout, and Dolly Varden.⁴ Angling opportunities include largemouth bass, yellow perch, pumpkinseed sunfish, and black crappie, in addition to the cutthroat trout.³ Accordingly, Big Lake qualifies as a Critical Area under the Skagit County Code 14.24 Critical Areas Ordinance. Among other criteria for this designation, the ordinance lists areas with which endangered, threatened, and sensitive species and anadromous fish species have a primary association.

Big Lake is tributary to Nookachamps Creek, which hosts Chinook salmon (fall run) rearing and also has existing or potential habitat for coho salmon (spawning and rearing), bull trout, and Dolly Varden.⁴ The creek has 303(d) impairment listings in common with Big Lake and some others,

² <https://www.skagitcounty.net/Departments/PublicWorksSurfaceWaterManagement/biglake.htm> (accessed November 11, 2024).

³ <https://wdfw.wa.gov/fishing/locations/lowland-lakes/big-lake> (accessed November 11, 2024).

⁴ Montgomery Water Group, Inc. 2007. Big Lake Drainage Management Plan, Final Draft. Board of County Commissioners, Skagit County Public Works Department, Mount Vernon, WA. <https://www.skagitcounty.net/PublicWorksNaturalResourcesManagement/Documents/Big%20Lake%20DMP/Text/Big%20Lake%20Drainage%20Management%20Plan%20Final%2011%2009%2007.pdf> (accessed November 11, 2024).

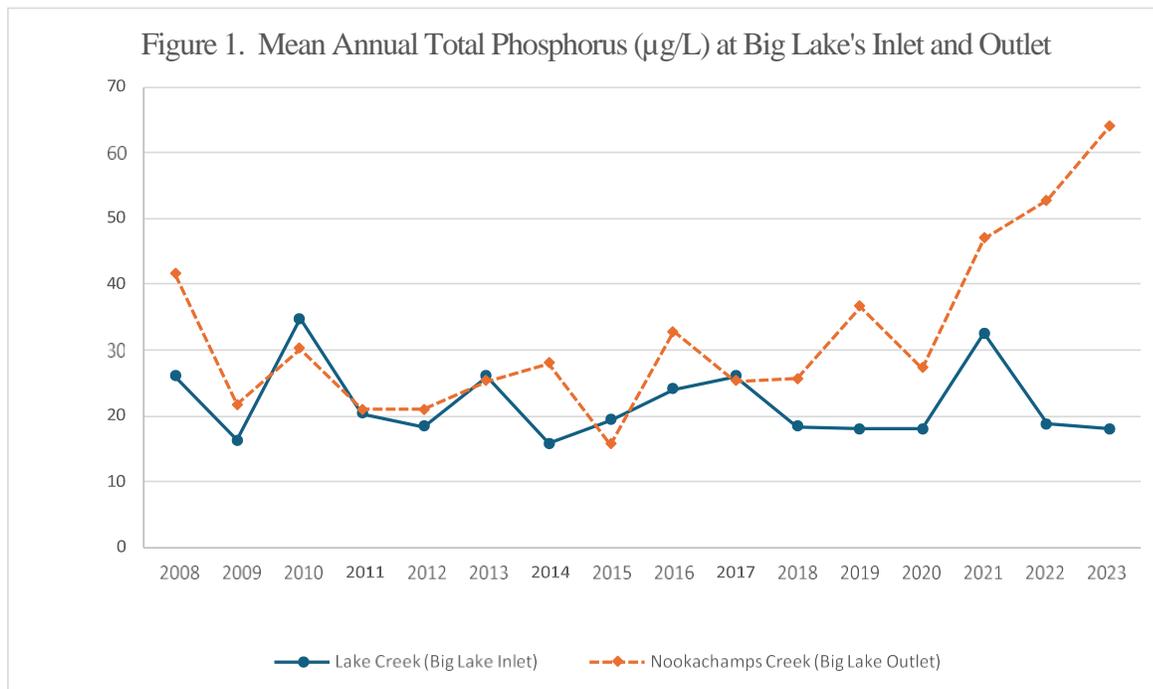
including dissolved oxygen. That quantity could be affected by conditions in the lake, a subject I cover later.

Table 1. Big Lake Impairments under Clean Water Act Section 303(d)⁵

Parameter	Medium	Category ^a
Hexachlorobenzene	Tissue	5
Dioxin	Tissue	5
Polychlorinated Biphenyls (PCBs)	Tissue	5
Invasive Exotic Species	Habitat	4C
Total Phosphorus	Water	2
2,3,7,8 TCDD TEQ	Tissue	2

^a Water bodies are designated as Category 5 if they have: (1) data showing that water quality standards have been violated for one or more pollutants; (2) no Total Maximum Daily Load (TMDL) or pollution control program in place; and (3) impaired designated uses, such as for drinking, recreation, aquatic habitat, and industrial use. Category 4C waters are impaired by causes that cannot be addressed through a TMDL plan, including low water flow, stream channelization, and dams. In Category 2 are waters of concern based on evidence of problems.

Figure 1 presents annual mean total phosphorus (TP) concentrations measured by Skagit County Public Works Natural Resources Division at Big Lake’s inlet and outlet since 2008. It may be seen that the inlet concentrations have been relatively stable around approximately 20 µg/L over those years. The outlet concentrations, representing those being released from the lake, were also fairly stable around approximately 30 µg/L through 2020 but then began to climb steeply. The mean concentration reached 64 µg/L, over twice the usual historic level, in the most recent year.



⁵ <https://apps.ecology.wa.gov/waterqualityatlas/wqa/map?CustomMap=y&BBox=-14338616,5395963,-12562831,6503994&RT=0&Layers=27&Filters=y,n,n,n,n,n> (accessed November 11, 2024).

In 1999, the Department of Ecology established the recommended TP maximum concentration for Big Lake as 20 ug/L.⁶ This criterion is consistent with WAC 173-201A-230 establishing lake nutrient criteria.⁷ While that level was exceeded more often than achieved in earlier years, the differential was not large until 2021 and more than tripled by 2023. Also, the data plotted in Figure 1 are annual means; some individual measurements are higher.

Eutrophication in Big Lake

What Eutrophication Is

Eutrophication is the process by which a body of water becomes enriched in nutrients that stimulate the growth of photosynthesizing primary producers (algae and plants), usually resulting in negative effects on the aquatic ecosystem. The growth of an algal cell or plant tends to be controlled by, more than any other agent, the nutrient in least supply relative to the physiological need, known as the limiting nutrient. That nutrient is generally either phosphorus (P) or nitrogen (N), but in fresh waters is more often P. N still can be limiting at times, for example when high algal biomass incorporates much of the P supply, leaving little available in the water.

Addition of the limiting nutrient not only increases algal abundance but also tends to change the community from single-celled organisms to filamentous forms, which are less desirable for several reasons. They are generally an inferior food source for wildlife; clog water intakes, conveyances, and boat motors; and foul beaches when they wash up on them. Some filamentous blue-green algae produce toxins that can kill an animal that drinks directly from the water and must be removed before distributing to humans.

When the increased masses of algae and plants die, bacteria decomposing them exert a large demand on the oxygen dissolved in the water and reduce the amount available for aquatic life. Other sources of organic material issuing from a construction site or urban community supplement this oxygen demand. It is not unusual for a eutrophic lake to have little or sometimes no oxygen in the colder waters at the bottom, and reduced oxygen even near the surface.

Oxygen depletion is not only an issue for the lake but also for the outlet stream, Nookachamps Creek, which is already impaired for dissolved oxygen (DO). DO tends to be lowest in the warmest months of the year, because as temperature rises the capacity for oxygen to dissolve in water decreases. In the June-August period of 2023, DO in Nookachamps Creek at the lake discharge averaged 2.85 mg/L lower than at the lake inlet. It was as low as 6.54 mg/L, well below the 10 mg/L state water quality criterion.⁸ The salmonids in the stream are particularly sensitive to reduced oxygen levels. Decomposable algae and plants, as well as low-oxygen water, entering from the lake are aggravating factors.

⁶ <https://apps.ecology.wa.gov/approvedwqa/approvedpages/viewapprovedlisting.aspx?ListingId=6163> (accessed November 13, 2024).

⁷ <https://app.leg.wa.gov/WAC/default.aspx?cite=173-201A-230&pdf=true> (accessed November 13, 2024).

⁸ Data from Emma Santana, Skagit County, emmas@co.skagit.wa.us.

An anaerobic condition at the water-sediment interface along the lake bed enables chemical reactions that release a variety of deleterious pollutants into the water column. One of these substances is phosphorus itself, which stimulates further algal growth. Thus, eutrophication sets up a feedback loop compounding the problem. Oxygen depletion at the sediments also releases ammonia, iron, manganese, other metals that are toxic to fish and invertebrates, hydrogen sulfide, methane, and other organic compounds.

Another negative effect of eutrophication is increased daytime pH, through heightened extraction of carbon dioxide during photosynthesis by the abundant algae and plants. Removal of carbon dioxide from the water raises pH through reduction of bicarbonate, a buffering agent, which chemically dissociates to replenish the lost carbon dioxide. The rise of water pH also drives ammonia toward the unionized form (NH_3), which is more toxic to aquatic life than ionized ammonia (NH_4^+).

Excessive aquatic plants have several additional negative impacts. They disrupt food chains by altering habitat availability for fish and block light, making it harder for fish to find food and avoid predators. Heavy plant growth interferes with navigation and recreational activities such as boating, swimming, fishing and water-skiing. They also create stagnant water, providing good breeding ground for mosquitoes.

Assessing Big Lake Eutrophication

Lake trophic state is a measure of the relative amount of primary production through photosynthesis by algae and plants, and thus the degree of eutrophication. Trophic states are based on lake fertility and are typically classified as one of the following:

- Oligotrophic—Relatively few nutrients (nitrogen and phosphorus), high levels of dissolved oxygen, low algal concentrations, clear water;
- Mesotrophic—Medium amount of nutrients, moderately clear water, some algal blooms mostly in late summer, oxygen depletion at the bottom of the lake as biomass decomposes;
- Eutrophic—Nutrient rich, high level of primary production, reduced clarity, seasonally deficient in oxygen; or
- Hypereutrophic: Extremely rich in nutrients, highest primary production, poor clarity, broadly oxygen deficient.

Various systems have been proposed to classify trophic state. Commonly used classifications use three variables: (1) total phosphorus (TP); (2) chlorophyll *a*, a pigment in algae and plants that is most essential for photosynthesis, proportional to and representative of the primary producer biomass present in a water sample; and (3) Secchi depth, a measure of water clarity, how deep light can penetrate, determined by lowering a weighted disk on a cord into the water until it's no longer visible, raising it until it just becomes visible again, and determining its depth below the surface with a scale marked on the cord.

The North American Lake Management Society assimilated systems developed by Carlson (1977),⁹ Vollenweider and Kerekes (1980),¹⁰ and Carlson and Simpson (1996)¹¹ as the bases for a recommended classification.¹² In addition to the three variables cited above, this system uses a Trophic State Index (TSI) from Carlson (1977). Carlson actually proposed three TSIs based on the three key variables. Table 2 shows the classification of Big Lake according to this system. In addition to the latest mean annual TP concentration presented earlier, there is a 2023 chlorophyll *a* value from a Western Washington University monitoring program.¹³

Table 2. Classification of Big Lake Trophic Status

Variable	Big Lake Value	Criterion Range Containing Big Lake Value	Classification
Total phosphorus (TP)	64 µg/L	24-96 µg/L	Eutrophic
Chlorophyll <i>a</i> (Chl)	11.8 µg/L ^a	7.3-56 µg/L	Eutrophic
TSI(TP) ^b	64	50-70	Eutrophic
TSI(Chl) ^b	54	50-70	Eutrophic

^a Data from <https://diatom.cenv.wvu.edu/?page=singlelake:BIG>; the 2023 chlorophyll *a* concentration was the highest measured in the most recent 10 years.

^b From Carlson (1977), $TSI(TP) = 14.42 \times \ln(TP) + 4.15$; $TSI(Chl) = 9.81 \times \ln(Chl) + 30.6$; where \ln is the natural logarithm.

This analysis places Big Lake roughly midway in the eutrophic category, clearly outside the less enriched mesotrophic zone. It is therefore already relatively advanced in eutrophication and experiencing the elevated algal and aquatic plant growths characteristic of that state. It is vulnerable to further deterioration with increase phosphorus input. It is my opinion that the Overlook Crest development as proposed will result in substantial increase in the phosphorus and other pollutants reaching Big Lake. I explain the reasons for my judgment and what should be done to avoid that outcome in the remainder of this letter.

PREFACE TO MY ASSESSMENT

The Overlook Crest development poses multiple threats to the Big Lake ecosystem both during construction and over the years when occupied by residents. Conventional practice in the stormwater management field is to counter these risks by measures to prevent the creation of problems (*i.e.*, excessive runoff and pollutants in that flow) as much as possible and then apply backup practices to control runoff quantities and recapture pollutants before they can damage

⁹ Carlson, R.E. 1977. A Trophic State Index for Lakes. *Limnology and Oceanography* 22(2):361-369.

¹⁰ Vollenweider R.A and J.J. Kerekes. 1980). Background and Summary Results of the DECO Cooperative Program on Eutrophication. In: Proceedings of the International Symposium on Inland Waters and Lake Restoration. U.S. Environmental Protection Agency, EPA 440-5-81-010, p. 25-36, <https://nepis.epa.gov/Exe/ZyPDF.cgi/9100Z7H5.PDF?Dockkey=9100Z7H5.PDF> (accessed November 15, 2024).

¹¹ Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society.

¹² <https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/> (accessed on November 13, 2024).

¹³ I have not found any Secchi depth readings for Big Lake.

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receiving waters. Preventive techniques are called source controls. Flow modulation practices seek to maintain pre-development discharge volumes and peak flow rates, and treatment controls remove pollutants before discharge to the receiving water. There are many options in these categories, and they differ in performance.

In the next several sections of this letter, I evaluate source controls and backup practices put forth for both the construction and long-term phases of the Overlook Crest development, to the extent they have been presented. There are many details missing in the available information. In these circumstances, I critique the proposals that have been issued and offer my opinions regarding the practices that should be adopted.

ASSESSMENT OF THE CONSTRUCTION PHASE OF THE PROPOSED DEVELOPMENT

Introduction

The Stormwater Plan on page 12 states that a Stormwater Pollution Prevention Plan (SWPPP) narrative will be provided within the civil site plan drawings. It further declares that this SWPPP and corresponding Temporary Erosion & Sediment Control Plan (TESC) has been created using the 2019 Manual¹⁴ to ensure that the BMPs selected will meet Construction General Stormwater NPDES permit from Ecology. It does not appear that these documents actually have been created. Because the proposed construction poses formidable problems for managing construction site pollutants, potentially damaging to the Big Lake ecosystem, they should be produced and presented to the County and citizens for evaluation before further project consideration. The documents should fully detail the best management practices (BMPs) that will be used to control pollutants from all construction-related sources. Next, I detail factors creating the challenges and how they should be met with effective practices.

Slope Considerations

As I noted above, site slopes range between 3 percent and 35 percent, with an average slope of approximately 13 percent. These relatively steep slopes pose definite challenges for successfully managing construction-phase stormwater to comply with the permit's requirements.

Slope is a leading factor in soil erosion and sediment loss from a construction site. Thus, it is especially crucial to comprehensively address means of avoiding sediment transport from this site or, at the very least, holding it to a *de minimis* level. Achieving this goal requires careful, detailed analysis and development of a SWPPP incorporating superior BMPs tailored to the site's circumstances.

Construction zones cleared of vegetation and not otherwise stabilized yield much more sediment compared to the original area well covered with plants and to the same area restabilized with vegetative cover following construction. Measurements and estimates using a mathematical model

¹⁴ Referring to edition of Ecology's Stormwater Management Manual for Western Washington issued in 2019. The manual was updated in 2024, and that edition should be the basis for all aspects of Overlook Crest stormwater management.

(Revised Universal Soil Loss Equation Version 2, RUSLE2) indicate 30 to more than 1000 times as much soil loss can occur after vegetation clearing compared to before clearing. Therefore, one year of construction with no or inadequate erosion controls can release into the environment as much sediment loading as occurred over decades or even centuries before the piece of land had been cleared. All soils contain phosphorus, and poorly controlled erosion and the resulting sediment transport would be very damaging to the Big Lake ecosystem.

Going further into the matter of slope as an important determinant of erosion, RUSLE2 estimates soil loss potential according to variables representing rainfall characteristics, soils, slope length, vegetation cover, BMPs, and contributing area, in addition to slope steepness. All other factors being equal, the equation predicts the approximate increases in soil loss at different slope gradients given in Table 3. It can be seen that the rate of soil loss escalates greatly with increasing gradient. Slopes in the upper ranges of Table 3, and even greater, do exist in the areas to be disturbed for the Overlook Crest development. Even with the average slope on the site, uncontrolled soil loss is projected to be more than four times as great as on relatively flat ground. Owing to these circumstances and the related high potential soil loss, before the project moves forward, there should be full analysis and construction SWPPP development, followed by assessment by the County and the public.

Soils and Hydrology

Beyond giving insufficient attention to the topographic challenges to limiting sediment export during construction, the project documents likewise have given little emphasis to the potential erosiveness of site's soils. RUSLE2 takes soils and their erosivity property into account with a variable termed the K Factor, an index that quantifies the relative susceptibility of the soil to sheet and rill erosion. Values range from about 0.02 for the least erodible soils to 0.64 for the most erodible.¹⁵ Thus, the challenge of erosion on a construction site can vary by more than 30 times due to soils alone. Soil properties affecting the K Factor include texture, organic matter content, structure, and saturated hydraulic conductivity. These characteristics must be known for a proper analysis of erosion potential and effective strategizing to defeat it.

Table 3. Comparison of Estimated Soil Loss as Slope Increases from 3 Percent

Slope (%)	Estimated Soil Loss Compared to 3% Slope ^a
6	1.8 times
10	3.0 times
14	4.7 times
20	7.0 times
25	8.9 times
30	10.7 times

^a From Table 4-3 of Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE).

¹⁵ Natural Resources Conservation Service. 2001. Revised Universal Soil Loss Equation (RUSLE2) Handbook. U.S. Department of Agriculture, Washington, DC, https://www.nrcs.usda.gov/sites/default/files/2022-10/RUSLE2%20Handbook_0.pdf, (accessed November 15, 2024).

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Agricultural Handbook No. 703, U.S. Department of Agriculture, Washington, DC. The example is for a slope 50 ft in length.

Since this information is not available in comprehensive form, the K factors around the site cannot be firmly established. Tokul gravelly loam soil predominates on the site according to Figure 3 in the Stormwater Plan. Loams do not generally have the lowest K values but can be in the moderate or even higher ranges depending on the controlling characteristics. Without thorough attention to the exact characteristics of soils that will be disturbed, it is impossible to make a proper assessment of erosiveness and the BMPs that will be necessary to prevent or mitigate it.

Producing a truly site-specific SWPPP will require hydrologic modeling of flows to be generated during construction; passed through on-site conveyances; probably held the golf course ponds for a time; and then discharged. This modeling should be performed with the current version of the Western Washington Hydrologic Model (WWHM2012). Resource protection demands that flows are estimated as well as possible to avoid erosion of conveyance channels, to size equipment correctly, and to protect the receiving waters from high discharges during construction.

It is clear from the project documents that this essential hydrologic modeling has not occurred. Approval of the project should not move further with this project until these construction-phase soils and hydrology assessments occur. They must then be incorporated in a project-specific SWPPP, along with the topographic considerations, for proper judgment of the construction-phase stormwater management plan.

The Importance of Effective Construction-Phase BMPs

Contaminants from a poorly controlled construction site include sediments, the pollutants for which they are a transport medium, and a host of harmful substances associated with construction materials, wastes, and equipment. Fueling of vehicles, other equipment, or both almost always occurs on large construction sites. Maintenance and cleaning also sometimes take place. Careless operations release petroleum products, which are then picked up and transported in runoff. Paint, solvents, cleaners, and other chemicals used in construction are sources of toxic organics.

The Stormwater Plan's program to mitigate these pollutants is insufficient for me even to develop a critique. While there are some specific BMPs mentioned on page 9 of the Subsurface Exploration, Geologic Hazard, Infiltration Feasibility, and Preliminary Geotechnical Engineering Report (the Geotechnical Report) in the Appendix, there is no expressed commitment to use them. Also, there is no indication of how the construction runoff will ultimately be treated and discharged. I can speculate that the topography and flow patterns on the site will direct it into the golf course ponds, but that is not stated. If it is the case, will the ponds be in their present form or modified to the final configuration? In either case, there appears to be no assessment if they will be adequate for the purpose of minimizing sediment export to Big Lake. If in their final form, collection of construction sediments could reduce their volume, and hence their future effectiveness, unless those sediments are removed when construction is complete.

It is important that sediment addition to Big Lake be *de minimis* given that eroded soils transport phosphorus, which is generally present in soils and to which the lake is sensitive and already

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degraded. As pointed out above, the prevalent slopes on the site complicate achieving this goal. In this situation the best available erosion and sediment controls must be employed. Because the Stormwater Plan is so sketchy regarding construction-phase stormwater management and it is so crucial, I have made the effort to outline a program to which the development applicant should commit and the County should demand, as follows.

Recommended Construction-Phase BMPs

Construction Management Practices

The program I recommend starts with source controls to prevent or reduce to the greatest extent possible soil erosion and sediment transport from the site. The first measures to consider and make maximum use of are construction management measures such as:

- Maintain existing vegetation cover, if it exists, to the greatest extent technically feasible.
- Perform ground-disturbing work in the dry season, with the smaller risk of erosion, and work off disturbed ground in the higher risk wet season.
- Limit ground disturbance to the amount that can be effectively controlled temporarily in the event of rain.
- Use natural depressions and plan excavations to drain runoff internally and isolate areas of potential sediment and other pollutant generation from draining off the site, so long as safe in large storms.
- Schedule and coordinate rough grading, finish grading and erosion control applications to be completed in the shortest possible time over-all and with the shortest possible lag between these work activities.

Soil Stabilization Practices

An effective construction-phase BMP plan continues with stabilizing exposed soil with a cover appropriate to the site conditions, season and future work plans; for example:

- Rapidly stabilize disturbed areas that could drain off the site and will not be worked again, with permanent vegetation supplemented with highly effective temporary erosion control measures until at least 90 percent vegetative soil cover is achieved.
- Rapidly stabilize disturbed areas that could drain off the site and will not be worked again for more than three days, with highly effective temporary erosion control measures.
- If 0.1 inch of rain or more is predicted with a probability of 40 percent or greater, before the rain falls, stabilize or isolate disturbed areas that could drain off the site, and that are being

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actively worked or will be within three days, with measures that will prevent or minimize to the greatest extent technically feasible the transport of sediment off the property.

Additional Erosion and Sediment Transport Reduction Practices

Additional source control measures that should be employed as appropriate to the site and conditions are:

- Specify emergency stabilization and/or runoff collection procedures (e.g., using temporary depressions) for areas of active work when rain is forecast.
- If runoff can enter storm drains, use a perimeter control strategy as a backup where some soil exposure will still occur, even with the best possible erosion control (the above measures).
- Specify flow control BMPs to prevent or minimize to the greatest extent technically feasible the following:
 - Flow of relatively clean off-site water over bare soil or potentially contaminated areas;
 - Flow of relatively clean intercepted groundwater over bare soil or potentially contaminated areas;
 - High velocities of flow over relatively steep and/or long slopes, in excess of what erosion control coverings can withstand; and
 - Erosion of channels by concentrated flows either by using channel lining, velocity control, or both.
- Minimize the number of construction entrances. Specify stabilization of construction entrance and exit areas, provision of a nearby tire, undercarriage, and chassis wash for dirty vehicles leaving the site with a wash water sediment trap, and a sweeping plan.
- Stabilize construction roads with crushed rock.

Construction-Site Stormwater Runoff Treatment Practices

All of the above BMPs are source controls, designed to prevent or minimize erosion and sediment transport. They are essential and excellent measures to employ but are unlikely to be preventive enough for the protection of Big Lake during a large construction project on relatively steep slopes in its watershed. They must be backed by effective sediment capture. As I speculated earlier, the Overlook Crest construction-phase stormwater runoff will flow to the golf course ponds. For that purpose, I do not consider those ponds, in whatever configuration, to be adequate for capturing the transported sediments and keeping them out of Big Lake.

Ecology's Stormwater Management Manual for Western Washington states, under the topic BMP C250, that a sediment pond is effective at removing larger particulate matter by gravity settling, but ineffective at capturing smaller particulates and may not be adequate to ensure compliance with the water quality standards in the receiving water. It advises that BMPs C250 (chemical treatment) and C251 (filtration) can reliably provide exceptional reductions of turbidity and associated pollutants, which includes phosphorus. These practices have been employed at hundreds of construction projects in Washington over many years. It is my strong opinion that an appropriate selection of treatment elements among these technologies is essential to protect Big Lake from negative impacts caused by Overlook Crest construction.

The advanced treatments employed at Washington construction sites generally involve filtration assisted either by chemical polymer addition or electrostatic coagulation. For years, chitosan, a bio-polymer derived from crab and shrimp shells, has performed extremely well at construction sites in reducing sediment loadings through particle flocculation and subsequent filtration, as well as in reducing metallic and organic pollutants in contaminated groundwater exposed in dewatering construction sites. The polymer is generally employed in a chitosan-enhanced sand filtration (CESF) configuration. Testing and experience have shown CESF capable of greatly reducing concentrations of a range of pollutants, including TSS, zinc, other metals, petroleum derivatives, and nutrients (phosphorus and nitrogen) to levels far below the regulatory limits.¹⁶

Chemical polymer alternatives to chitosan yield even better results for some runoff streams. The optimum polymer is typically identified by conducting bench tests on several alternatives using the actual runoff from the site at issue to determine which one maximizes flocculation.

An alternative to chemical polymer coagulation is electrocoagulation. In an electrocoagulation cell, multiple reactions take place simultaneously. First, a metal ion is driven into the water from the anode (positive pole). Meanwhile, electrons flow from the cathode (negative pole) to destabilize surface charges on suspended solids and emulsified oils. As the reaction continues, flocculation occurs, forming large masses that entrain suspended solids, heavy metals, emulsified oils, and other contaminants. Finally, the masses are removed from the water in downstream solids separation and filtration process steps. Like CESF, electrocoagulation is now in industrial stormwater application. Testing and experience have also shown electrocoagulation to have performance capability equivalent to CESF, including decreasing the same range of pollutants, to levels far below the specified limits.¹⁷ Another similarity with CESF is that the equipment is modular and flexible.

¹⁶ Crini, G., N. Morin-Crini, N. Fatin-Rouge, S. Deon, and P. Fievet. 2017. Metal removal from aqueous media by polymer-assisted ultrafiltration with chitosan. *Arabian Journal of Chemistry*, 10(2):S3826-S3839; see <http://www.waterworld.com/articles/uwm/articles/print/volume-2/issue-1/features/biopolymer-offers-biodegradable-alternative-in-water-treatment.html> (last accessed on April 25, 2023) and DMRs submitted by Industrial Stormwater General Permit holders using CESF in Washington state.

¹⁷ Sahu, O., B. Mazumdar, and P.K. Chaudhari. 2014. Treatment of Wastewater by Electrocoagulation: a Review. *Environmental Science Pollution Research* 21:2397–2413.

Herrera Environmental Consultants. 2011. Literature Review of Existing Treatment Technologies for Industrial Stormwater. Washington Department of Ecology, Northwest Regional Office, Bellevue, Washington.

Several companies¹⁸ market advanced treatment systems using such media. Treatment units can be installed flexibly where space exists, and vendors offer units in a modular form that can be moved onto a site quickly and even shifted around to different positions if circumstances change.

Control of Other Construction-Site Pollutants

The preceding discussion has emphasized the sediment that may issue from the construction site and compromise receiving water quality. Just as the Stormwater Plan is incomplete in covering this area, it is equally vague on management of construction site pollutants besides sediments. These sources include construction materials; wastes produced; and pollutants associated with vehicles and other mechanized equipment, such as fuels, lubricants, and cleaning materials. These substances can introduce toxic pollutants to storm runoff, such as heavy metals, petroleum products, and organic chemicals derived from fossil fuels. A SWPPP should be produced and evaluated before further project consideration, and it should fully detail the BMPs that will be used to control pollutants from all sources.

The construction site should be managed to avoid the release of these contaminants by preventing contact between rainfall or runoff and potentially polluting construction materials, processes, wastes, and vehicle and equipment fluids by such measures as enclosures, covers, and containments, as well as berming to direct runoff. Construction vehicles larger than pick-up trucks parked for more than two days should be located so that any fluid leaks cannot contaminate stormwater runoff. The best way of preventing contamination is to park in a location that cannot drain into any stormwater conveyance leaving the site. If a selected location could drain away, it should be modified by slightly recessing the parking spots to prevent draining out. An alternative if such a location cannot be found, is to place leakage collection trays under the vehicles. Any vehicle observed to be leaking any significant quantity of a fluid should be repaired immediately.

Inspection and Maintenance

All areas disturbed by construction activities, all BMPs, and all stormwater discharge points must be inspected at least once every calendar week and within 24 hours of any discharge from the site. All BMPs must be maintained and repaired as needed to ensure continued performance of their intended function.

POTENTIAL POST-CONSTRUCTION STORMWATER POLLUTANT DISCHARGES

Water Pollutants of Concern and Their Sources

Hundreds of water pollutants are associated with urban development and its human facilities and activities. These pollutants fall into the categories of: (1) solid particles, which create their own negative impacts and also transport pollutants in the other categories; (2) nutrients, particularly phosphorus and nitrogen, which as I have discussed over-enrich receiving waters and cause harmful algae and plant growths; (3) oxygen-demanding materials, which deplete dissolved oxygen needed

¹⁸ For example, WaterTectonics, Inc., Everett, Washington; Clear Water Services, Everett, Washington; Clear Creek Systems, Pacific, Washington.

by aerobic life; (4) metals, some of which, like copper and zinc, are toxic to aquatic life; (5) petroleum products, which have toxic and nuisance effects in receiving waters; (6) organic chemicals, including pesticides and numerous other household and commercial chemicals, again many of them toxic to aquatic organisms as well as humans and wildlife; and (7) pathogenic (disease-causing) organisms. I further report on the negative impacts of these pollutants below under the topic heading Environmental Harm Associated with Stormwater Pollutants of Concern for the Big Lake Ecosystem.

After a development is occupied, human activities such as vehicular transportation, lawn care, and pet keeping introduce pollutants from several of the categories listed above. Pollutants in all seven categories listed above issue from a site such as Overlook Crest.

Quantification of Residential Land Use Pollutant Releases

Table 4 gives the concentrations of common stormwater pollutants associated with activities occurring during construction and occupation of a residential community in comparison to drainage from open (undeveloped) land, such as the present forested site. With the exceptions of total suspended solids, nitrate + nitrite-nitrogen, and total phosphorus, concentrations in flows from the developed land use range from 190 to 260 percent higher than in open land runoff. Total phosphorus concentration is 20 percent higher in runoff from the residential land use compared to open land.

In addition to concentration (mass/unit volume of water), pollutant mass loading (mass/unit time) is instrumental in water quality. Concentration represents exposure to the contaminant at a point in time and thus is the major factor in acute effects on receptor organisms. Mass loading represents a cumulative exposure over time, creating a chronic stress on life forms and aggregate contaminant collection in a repository such as the aquatic sediments. Loading is the multiplication product of concentration times flow volume over the time period and can be expressed on the basis of unit area (kg/ha-year) or total catchment (kg/year). With the construction of impervious surfaces and lawns in place of native landscapes, urbanization increases runoff volume. Table 4 shows that it generally also increases concentrations. Therefore, we would anticipate seeing substantially elevated pollutant mass loadings in developed versus undeveloped runoff.

Table 5 shows that expectation to be borne out. Loadings from the developed compared to undeveloped land uses are generally about 50-400 percent greater, although ranging much higher for TSS, total phosphorus, and total lead. Mass loading of phosphorus, the particularly critical pollutant in the Big Lake case, is projected to be 10 times (1000 percent) as high. The ultimate, long-term burden of unmitigated urban stormwater runoff on water quality is thus a function of both hydrologic modification and release of chemical, physical, and biological agents by urban inhabitants and their possessions and activities.

Table 4. Median Pollutant Concentrations in Stormwater Runoff from Two Land Use Types from the National Stormwater Quality Database¹⁹

Pollutant	Unit	Open Space	Residential
Total suspended solids (TSS)	mg/L	51	48
Total phosphorus	µg/L	25	30
Total Kjeldahl nitrogen ^a	µg/L	60	140
Nitrate + nitrite-nitrogen	µg/L	60	60
Biochemical oxygen demand (BOD)	mg/L	4.2	9.0
Chemical oxygen demand (COD)	mg/L	21	55
Total copper	µg/L	5	12
Total lead	µg/L	5	12
Total zinc	µg/L	39	73
Fecal coliform bacteria	No./100 mL	3100	7750

^a Nitrogen in the organic plus inorganic ammonia and ammonium forms.

Table 5. Pollutant Loadings in Storm Runoff from Three Land Use Types as Reported in the Stormwater Literature^a

Pollutant	Unit	Undeveloped ^b	Residential ^c
Total suspended solids (TSS)	kg/ha-year	3	250
Total phosphorus	kg/ha-year	0.03	0.3
Total Kjeldahl nitrogen	kg/ha-year	2.5 as total nitrogen*	2.5
Nitrate + nitrite-nitrogen	kg/ha-year		1.4
Biochemical oxygen demand (BOD)	kg/ha-year	NA ^d	27
Chemical oxygen demand (COD)	kg/ha-year	NA ^d	50
Total copper	kg/ha-year	0.01**	0.03
Total lead	kg/ha-year	0.005	0.05
Total zinc	kg/ha-year	0.03**	0.10
Fecal coliform bacteria***	No./ ha-year	1.0 x 10 ¹⁰	3.8 x 10 ¹⁰

^a Source: Burton, G.A., Jr. and R.E. Pitt. 2002. *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers*. Lewis Publishers, Boca Raton, FL (Table 2.5), except:

* Beaulac, M.N. and K.H. Reckhow. 1982. An Examination of Land Use - Nutrient Export Relationships. *Journal of the American Water Resources Association* 18:1013-1024.

** Wanielista, M.P. and Y.A. Yousef. 1993. *Stormwater Management*. John Wiley and Sons, Inc., New York, New York, USA (Table 5.19).

*** Shaver, E., R. Horner, J. Skupien, C. May, and G. Ridley. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, 2nd Ed. North American Lake Management Society, Madison, Wisconsin, USA (Table 3-13).

^b “Woodland” for total copper and total zinc; “parks” for total suspended solids, total phosphorus, and total lead; “forest” for remaining pollutants (Note: Multiple sources were consulted for the undeveloped category since data for the various pollutants were not reported in consistent land use terms.).

^c Medium-density residential (approximately 20 percent impervious).

^d Not available.

¹⁹ Shaver, E., R. Horner, J. Skupien, C. May, and G. Ridley. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, 2nd Ed. North American Lake Management Society, Madison, Wisconsin, USA.

ASSESSMENT OF THE PROPOSED POST-CONSTRUCTION STORMWATER MANAGEMENT PRACTICES

Pollution Source Controls

Introduction

Effective stormwater management begins with controls implemented to prevent or reduce the release of pollutants in the first place. Source controls can be 100 percent effective if they fully isolate potential contaminant sources from contact with rainfall or runoff. In contrast, conventional stormwater treatment systems are not nearly 100 percent efficient. Even the best available do not achieve that performance level. There are two categories of source controls: (1) operational, which are procedures that reduce the potential for exposure of pollutants; and (2) structural, which physically separate contaminants from rainfall and runoff.

In this section of my letter I list the source controls proposed in the Stormwater Plan and assess each with respect its potential to accomplish the goal of pollutant isolation. In following sections I present my opinions of the Stormwater Plan's proposals to treat runoff over the long term in the finished development.

My Assessment of Proposed Source Controls

The Stormwater Plan makes the following claims, which I present in summary form with page number references and then critique each.

Page10: The proposed plat development is not expected to create new pollutant sources.

Tables 4 and 5 above demonstrate that this claim is fatuous.

Page10: No sources of bacteria are known to exist onsite or are proposed.

There is no plan to prohibit pets or impervious surfaces, which collect and concentrate bird and other wildlife droppings. Again Tables 4 and 5 refute this claim.

Page10: Chemicals for grounds and landscape maintenance, including detergents, cleaning products, and fertilizers will be stored indoors to prevent contact with stormwater.

They may be stored in indoors, but they will be spread outdoors through lawn and garden work and vehicle, pavement, and structure washing.

Pages 12-13: Pollutant sources for residential plat and road projects include vehicular traffic, fertilizers, and other detergents or chemicals typical to residential building and road maintenance activities. Pollution will be controlled at the source to the maximum extent possible.

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The passage names ten source control BMPs from the 2019 Manual that have been reviewed for this project but goes no farther to reveal which, if any, will go beyond review to implementation.

Specific source controls should be formulated in all of these categories and detailed in the Stormwater Plan.

Assessment of Proposed Post-Construction Stormwater Treatment and Recommendations for Improvement

Critique of the Pond Proposal

As described earlier, the proposal is to use revised golf course ponds to serve for both stormwater flow control and treatment. The size to which the ponds are to be revised was determined with Ecology's Western Washington Hydrologic Model (2012 version). Like all mathematical models intended to represent natural conditions, it has simplifications. One is having only three categories of slopes: 0-5 percent, flat; 5-15 percent, moderate; and 15+ percent, steep. In contrast to the earlier characterization of the average site slope at 13 percent, the Stormwater Plan states in the modeling section that the average is 8 percent and that the site was modeled as moderate in slope. That choice tends to underestimate runoff production and hence the pond volume necessary to control flow and reduce pollutants to the regulatory requirements. A superior approach would be to divide the site into the three slope categories by the respective areas, model them separately, and rout the combined flow to the ponds.

While my recommended modeling alteration would tend to improve pond performance, I do not consider any wet pond configuration as the lone stormwater treatment to be sufficiently protective of Big Lake. The International Stormwater BMP Database summarizes the results of 75 studies performed on wet ponds and reports the median total phosphorus concentration discharged as 120 µg/L, with a maximum of 129 and minimum of 104 µg/L.²⁰ It is clear from this extensive database and relatively consistent performance that a wet pond cannot be expected to discharge phosphorus at less than about double the current Big Lake concentration. The Aqua-Swirl pre-treatment devices at the two pond inlets, while approved for some purposes under Ecology's TAPE BMP assessment program, are not recognized for phosphorus as a target pollutant and will offer essentially no benefit in that regard. The wet pond must either be replaced or supplemented by another stormwater management practice to protect the lake. I see two options for doing so, which I discuss in the following paragraphs. The Stormwater Plan must be updated with an improved treatment system and submitted for County and citizen assessment before further consideration of the development proposal.

Consideration of Infiltration

On page 15, the Stormwater Plan says that native soils do not infiltrate and infiltration systems are infeasible for use at this site. There are inconsistencies in the evidence regarding this point. Pages 5-6 state, "Tokul gravelly loam, the predominate soil on the site, consists of volcanic ash

²⁰ https://www.waterrf.org/system/files/resource/2020-11/DRPT-4968_0.pdf, Table 4.3 (accessed November 15, 2024).

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mixed with loess over glacial till and is classified as hydrologic group 'B'. Hydrologic group 'B' soils have moderate infiltration rates when thoroughly wetted." Figure 3, in fact, shows the Tokul soil to cover 85 percent of the site. The infiltration characteristics of the site should be investigated more broadly and thoroughly. There may be localized areas that could infiltrate sufficiently to disperse roof, driveway, and/or lawn runoff.

It is true that the Tokul soil is generally underlain by Vashon lodgement till, which is restrictive to percolation. In these circumstances, there is still the possible option of deep infiltration, which uses wells to discharge water below the restrictive layer. The Geotechnical Report states that investigation of deeper stormwater infiltration strategies was outside of the scope of the investigation and proposes additional work. That work should be conducted to determine its feasibility. The Manual offers BMP T7.50, Drywells, to accomplish deep infiltration.

The advantage of infiltration is that it would prevent or minimize the discharge of any runoff and the accompanying pollutant loading from the areas draining to the wells or dispersion areas. If analysis determines that stormwater from even the largest storms would infiltrate in the deep wells and by dispersion, the lake would be spared increased pollutant discharges. In that case, the golf course ponds need not be modified in any way. If there could still be discharge from the development in relatively large storms, the golf course ponds would be altered only as necessary to control the rate of flows released downstream.

The Bioretention Alternative

The second option is installing bioretention systems within the development. Bioretention is a stormwater management practice that uses the chemical, biological, and physical properties of plants, soil microbes, and the mineral aggregate and organic matter in soils to transform, remove, or retain pollutants from stormwater runoff. Bioretention BMPs are:

- Shallow landscaped depressions with a designed soil mix and plants adapted to the local climate and soil moisture conditions;
- Designed to mimic natural forested conditions, where healthy soil structure and vegetation promote the infiltration, storage, filtration, and slow release of stormwater flows; and
- Typically, small- to medium-scale, dispersed, and integrated into the site as a landscape amenity.

In my concept there would likely be a set of several units placed to receive all of the runoff from the new road extended through the development, the greatest pollutant source, and any stormwater that flows onto the road from the residential properties. Designing the development to keep as much runoff as possible from entering the road would reduce the size and therefore the cost of bioretention.

Bioretention should be designed, constructed, and maintained as specified by BMP T7.30 in the 2024 Stormwater Management Manual for Western Washington. This updated specification

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incorporates new high performance bioretention soil mixes based on recent research. The mix that best captures phosphorus, as well as the other pollutants of concern, and improves vegetation success for enhanced pollutant removal, labeled Type 3, includes a 2-inch compost surface layer over a primary layer and, below it, a polishing layer. The 18-inch primary layer contains 70 percent sand, 20 percent coir, and 10 percent high carbon wood ash (biochar) by volume. The 12-inch polishing layer has 90 percent sand, 7.5 percent activated alumina, and 2.5 percent iron aggregate by volume. It is very important that this specific medium be specified, because it has been expressly formulated and verified to be the best choice for reducing phosphorus.

According to Manual page 902, bioretention can be used, with or without an underdrain, near phosphorus-sensitive waterbodies. Constructing without an underdrain is the better configuration, because it offers the opportunity to reduce the quantity of surface discharge that would still contain some contaminants, if some infiltration occurs even if it is not complete. It should be carefully determined what portions of the site can host bioretention without underdrains and what areas must have them. With the relatively steep slopes, there are probably areas where flow across the till layer could surface at locations causing problems such as slope instability and basement wetting.

With this alternative, I envision that the golf course ponds would still be converted to a combined detention/wet pond system, generally as laid out in the Stormwater Plan. They probably would not have to be enlarged as much, or perhaps not at all, because bioretention would reduce runoff quantity. How much depends on the water loss that accrues from infiltration and evapotranspiration. There would still have to be an outlet structure for discharge flow control.

The Importance of BMP Maintenance

Wet ponds and bioretention units require regular inspection and maintenance to retain effectiveness. Bioretention and wet pond maintenance specifications are on Manual pages 934-935 and 1016, respectively. The U.S. Environmental Protection Agency has also produced maintenance guidance for bioretention²¹ and wet ponds.²² The Overlook Crest developer must develop detailed maintenance instructions consistent with these specifications and set up mechanisms to ensure that they are funded and regularly and thoroughly implemented.

²¹ Stormwater Best Management Practice Bioretention (Rain Gardens), EPA-832-F-21-031L, <https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf>; and Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots, Technical Memorandum, https://www.epa.gov/sites/default/files/2016-11/documents/final_gi_maintenance_508.pdf (both accessed November 15, 2024).

²² Stormwater Wet Pond and Wetland Management Guidebook, EPA 833-B-09-001 <https://www3.epa.gov/npdes/pubs/pondmgmtguide.pdf> (accessed November 15, 2024).

ENVIRONMENTAL HARM ASSOCIATED WITH STORMWATER POLLUTANTS OF CONCERN FOR THE BIG LAKE ECOSYSTEM

Phosphorus

As I covered extensively above, phosphorus is a pollutant of particular concern for Big Lake, a discussion I do not repeat here. The deficiencies of the construction and post-construction stormwater management plans that I have described will aggravate the already eutrophic state in my opinion. The improvements I recommend are crucial for any chance to avoid exacerbating that condition in the face of such a major land use change in the lake's watershed.

Particulates

Solid particles discharged to water (measured as TSS and turbidity) have a number of potential negative ecological effects, regardless of their specific physical or chemical nature, including:

- Changing the structure and chemical characteristics of the lake's bed, thus altering the optimum habitat for benthic invertebrates and bottom-dwelling fish;
- Reducing visibility, making it harder for fish to find food and avoid predators;
- Reducing light penetration to underwater plants and algae;
- Abrading the soft tissues of fish and juvenile amphibians, especially gills; and
- Transporting other pollutants, such as phosphorus and the metals sourced from lubricants and wear of vehicle components.

As I have demonstrated, construction and occupancy of the development as planned will increase particulate input to the lake. Only excellent mitigation measures such as I have proposed offer the opportunity avoid that outcome.

Decomposable Organics

Organic residues decompose over time from their original complex formulations to their constituent compounds and, ultimately, chemical elements. The breakdown begins in surface deposits as a physical deconstruction, with reduction of larger pieces to smaller particles and, less visibly, to very small dust particles. Simultaneously, a biochemical process begins in which heterotrophic bacteria and fungi exploit the wood material as a carbon source to support their growth. This process advances the particle size reduction. When the particles flow with stormwater runoff into a water body, the decomposition process continues. The microorganisms consume oxygen taken from the water, thus exerting what is termed an "oxygen demand." BOD and COD are commonly used measures of oxygen depletion potential associated with biological decomposition. Organics already broken down into relatively small particulates degrade more rapidly and, consequently, exert more

oxygen demand than a larger piece of equivalent mass.²³ Oxygen dissolves from the atmosphere into water bodies, but the oxygen demand exerted by decomposing microorganisms can exceed the rate of oxygen dissolution with a large supply of degradable organics.

Aerobic aquatic life, including fish and their invertebrate food sources, require sufficient oxygen to support their physiological processes. Highly depleted dissolved oxygen is fatal, at somewhat different levels depending on species. Salmonids, including threatened and endangered salmon, are the most sensitive fish in this respect. Even if not drawn down to a lethal level, somewhat depleted oxygen interferes with such processes as feeding, avoiding predators, and growth.

As I pointed out above, Nookachamps Creek downstream of Big Lake is impaired by low dissolved oxygen. If organic matter input rises, both from the development upslope and excessive algal and plant growth in the lake, the increase will worsen this situation.

Reducing organic sources and transport is necessary to avoid these impacts. The Stormwater Plan does not provide sufficient source controls and treatment to do so effectively and must be upgraded as I have proposed.

Metals

Both copper and zinc are toxic to fish and other aquatic life, much more so than to mammals. There is a large body of literature on the specific lethal and negative sublethal effects of these metals on fish and other aquatic life. Particularly in the dissolved forms, they are toxic to aquatic organisms in relatively low concentrations. Equivalent concentrations and higher are often measured in urban stormwater. The effects of both metals on aquatic organisms can be directly lethal or sublethal but detrimental to such life cycle functions as migration, reproduction, rearing, feeding, growth, disease resistance, and predator avoidance.

Copper, especially, has received a great deal of attention for its inhibition of various salmonid physiological processes, to the detriment of migration, feeding, reproduction, and rearing. The mechanisms bringing about these adverse effects include fraying of gills, diminishing their physiological processes, and reduction of olfactory ability (sense of smell).²⁴ The onset of negative consequences depends on species and water pH, dissolved organic carbon, and hardness but begins as low as approximately 5 µg/L or even less.

Baldwin et al. (2003)²⁵ used coho salmon olfactory capacity, a reliable indicator of sublethal toxicity, in a series of studies. Exposure to 10 µg/L of copper for 30 minutes reduced responses to three odorants by 35-67 percent, and the reduced olfactory function persisted for hours. Impairment was evident within 10 minutes for exposures ranging from 2 to 20 µg/L. The researchers defined

²³ E.g., Rex J., S. Dubé, P. Krauskopf, and S. Berch. 2016. Investigating Potential Toxicity of Leachate from Wood Chip Piles Generated by Roadside Biomass Operations. *Forests*, 7, 40.

²⁴ Solomon, F. 2009. Impacts of Copper on Aquatic Ecosystems and Human Health. *MINING.com*, January 2009, pp. 25-28.

²⁵ Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. *Environmental Toxicology and Chemistry* 22(10):2266-2274.

the threshold for sublethal, copper-induced coho neurotoxicity to be 25 percent reduction in olfactory responses. They found the threshold to be 2.3-3.0 µg/L (depending on odorant) above the 3.0 µg/L background in source water; i.e., the presence of approximately 5-6 µg/L of copper reduced olfactory function by 25 percent.

Zinc concentrations as low as 93 µg/L have been found to be lethal to 50 percent of juvenile rainbow trout in 96 hours of exposure.²⁶ Sublethal effects at even lower concentrations include avoidance of rearing habitat and inhibited immune response.²⁷ Such negative effects interfere with growth, ability to avoid predators, and resistance to disease.

The negative effects of metal toxins are not necessarily limited to short-term, acute lethal or medium-term sublethal impacts. Over time an organism can accumulate metals in tissue, a process known as bioaccumulation. When predators consume organisms with bioaccumulated metals, they concentrate them in their tissues. The top predator in an aquatic ecosystem tends to have the highest concentrations, through biomagnification up the food chain. Fish and their food sources in the benthic macroinvertebrate community are subject to these impacts.

Aquatic sediments become repositories for particulate metals through gravity settling and for dissolved metals through various adsorption and ion exchange processes. In addition to their toxicity to bottom-dwelling organisms, these captured metals can become remobilized into the water column by disturbance and dissolution, and thus harm pelagic aquatic life long after their initial release.

As with the other sources of environmental harm, stormwater management as currently conceived for the development will not control metals sufficiently to avoid adding to the toxic burden on life in the Big Lake ecosystem. It must be improved in the ways I have recommended.

Bacteria

As Tables 4 and 5 demonstrate, development increases bacteria in stormwater. Sources include pets, leaking recreational vehicles, and concentration of wildlife droppings on impervious surfaces. According to WAC 173-201A-600, as a water of the state not named in Table 602, Big Lake is to be protected for primary contact recreation. Controls counteracting the sources and runoff treatment supplementary to the golf course ponds are needed to comply.

Petroleum Derivatives

Crude oil and its derivatives contain numerous chemicals, certain ones (*e.g.*, many in the polyaromatic hydrocarbon group) of which are toxic to aquatic life. They produce harmful sublethal, if not immediately lethal, reactions negatively affecting reproduction, development, and behavior. These materials decompose relatively slowly and tend to accumulate in the aquatic

²⁶ Chapman, G.A. 1978. Toxicities of Cadmium, Copper, and Zinc to Four Juvenile Stages of Chinook Salmon and Steelhead. *Transactions of the American Fisheries Society* 107: 841-847.

²⁷ Price, M.H.H. 2013. Sub-lethal Metal Toxicity Effects on Salmonids: A Review. Report prepared for SkeenaWild Conservation Trust. Smithers, BC.

environment. The gradual decomposition reduces the oxygen supply needed by aerobic water life, from fish to the microorganisms responsible for the breakdown themselves. This oxygen demand aggravates that created by biodegradable particles.

Tire Rubber Additive

Recently, an obscure additive to tire rubber was identified as instrumental in coho salmon pre-spawn mortality, previously unexplained acute mortality when adult salmon migrate to creeks to reproduce and are exposed to stormwater flows. The compound is the quinone transformation product of *N*-(1,3-dimethylbutyl)-*N'*-phenyl-*p*-phenylenediamine (6PPD), a globally ubiquitous tire rubber antiozonant (preventive of deterioration by ozone) and antioxidant. 6PPD is mobile within the rubber and slowly “blooms” to the tire surface where it forms a scavenger-protective film, reacting with the ozone more quickly than the ozone can react with the rubber.²⁸ This process forms 6PPD-quinone, among other products.²⁹

Analysis of representative roadway runoff and stormwater-affected creeks of the U.S. West Coast indicated widespread occurrence of 6PPD-quinone (< 0.3 to 19 µg/L) at toxic concentrations (median lethal concentration, LC₅₀, of 0.8 ± 0.16 µg/L).³⁰ More recent work has set the LC₅₀ for juvenile coho salmon even lower, at 95 ng/L (0.095 µg/L).³¹

Developing Overlook Crest will substantially increase automotive traffic in the Big Lake watershed, and the Stormwater Plan gives no attention to mitigating its negative consequences. Based on research by Spromberg et al. (2016),³² Ecology has rated bioretention such as I have recommended to have a “high” level of effectiveness in removing 6PPD-Q from stormwater runoff.³³ This BMP also performs relatively well among the available alternatives in capturing petroleum derivatives; metals; and particulates; and, with the appropriate soil, nutrients as well. The Stormwater Plan should make maximum use of it.

²⁸ Lattimer, R.P., E.R. Hooser, R.W. Layer, and C.K. Rhee. 1983. Mechanisms of Ozonation of *N*-(1,3-Dimethylbutyl)-*N'*-Phenyl-*p*-Phenylenediamine. *Rubber Chemistry and Technology* 56(2):431–439.

²⁹ Seiwert, B., M. Nihemaiti, M. Troussier, S. Weyrauch, and T. Reemtsma. 2022. Abiotic Oxidative Transformation of 6-PPD and 6-PPD Quinone from Tires and Occurrence of their Products in Snow from Urban Roads and in Municipal Wastewater. *Water Research* 212:118122.

³⁰ Tian, Z. et al. 2020. A Ubiquitous Tire Rubber-Derived Chemical Induces Acute Mortality in Coho Salmon. *Science* 371(6525):185–189.

³¹ Tian, Z., M. Gonzalez, C.A. Rideout, H.N. Zhao, X. Hu, J. Wetzel, E. Mudrock, C.A. James, J.K. McIntyre, and E.P. Kolodziej. 2022. 6PPD-Quinone: Revised Toxicity Assessment and Quantification with a Commercial Standard. *Environmental Science & Technology Letters* 9(2):140–146.

³² Spromberg, J. A., Baldwin, D. H., Damm, S. E., McIntyre, J. K., Huff, M., Sloan, C. A., Anulacion, B. F., Davis, J. W., & Scholz, N. L. (2016). EDITOR’S CHOICE: Coho salmon spawner mortality in western US urban watersheds: Bioinfiltration prevents lethal storm water impacts. *Journal of Applied Ecology*, 53(2), 398–407.

<https://doi.org/10.1111/1365-2664.12534> (accessed November 14, 2024).

³³ Environmental Assessment and Water Quality Programs. 2022. 6PPD in Road Runoff, Assessment and Mitigation Strategies, Publication 22-03-020. Washington State Department of Ecology Olympia, Washington, <https://apps.ecology.wa.gov/publications/documents/2203020.pdf> (accessed November 15, 2024).

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A FINAL WORD

In this letter I have described a number of potential negative impacts consequential to the Big Lake ecosystem. I further pointed out major shortcomings in the development proponent's plans for construction and post-construction stormwater management, making it highly probable that those problems will occur. For these reasons, the proposed development should be subjected to a full environmental impact assessment.

I would be pleased to answer any questions you may have and invite you to contact me if you wish.

Sincerely,

A handwritten signature in cursive script that reads "Richard R. Horner".

Richard R. Horner

Attachments: Attachment A; Background and Experience; Richard R. Horner, Ph.D.
Attachment B; *Curriculum Vitae*

ATTACHMENT A

BACKGROUND AND EXPERIENCE

RICHARD R. HORNER, PH.D.

I have 57 years of professional experience, 44 teaching and performing research at the college and university level. For the last 46 years I have specialized in research, teaching, and consulting in the area of stormwater runoff and surface water management.

I received a Ph.D. in Civil and Environmental Engineering from the University of Washington in 1978, following two Mechanical Engineering degrees from the University of Pennsylvania in 1965 and 1966. Although my degrees are all in engineering, I have had substantial course work and practical experience in aquatic biology and chemistry.

For 12 years beginning in 1981, I was a full-time research professor in the University of Washington's Department of Civil and Environmental Engineering. From 1993 until 2011, I served half time in that position and had adjunct appointments in two additional departments (Landscape Architecture and the College of the Environment's Center for Urban Horticulture). I spent the remainder of my time in private consulting through a sole proprietorship. My appointment became emeritus in late 2011, but I have participated in some research and teaching since then while maintaining my consulting practice.

My research, teaching, and consulting embrace all aspects of stormwater management, including determination of pollutant sources; their transport and fate in the environment; physical, chemical, and ecological impacts; and solutions to these problems through better structural and non-structural management practices.

I have conducted numerous research investigations and consulting projects on these subjects. Serving as a principal or co-principal investigator on more than 40 research studies, my work has produced three books, approximately 30 papers in the peer-reviewed literature, and over 20 reviewed papers in conference proceedings. I have also authored or co-authored more than 80 scientific or technical reports.

In addition to graduate and undergraduate teaching, I have taught many continuing education short courses to professionals in practice. My consulting clients include federal, state, and local government agencies; citizens' environmental groups; and private firms that work for these entities, primarily on the West Coast of the United States and Canada but in some instances elsewhere in the nation.

Over a 17-year period beginning in 1986 I spent a major share of my time as the principal investigator on two extended research projects concerning the ecological responses of freshwater resources to urban conditions and the urbanization process. I led an interdisciplinary team for 11 years in studying the effects of human activities on freshwater wetlands of the Puget Sound lowlands. This work led to a comprehensive set of management guidelines to reduce negative

effects and a published book detailing the study and its results. The second effort involved an analogous investigation over 10 years of human effects on Puget Sound's salmon spawning and rearing streams. These two research programs had broad sponsorship, including the U.S. Environmental Protection Agency, the Washington Department of Ecology, and a number of local governments.

Nationally, I conducted research sponsored by the National Science Foundation, U.S. Environmental Protection Agency, Water Environment Research Foundation, Transportation Research Board, and Electric Power Research Institute. In Washington, I have performed research for the Washington State Department of Transportation, Washington Department of Ecology, City of Seattle Public Utilities, King County Water and Land Resources Division and its predecessor Municipality of Metropolitan Seattle, King County Roads Division, and Washington Sea Grant.

I now serve or have served on technical advisory panels concerning stormwater issues for Seattle-Tacoma International Airport and King County Water and Land Resources Division. I was one of 14 signatories from the scientific community of a 2006 letter to the Puget Sound Partnership giving recommendations for improving water quality and aquatic and human ecosystems through improved stormwater runoff management (<https://special.seattletimes.com/s/ABPub/2008/05/10/2004406008.pdf>).

I have helped to develop stormwater management programs in Washington State, California, and British Columbia and studied such programs around the nation. I was one of four principal participants in a U.S. Environmental Protection Agency-sponsored assessment of 32 state, regional, and local programs spread among 14 states in arid, semi-arid, and humid areas of the West and Southwest, as well as the Midwest, Northeast, and Southeast. This evaluation led to the 1997 publication of "Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation" (subtitled "A Comprehensive Review of the Institutional Framework of Successful Urban Runoff Management Programs").

In California I have been a federal court-appointed overseer of stormwater program development and implementation at the city and county level and for two California Department of Transportation districts. I was directly involved in the process of developing the 13 volumes of Los Angeles County's Stormwater Program Implementation Manual, working under the terms of a settlement agreement in federal court as the plaintiffs' technical representative. My role was to provide quality-control review of multiple drafts of each volume and contribute to bringing the program and all of its elements to an adequate level. I have also evaluated and contributed in various ways to the stormwater programs in Los Angeles, San Diego, Orange, Riverside, San Bernardino, Ventura, Santa Barbara, San Luis Obispo, and Monterey Counties, as well as a regional program for the San Francisco Bay Area. At the recommendation of San Diego Baykeeper, I have been a consultant on stormwater issues to the City of San Diego, the San Diego Unified Port District, and the San Diego County Regional Airport Authority.

Over the past 30 years I have been a consultant to and expert witness for the U.S. Department of Justice and a number of national and regional environmental organizations in Clean Water Act cases. They include Natural Resources Defense Council, Earthjustice, Center for Biological

Diversity, and members of the Waterkeeper Alliance in the states of Washington, Oregon, and California.

I have been a member of the science team for Salmon-Safe, Inc. for 20 years. Salmon-Safe recognizes landowners who meet prescribed standards for aiding salmon protection and recovery. My role is to assess candidates' programs and performance, mainly concentrating on stormwater, and participate with other members of the team in certification decisions.

I was a member of the National Academy of Sciences-National Research Council ("NAS-NRC") committee on Reducing Stormwater Discharge Contributions to Water Pollution. NAS-NRC committees bring together experts to address broad national issues and give unbiased advice to the federal government. The present panel was the first ever to be appointed on the subject of stormwater. Its broad goals were to understand better the links between stormwater discharges and impacts on water resources, to assess the state of the science of stormwater management, and to apply the findings to make policy recommendations to the U.S. Environmental Protection Agency relative to municipal, industrial, and construction stormwater permitting. My principal contribution to the committee's final report, issued in October 2008, was the chapter presenting the committee's recommendations for broadly revamping the nation's stormwater program.

ATTACHMENT B

CURRICULUM VITAE

HORNER, Richard Ray

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University of Washington:
Emeritus Research Associate Professor,
Departments of Landscape Architecture and Civil
and Environmental Engineering and
Sole Proprietor Consultant

EDUCATION

- 1976 - 1978 University of Washington, Seattle, Washington; Ph.D. (Civil Engineering)
- 1965 - 1966 University of Pennsylvania, Philadelphia, Pennsylvania; M.S. (Mechanical Engineering)
- 1961 - 1965 University of Pennsylvania, Philadelphia, Pennsylvania; B.S. *Cum Laude* (Mechanical Engineering)

HONORS AND AWARDS

Augustus Trask Ashton Scholarship, University of Pennsylvania, 1961 - 65
Annual Academic Honors, University of Pennsylvania, 1961 - 65
Tau Beta Pi National Engineering Honor Society
National Science Foundation Traineeship, University of Pennsylvania, 1965 - 66

EMPLOYMENT

- 1986 - Present Richard R. Horner, Sole Proprietor (offering services in environmental engineering and science)
- 2011 - Present University of Washington, Seattle, Washington
Emeritus Research Associate Professor
- 1981 - 2011 University of Washington, Seattle, Washington
Research Associate Professor
- 1986 - 1990 King County, Seattle, Washington
Coordinator of Puget Sound Wetland and Stormwater Management Research Program (part-time; continued under contract to University of Washington)
- 1969 - 1981 Northampton Community College, Bethlehem, Pennsylvania
Engineering Department (Coordinator, 1971 - 73 and 1978 - 79)

Environmental Studies Department (Co-coordinator, 1973 - 76 and 1978 - 1981)
Professor, 1978 - 1981; Associate Professor, 1973 - 78;
Assistant Professor, 1969 - 73,
Leave of Absence, 1977 - 78; Sabbatical Leave, 1976 - 77

1977 - 1978 University of Washington, Seattle, Washington
Department of Civil Engineering
Research Engineer, Highway Runoff Water Quality Project

1976 - 1977 University of Washington, Seattle, Washington
Department of Civil Engineering and Institute for Environmental Studies
Research Assistant and Teaching Assistant

1966 - 1969 Exxon Research and Engineering Company, Florham Park, New Jersey;
Project Engineer

1965 - 1966 University of Pennsylvania, Philadelphia Pennsylvania
Department of Mechanical Engineering; Research Assistant

NATIONAL COMMITTEES

National Academy of Sciences Panel on Reducing Stormwater Discharge Contributions to Water Pollution, 2007-2008.

Technical Advisory Panel for Water Environment Federation projects on Decentralized Stormwater Controls for Urban Retrofit and Combined Sewer Overflow Reduction, 2005-2007.

Co-chair, Engineering Foundation Conference on Effects of Watershed Development and Management on Aquatic Ecosystems, 1996.

National Academy of Sciences Panel on Costs of Damage by Highway Ice Control, 1990-91.

U.S. Environmental Protection Agency National Wetland Research Planning Panel, 1988, 1991.

RESEARCH PROJECTS

* Principal Investigator.

** Co-Principal Investigator. (Where undesignated, I was a member of the faculty investigation team without principal investigator status).

Effects of Waterfront Stormwater Solutions Prototypes on Water Quality Runoff in Puget Sound near Pomeroy Park - Manchester Beach; Washington Sea Grant; \$148,838; 2015-17.

Development of a Stormwater Retrofit Plan for Water Resources Inventory Area (WRIA) 9 and Estimation of Costs for Retrofitting all Developed Lands of Puget Sound; U.S. Environmental Protection Agency and King County (WA); \$243,619; 2010-13.

Ultra-Urban Stormwater Management; Seattle Public Utilities; \$1,130,000; 1999-2008.*

Roadside Vegetation Management Study; Washington State Department of Transportation; \$50,000; 2004-05.

The Ecological Response of Small Streams to Stormwater and Stormwater Controls; U. S. Environmental Protection Agency, cooperating with Watershed Management Institute (Crawfordsville, FL); \$579,117; 1995-2003.*

Vegetated Stormwater Facility Maintenance; Washington State Department of Transportation; \$86,000; 1998-2000.*

Roadside Drainage System Management for Water Quality Improvement; King and Snohomish (WA) Counties; \$70,000; 1997-2000.*

Standardization of Wet Weather Protocols for Stream Impact and Treatment Technology Performance Assessments; Water Environment Research Foundation, cooperating with Water Research Center (Huntington Valley, Pennsylvania) and University of Illinois; \$125,000; 1996-97.

Road Shoulder Treatments for Water Quality Protection; Washington State Department of Transportation and King County Roads Division; \$90,000; 1995-96.**

Control of Nuisance Filamentous Algae in Streams by Invertebrate Grazing; National Science Foundation; \$193,691; 1994-96.

Criteria for Protection of Urban Stream Ecosystems; Washington Department of Ecology; \$230,000; 1994-96.

Region-Specific Time-Scale Toxicity in Aquatic Ecosystems; Water Environment Research Foundation, cooperating with Water Research Center (Huntington Valley, Pennsylvania) and University of Illinois; \$670,000; 1994-96.

Establishing Reference Conditions for Freshwater Wetlands Restoration; U. S. Environmental Protection Agency; \$75,000; 1993-97.

Stormwater Management Technical Assistance to Local Governments; Washington Department of Ecology; \$115,000; 1992-93.*

Center for Urban Water Resources Management; Washington Department of Ecology; \$336,490; plus \$157,400 matching support from seven local governments; 1990-93.*

University of Washington Cooperative Unit for Wetlands and Water Quality Research; King County, Washington; amount varied by year; 1987-95.*

Assessment of Portage Bay Combined Sewer Overflows; City of Seattle; \$132,676; 1990-91.*

Velocity-Related Critical Phosphorus Concentrations in Flowing Water, Phase 3; National Science Foundation; \$108,332; 1988-90.**

Design of Monitoring Programs for Determining Shellfish Bed Bacterial Contamination Problems; Washington Department of Ecology; \$12,000; 1988-89.*

Puget Sound Protocols Development; Tetra Tech, Inc. and Puget Sound Estuary Program; \$10,144; 1988.*

Improving the Cost Effectiveness of Highway Construction Site Erosion/Pollution Control, Phase 2; Washington State Department of Transportation; \$97,000; 1987-89.*

Wetland Mitigation Project Analysis; Washington State Department of Transportation; \$74,985; 1987-89.*

Lake Chelan Water Quality Assessment; Harper-Owes, consultant to Washington State Department of Ecology; \$42,977; 1986-88.

Quality of Management of Silver Lake; City of Everett; \$67,463; 1986-88.

Effectiveness of WSDOT Wetlands Creation Projects; Washington State Department of Transportation; \$42,308; 1986-87.*

Improving the Cost Effectiveness of Highway Construction Site Erosion/Pollution Control; Washington State Department of Transportation; \$41,608; 1986-87.*

Management Significance of Bioavailable Phosphorus in Urban Runoff; State of Washington Water Research Center and Municipality of Metropolitan Seattle; \$32,738; 1986-87.**

Environmental Monitoring and Evaluation of Calcium Magnesium Acetate (CMA); Transportation Research Board of National Academy of Sciences; \$199,943; 1985-87.*

Conceptual Design of Monitoring Programs for Determination of Water Quality and Ecological Change Resulting from Nonpoint Source Discharges; Washington State Department of Ecology; \$49,994; 1985-86.**

Development of an Integrated Land Treatment Approach for Improving the Quality of Metalliferous Mining Wastewaters; Washington Mining and Mineral Resources Research Institute; \$4,000; 1985-86.*

Preliminary Investigation of Sewage Sludge Utilization on Roadsides; Washington State Department of Transportation; \$6,664; 1984-85.*

Source Control of Transit Base Runoff Pollutants; Municipality of Metropolitan Seattle; \$26,867; 1984-85.**

Lake Sammamish Future Water Quality; Municipality of Metropolitan Seattle; \$28,500; 1984-85.

Implementation of Highway Runoff Water Quality Research Results; Washington State Department of Transportation; \$13,998; 1984-85.*

Performance Evaluation of a Detention Basin and Coalescing Plate Oil Separator for Treating Urban stormwater Runoff; Washington State Water Research Center; 1984-85; \$11,724.**

Velocity-Related Critical Phosphorus Concentrations in Flowing Water, Phase 2; National Science Foundation; \$99,088; 1983-85.**

Development of a Biological Overland Flow System for Treating Mining Wastewaters; Washington Mining and Mineral Resources Research Institute; \$6,030; 1983-84.*

Nutrient Contributions of Agricultural Sites to the Moses Lake System; Moses Lake Conservation District; \$15,039; 1982-84.*

Planning Implementation of Runoff Water Quality Research Findings; Washington State Department of Transportation; \$12,735; 1982-83.**

Transport of Agricultural Nutrients to Moses Lake; Brown and Caldwell Engineers; \$22,725; 1982-83.**

Investigation of Toxicant Concentration and Loading Effects on Aquatic Macroinvertebrates; University of Washington Graduate School Research Fund; \$3,788; 1982.*

Sampling Design for Aquatic Ecological Monitoring; Electric Power Research Institute; \$542,008; 1981-86.

Velocity-Related Critical Phosphorus Concentrations in Flowing Water; National Science Foundation; \$70,310; 1980-82.

Highway Runoff Water Quality; Washington State Department of Transportation; \$461,176; 1977-82.

BOOKS

Shaver, E., R. Horner, J. Skupien, C. May, and G. Ridley. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, 2nd Edition. U.S. Environmental Protection Agency, Washington, D.C., 2007.

Azous, A. L. and R. R. Horner. *Wetlands and Urbanization: Implications for the Future*. Lewis Publishers, Boca Raton, FL, 2000.

Horner, R. R., J. J. Skupien, E. H. Livingston, and H. E. Shaver. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. Terrene Institute, Washington, D. C., 1994.

REFEREED JOURNAL PUBLICATIONS AND BOOK CHAPTERS

Wright, O.M., E. Istanbuluoglu, R.R. Horner, C.L. DeGasperi, and J. Simmonds. 2018. Is There a Limit to Bioretention Effectiveness? Evaluation of Stormwater Bioretention Treatment Using a Lumped Ecohydrologic Watershed Model and Ecologically-Based Design Criteria. *Hydrological Processes* 2018:1-17.

Chapman, C. and R.R. Horner. Performance Assessment of a Street-Drainage Bioretention System. *Water Environment Research* 82(2): 109-119, 2010.

Horner, R. R. et al. Structural and Non-Structural Best Management Practices (BMPs) for Protecting Streams. In *Linking Stormwater BMP Designs and Performance to Receiving Water Impact Mitigation*, B. K. Urbonas (ed.), American Society of Civil Engineers, New York, pp. 60-77, 2002.

Comings, K. J., D. B. Booth, and R. R. Horner. Storm Water Pollutant Removal by Two Wet Ponds in Bellevue, Washington. *Journal of Environmental Engineering* 126(4):321-330, 2000.

Anderson, E. L., E. B. Welch, J. M. Jacoby, G. M. Schimek, and R. R. Horner. Periphyton Removal Related to Phosphorus and Grazer Biomass Level. *Freshwater Biology* 41:633-651, 1999.

Horner, R. R., D. B. Booth, A. Azous, and C. W. May. Watershed Determinants of Ecosystem Functioning. In *Effects of Watershed Development and Management on Aquatic Ecosystems*, L. A. Roesner (ed.), American Society of Civil Engineers, New York, pp. 251-274, 1997.

Horner, R.R. Toward Ecologically Based Urban Runoff Management. In *Urban Runoff and Receiving Systems*, E.E. Herricks (ed.), Lewis Publishers, Boca Raton, Florida, pp. 365-378, 1995.

- Walton, S. P., E. B. Welch, and R. R. Horner. Stream Periphyton Response to Grazing and Changes in Phosphorus Concentration. *Hydrobiologia* 302:31-46, 1994.
- Reinelt, L. E. and R. R. Horner. Pollutant Removal from Stormwater Runoff by Palustrine Wetlands Based on a Comprehensive Budget. *Ecological Engineering* 4:77-97, 1995.
- Horner, R.R. and M.V. Brenner. Environmental Evaluation of Calcium Magnesium Acetate for Highway Deicing Applications. *Resources, Conservation and Recycling* 7:213-237, 1992.
- Brenner, M.V. and R.R. Horner. Effects of Calcium Magnesium Acetate on Dissolved Oxygen in Water. *Resources, Conservation and Recycling* 7:239-265, 1992.
- Reinelt, L.E., R.R. Horner, and R. Castensson. Nonpoint Source Water Quality Management: Improving Decision-Making Information through Water Quality Monitoring. *Journal of Environmental Management* 34:15-30, 1992.
- Horner, R.R., M.V. Brenner, R.B. Walker, and R.H. Wagner. Environmental Evaluation of Calcium Magnesium Acetate. In *Calcium Magnesium Acetate (CMA): An Emerging Bulk Chemical for Multi-purpose Environmental Applications*, D.L. Wise, Y.A. Lavendis, and M. Metghalchi (eds.), Elsevier Science Publishers B.V., The Netherlands, pp. 57-102, 1991.
- Horner, R.R., E.B. Welch, M.R. Seeley, and J.M. Jacoby. Responses of Periphyton to Changes in Current Velocity, Suspended Sediments and Phosphorus Concentration. *Freshwater Biology* 24:215-232, 1990.
- Horner, R.R. Long-Term Effects of Urban Stormwater on Wetlands. In *Design of Urban Runoff Quality Controls*, L.A. Roesner, B. Urbonas, and M.B. Sonnen (eds.), American Society of Civil Engineers, New York, pp. 451-466, 1989.
- Welch, E.B., R.R. Horner, and C.R. Patmont. Phosphorus Levels That Cause Nuisance Periphyton: A Management Approach. *Water Research* 23(4):401-405, 1989.
- Butkus, S.R., E.B. Welch, R.R. Horner, and D.E. Spyridakis. Lake Response Modeling Using Biologically Available Phosphorus. *Journal of the Water Pollution Control Federation* 60(9):1663-1669, 1988.
- Reinelt, L.E., R.R. Horner, and B.W. Mar. Nonpoint Source Pollution Monitoring Program Design. *Journal of Water Resources Planning and Management* 114(3):335-352, 1988.
- Welch, E.B., J.M. Jacoby, R.R. Horner, and M.R. Seeley. Nuisance Biomass Levels of Periphytic Algae in Streams. *Hydrobiologia*, 157:161-168, 1988.
- Reinelt, L.E., R. Castensson, and R.R. Horner. Modification of an Existing Monitoring Program to Address Nonpoint Source Pollution, A Case Study of the Svarta River Basin, Sweden. *Vatten* 43:199-208, 1987.

Mar, B.W., R.R. Horner, J.S. Richey, D.P. Lettenmaier, and R.N. Palmer. Data Acquisition, Cost-Effective Methods for Obtaining Data on Water Quality. *Environmental Science and Technology* 20(6):545-551, 1986.

Horner, R.R., J.S. Richey, and G.L. Thomas. A Conceptual Framework to Guide Aquatic Monitoring Program Design for Thermal Electric Power Plants. *Rationale for Sampling and Interpretation of Ecological Data in the Assessment of Freshwater Ecosystems*, Special Technical Publication 894 of the American Society for Testing and Materials, Philadelphia, Pennsylvania, pp. 86-100, 1986.

Welch, E.B., D.E. Spyridakis, J.I. Shuster, and R.R. Horner. Declining Lake Sediment Phosphorus Release and Oxygen Deficit Following Wastewater Diversion. *Journal of the Water Pollution Control Federation* 58(1):92-96, 1986.

Richey, J.S., B.W. Mar, and R.R. Horner. The Delphi Technique in Environmental Assessment, Part 1: Implementation and Effectiveness. *Journal of Environmental Management* 21:135-146, 1985.

Richey, J.S., R.R. Horner, and B.W. Mar. The Delphi Technique in Environmental Assessment, Part 2: Consensus on Critical Issues in Environmental Monitoring Program Design. *Journal of Environmental Management* 21:147-159, 1985.

Horner, R.R. and B.W. Mar. Assessing Impacts of Operating Highways on Aquatic Ecosystems. *Transportation Research Record* 1017:47-55, 1985.

Horner, R.R., E.B. Welch, and R.B. Veenstra. Development of Nuisance Periphytic Algae in Laboratory Streams in Relation to Enrichment and Velocity. In *Periphyton of Freshwater Ecosystems*, R.G. Wetzel (ed.), Dr. W. Junk BV, the Hague, The Netherlands, pp. 121-134, 1983.

Horner, R.R. and B.W. Mar. A Guide for Assessing Water Quality Impacts of Highway Operations and Maintenance. *Transportation Research Record* 948:31-40, 1983.

Chui, T.W., B.W. Mar, and R.R. Horner. A Pollutant Loading Model for Highway Runoff. *Journal of Environmental Engineering Division, ASCE* 108:1193-1120, 1982.

Horner, R.R. and E.B. Welch. Stream Periphyton Development in Relation to Current Velocity and Nutrients. *Canadian Journal of Fisheries and Aquatic Sciences* 38:449-457, 1981.

REVIEWED PROCEEDINGS PUBLICATIONS

Horner, R. R. Stormwater Runoff Flow Control Benefits of Urban Drainage System Reconstruction According to Natural Principles. Presentation at Puget Sound—Strait of Georgia Research Conference, Vancouver, B. C., 2003.

- May, C.W. and R.R. Horner. 2002. The Limitations of Mitigation-Based Stormwater Management in the Pacific Northwest and the Potential of a Conservation Strategy Based on Low-Impact Development Principles. Proc. 2002 ASCE Stormwater Conference, Portland, OR.
- Horner, R. R. and C. R. Horner. Performance of a Perimeter (“Delaware”) Sand Filter in Treating Stormwater Runoff from a Barge Loading Terminal. Proc. Comprehensive Stormwater and Aquatic Ecosystem Management Conf.; Auckland, New Zealand; February 1999, pp. 183-192, 1999.
- Horner, R. R. and C. W. May. Regional Study Supports Natural Land Cover Protection as Leading Best Management Practice for Maintaining Stream Ecological Integrity. Proc. Comprehensive Stormwater and Aquatic Ecosystem Management Conf.; Auckland, New Zealand; February 1999, pp. 233-248, 1999.
- Horner, R. R. Constructed Wetlands for Urban Runoff Water Quality Control. Proc. National Conf. on Urban Runoff Management; Chicago, Illinois; March 1993, pp. 327-340, 1995.
- Horner, R. R. Training for Construction Site Erosion Control and Stormwater Facility Inspection. Proc. National Conf. on Urban Runoff Management; Chicago, Illinois; March 1993, pp. 426-450, 1995.
- Horner, R. R. Overview of the Puget Sound Wetlands and Stormwater Management Research Program. Proc. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995, pp. 141-145, 1995.
- Horner, R. R. and L. E. Reinelt. Guidelines for Managing Urban Wetlands. Proc. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995, pp. 171-178, 1995.
- Taylor, B. K. Ludwa, and R. R. Horner. Urbanization Effects on Wetland Hydrology and Water Quality. Proc. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995, pp. 146-154, 1995.
- Reinelt, L.E. and R.R. Horner. Urban Stormwater Impacts on the Hydrology and Water Quality of Palustrine Wetlands in the Puget Sound Region. Proc. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1991; pp. 33-42.
- Horner, R.R. Environmental Effects of Calcium Magnesium Acetate, Emphasizing Aquatic Ecosystem Effects. Proc. Conf. on Environmental Impacts of Highway Deicing, Institute of Ecology Publication No. 33, University of California, Davis; 1990; pp. 97-119.
- Stockdale, E.C. and R.R. Horner. Using Freshwater Wetlands for Stormwater Management: A Progress Report. Proc. Wetlands 1988: Urban Wetlands and Riparian Habitat Symposium; Oakland, California, June 1988.

- Horner, R.R. Highway Construction Site Erosion and Pollution Control: Recent Research Results. Proc. 39th Annual Road Builders' Clinic; Moscow, Idaho; March 1988; pp. 37-54.
- Horner, R.R., F.B. Gutermuth, L.L. Conquest, and A.W. Johnson. Urban Stormwater and Puget Trough Wetlands. Proc. 1st Annual Meeting on Puget Sound Research; Seattle, Washington; March 1988; pp. 723-746.
- Weiner, R.F., R.R. Horner, and J. Kettman. Preliminary Comparative Risk Assessment for Hanford Waste Sites. Proc. Waste Management 88; Tucson, Arizona; February 1988.
- Stockdale, E.C. and R.R. Horner. Prospects for Wetlands Use in Stormwater Management. Proc. Coastal Zone 87 Conf.; Seattle, Washington; May 1987; pp. 3701-3714.
- Horner, R.R. A Review of Wetland Water Quality Functions, Proc. Conf. on Wetland Functions, Rehabilitation, and Creation in the Pacific Northwest: The State of Our Understanding; Port Townsend, Washington; May 1986; pp. 33-50.
- Bain, R.C., Jr., R.R. Horner, and L. Nelson. Nonpoint Pollution Control Strategies for Moses Lake, Washington. Proc. Fifth Annual Conf. North American Lake Management Society; Lake Geneva, Wisconsin; November 1985; pp. 170-176.
- Shuster, J.I., E.B. Welch, R.R. Horner, and D.E. Spyridakis. Response of Lake Sammamish to Urban Runoff Control. Proc. Fifth Annual Conf. North American Lake Management Society; Lake Geneva, Wisconsin; November 1985; pp. 229-234.
- Horner, R.R., J.S. Richey, and B.W. Mar. A General Approach to Designing Environmental Monitoring Programs. Proc. Pacific Section AAAS Sym. on Biomonitors, Bioindicators and Bioassays of Environmental Quality; Missoula, Montana; June 1985.
- Horner, R.R. Improvement of Environmental Impact Assessment of Nonpoint Sources of Water Pollution. Proc. Non-point Pollution Abatement Sym.; Milwaukee, Wisconsin; April 1985.
- Horner, R.R., E.B. Welch, M.M. Wineman, M.J. Adolfson, and R.C. Bain, Jr. Nutrient Transport Processes in an Agricultural Watershed. Proc. Fourth Annual Conf. North American Lake Management Society; McAfee, New Jersey; October 1984; pp. 221-228.
- Horner, R.R. and B.W. Mar. A Predictive Model for Highway Runoff Pollutant Concentrations and Loadings. Proc. Stormwater and Water Quality Management Model Users' Group Meeting. EPA 600/9-82-015; Alexandria, Virginia; March 1982; pp. 210-224.

TECHNICAL REPORTS

- Horner, R.R. Development of a Stormwater Retrofit Plan for Water Resources Inventory Area 9: Flow and Water Quality Indicators and Targets. King County Water and Land Resources Division, Seattle, Washington, 2013.
- Horner, R.R. and J. Gretz. Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices Applied to Meet Various Potential Stormwater Runoff Regulatory Standards. Report to U.S. Environmental Protection Agency by Natural Resources Defense Council, 2011.
- Horner, R.R. Section 4-2, Protection and Restoration Strategies for Watersheds and Tributaries; Chapter 4: A Science-Based Review of Ecosystem Protection and Restoration Strategies for Puget Sound and Its Watersheds; Puget Sound Science Update. Puget Sound Partnership, Tacoma, WA, 2010.
- Garrison, N., R.C. Wilkinson, and R. Horner. How Greening California Cities Can Address Water Resources and Climate Challenges in the 21st Century. Natural Resources Defense Council, 2009.
- Horner, R. R. Supplementary Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices (“LID”) for the San Francisco Bay Area. Natural Resources Defense Council, 2009.
- Horner, R. R. Initial Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices (“LID”) for the San Francisco Bay Area. Natural Resources Defense Council, 2009.
- Horner, R. R. Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices (“LID”) for Ventura County. Natural Resources Defense Council, 2008.
- Horner, R. R. and C. Chapman. NW 110th Street Natural Drainage System Performance Monitoring, With Summary of Viewlands and 2nd Avenue NW SEA Streets Monitoring. Report to City of Seattle Public Utilities, 2007.
- Horner, R. R. Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices (“LID”) for the San Diego Region. Natural Resources Defense Council, 2006.
- Horner, R. R. SPU Drainage Rate Analysis Options: Recommendations on Certain Technical Issues. Report to City of Seattle Public Utilities, 2005.
- Hill, K. and R. Horner. Assessment Of Alternatives In Roadside Vegetation Management. Report to Washington State Department of Transportation, 2005.

- Horner, R. R. and Entranco, Inc. Regional Detention Facilities Retrofit Project: Evaluation of Regional Stormwater Ponds for Water Quality Improvements. Report to City of Bellevue Utilities Department, 2005.
- Horner, R. R. and T. Osborn. Removal of Fecal Coliforms from Stormwater Runoff: A Literature Review. Report to City of Blaine, 2005.
- Horner, R.R., H. Lim, and S.J. Burges. Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects: Summary of the 2000-2003 Water Years, Water Resources Series Technical Report Number 181. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA. Report to City of Seattle Public Utilities, 2004.
- Horner, R.R., C.W. May, and E.H. Livingston. Linkages Between Watershed and Stream Ecosystem Conditions in Three Regions of the United States. Report to U.S. Environmental Protection Agency by Watershed Management Institute, Inc., Crawfordville, FL, 2003.
- Karr, J. R., R. R. Horner, and C R. Horner. EPA's Review of Washington's Water Quality Criteria: An Evaluation of Whether Washington's Criteria Proposal Protects Stream Health and Designated Uses. Report to National Wildlife Federation, 2003.
- Horner, R.R., H. Lim, and S.J. Burges. Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects, Water Resources Series Technical Report Number 170. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA. Report to City of Seattle Public Utilities, 2002.
- Miller, A.V., S.B. Burges, and R.R. Horner. Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects, Water Resources Series Technical Report Number 166. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA. Report to City of Seattle Public Utilities, 2001.
- Mills, M. and R. R. Horner. Comprehensive Ditch and Culvert Program. Report to City of Seattle Public Utilities, 2001.
- Colwell, S., R. R. Horner, D. B. Booth, and D. Gilvydis. A Survey of Ditches Along County Roads for Their Potential to Affect Storm Runoff Water Quality. Report to Snohomish County Surface Water Management Division, Snohomish County Road Maintenance, King County Land and Water Resources Division, King County Department of Transportation Road Maintenance, 2000.
- Cammermayer, J. W. and R. R. Horner. Vegetated Stormwater Facility Maintenance. Report to Washington State Department of Transportation, WA-RD-495.1, 2000.
- Azous, A. L. and R. R. Horner (eds.). Wetlands and Urbanization: Implications for the Future. Report to Washington Department of Ecology, 1997.

- May, C. W., E. B. Welch, R. R. Horner, J. R. Karr, and B. W. Mar. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Report to Washington Department of Ecology, 1997.
- Livingston, E. H., H. E. Shaver, J. J. Skupien, and R. R. Horner. Operation, Maintenance, and Management of Stormwater Management Systems. Report to U. S. Environmental Protection Agency, 1997.
- Livingston, E. H., H. E. Shaver, R. R. Horner, and J. J. Skupien,. Watershed Management Institute. Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation. Report to U. S. Environmental Protection Agency, 1997.
- St. John, M. S. and R. R. Horner. Effect of Road Shoulder Treatments on Highway Runoff Quality and Quantity. Report to Washington State Department of Transportation, WA-RD-429.1, 1997.
- Horner, R.R. Storm Drainage Water Quality Rate Basis Recommendations. Report to City of Bellevue Utilities Department, 1996.
- Horner, R. R. and C. R. Horner. Impacts on Aquatic Ecosystems and Organisms of Airplane and Airport Runway Deicing Chemicals. Report to Port of Seattle, Seattle, Washington, 1996.
- Horner, R. R. Constituents and Sources of Water Pollutants in Urban Stormwater Runoff. Report to Natural Resources Defense Council, Los Angeles, California, 1995.
- Horner, R. R. Program Recommendations and Review of Submittals for Los Angeles County Stormwater NPDES Compliance. Report to Natural Resources Defense Council, Los Angeles, California, 1995.
- Horner, R. R. and C. R. Horner. Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System, Part II, Performance Monitoring. Report to Alaska Marine Lines, Seattle, Washington, 1995.
- Horner, R. R. Review of Draft Design Memorandum, Lakemont Boulevard Extension. Report to City of Bellevue, Washington, 1995.
- Economic and Engineering Services, Inc. and R. R. Horner. Wetpond Restoration for Water Quality Enhancement. Report to City of Bellevue, Washington and Washington Department of Ecology, 1995.
- City of Bellevue Utilities Department (R. R. Horner contributing author). Characterization and Source Control of Urban Stormwater Quality. Report to Washington Department of Ecology, 1995.

- Horner, R. R. Constituents and Sources of Water Pollutants in Highway Stormwater Runoff. Report to Natural Resources Defense Council, Los Angeles, California, 1994.
- Horner, R. R. Program Recommendations and Review of California Department of Transportation Submittals for Santa Monica Bay Watershed Stormwater NPDES Compliance, Support Materials. Report to Natural Resources Defense Council, Los Angeles, California, 1994.
- Horner, R. R. Peer Review of Assessment of Potential Impacts from Sediment and Phosphorus Loading to Lewis Creek and Lake Sammamish - Lakemont Boulevard Extension Project. Report to City of Bellevue, Washington, 1994.
- Horner, R. R. Review of the Literature on Constructed Wetlands for Municipal Wastewater Treatment. Report to Kramer, Chin and Mayo, Inc., Seattle, Washington, 1994.
- Engineering Technologies Associates, Inc. and R. R. Horner. Conceptual Framework for Hydrograph Classification. Report to Water Research Center, Huntington Valley, Pennsylvania, 1994.
- Horner, R. R. Phantom Lake Stormwater Controls Evaluation, Review of Water Quality Data and Literature. Report to CH2M-Hill, City of Bellevue Storm and Surface Water Utility, and Boeing Computer Services Corporation, Bellevue, Washington, 1993.
- Horner, R. R. Boeing Customer Service Training Center Stormwater Quality Monitoring and Assessment Program. Report to Boeing Commercial Airplane Company, Sverdrup Corporation, and City of Renton, Washington, 1992.
- Welch, E.B., R.J. Totorica and R.R. Horner. Approach to Developing Nutrient Loading Criteria for Franklin D. Roosevelt Lake. Report to Washington Department of Ecology, Olympia, 1992.
- Municipality of Metropolitan Seattle (R. R. Horner contributing author). Biofiltration Swale Performance, Recommendations, and Design Considerations. Report to Washington Department of Ecology, Olympia, 1992.
- Horner, R.R. and P. Kalina. Water Quality Assessment of Portage Bay. Report to City of Seattle, 1991.
- Horner, R.R. and C.R. Horner. Transport and Fate of Metal and Organic Toxicants in Arid-Region Wetlands. Report to U.S. Environmental Protection Agency, Corvallis Laboratory, 1991.
- King County Resource Planning Section (R. R. Horner contributing author). Development of Guidance for Managing Urban Wetlands and Stormwater. Report to Washington Department of Ecology, Olympia, 1991.

- Horner, R.R. and C.R. Horner. Use of Underdrain Filter Systems for the Reduction of Stormwater Runoff Pollutants: A Literature Review. Report to Kramer, Chin and Mayo, Inc., 1990.
- Reinelt, L.E. and R.R. Horner. Characterization of the Hydrology and Water Quality of Palustrine Wetlands Affected by Urban Stormwater. Report prepared for the Puget Sound Wetlands and Stormwater Management Research Program, Seattle, WA, 1990.
- Horner, R. R. Analysis of Proposed Surface Water Source Control Requirements for the Commencement Bay Nearshore/Tideflats Superfund Area. Report to Port of Tacoma, Washington, 1989.
- Horner, R.R. and K.J. Raedeke. Guide for Wetland Mitigation Project Monitoring. Report to Washington State Department of Transportation, 1989.
- Horner, R.R., J. Guedry, and M.H. Korten Hof. Improving the Cost-Effectiveness of Highway Construction Site Erosion and Pollution Control. Report to Washington State Department of Transportation, 1989.
- Horner, R.R., J. Guedry, and M.H. Korten Hof. Highway Construction Site Erosion and Pollution Control Manual. Report to Washington State Department of Transportation, 1989.
- Horner, R.R., M.V. Brenner, and C.A. Jones. Design of Monitoring Programs for Determining Sources of Shellfish Bed Bacterial Contamination Problems. Report to Washington Department of Ecology, 1989.
- Horner, R. R. and C. R. Horner. A Technical Review of the Sediment/Toxicant Retention and Nutrient Removal Transformation Functions of WET 2.0. Report to ASci Corporation and U. S. Environmental Protection Agency, Duluth, Minnesota, 1989.
- Horner, R. R. and M. Benjamin. Washington State Pulp and Paper Plant Water Treatment Effluent Limitations. Report to Technical Resources, Inc., Rockville, Maryland, 1988.
- Tetra Tech, Inc., University of Washington (R.R. Horner), and Battelle Pacific Northwest Laboratories. Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Waters of the Puget Sound Region. Report to Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, 1988.
- Horner, R.R. Biofiltration Systems for Storm Runoff Water Quality Control. Report to Municipality of Metropolitan Seattle, Seattle, 1988.
- URS Consultants, R.R. Horner, Matrix Management Group, Weston/Northwest Cartography, and Water Resources Associates. City of Puyallup Stormwater Management Program. Report to City of Puyallup, 1988.

- Welch, E.B., J. Oppenheimer, R.R. Horner, and D.E. Spyridakis. Silver Lake Water Quality Nutrient Loading and Management. Report to City of Everett, 1988.
- Horner, R.R. Environmental Monitoring and Evaluation of Calcium Magnesium Acetate (CMA)--Final Report. Report to National Research Council, National Academy of Sciences, 1988.
- Horner, R.R., E.B. Welch, S.R. Butkus, and D.E. Spyridakis. Management Significance of Bioavailable Phosphorus. Report to Municipality of Metropolitan Seattle and State of Washington Water Research Center, 1987.
- Horner, R.R. and S.E. Cassatt. Effectiveness of Wetlands Creation in Mitigating Highway Impacts. Report to Washington State Department of Transportation, 1987.
- Horner, R.R. and M.H. Kortenhof. Improving the Cost-Effectiveness of Highway Construction Site Erosion/Pollution Control, Phase 1. Report to Washington State Department of Transportation, 1987.
- Horner, R.R., B.W. Mar, L.E. Reinelt, and J.S. Richey. Design of Monitoring Programs for Determination of Ecological Change Resulting from Nonpoint Source Water Pollution in Washington State. Report to Washington State Department of Ecology, 1986.
- Horner, R.R., E.B. Welch, M.R. Seeley, and J.M. Jacoby. Velocity-Related Critical Phosphorus Concentrations in Flowing Water, Phase II. Report to National Science Foundation, 1986.
- Horner, R.R., J.S. Richey, and D.P. Lettenmaier. Source Control of Transit Base Runoff Pollutants--Final Report. Report to Municipality of Metropolitan Seattle, 1985.
- Welch, E.B., R.R. Horner, D.E. Spyridakis, and J.I. Shuster. Response of Lake Sammamish to Past and Future Phosphorus Loading. Report to Municipality of Metropolitan Seattle, 1985.
- Horner, R.R. and S.R. Wonacott. Performance Evaluation of a Detention Basin and Coalescing Plate Oil Separator for Treating Urban Stormwater Runoff. Report to State of Washington Water Research Center and U.S. Geological Survey, 1985.
- Cahn, D.C. and R.R. Horner. Preliminary Investigation of Sewage Sludge Utilization in Roadside Development. Report to Washington State Department of Transportation, 1985.
- Horner, R.R. Highway Runoff Water Quality Research Implementation Manual, Vol. 1-2, FHWA WA-RD 72.1,2. Report to Washington State Department of Transportation, 1985.
- Horner, R.R. Suggested Revisions to WSDOT Manuals for Implementing Washington State Highway Runoff Water Quality Research Results, FHWA WA-RD 72.3. Report to Washington State Department of Transportation, 1985.

- Mar, B.W., D.P. Lettenmaier, R.R. Horner, J.S. Richey, R.N. Palmer, S.P. Millard, and M.C. MacKenzie. Sampling Design for Aquatic Ecological Monitoring, Vol. 1-5. Final Report on Electric Power Research Institute, Project RP1729-1, 1985.
- Horner, R.R., J.S. Richey, D.P. Lettenmaier, and J.F. Ferguson. Source Control of Transit Base Runoff Pollutants, Task 1--Interim Report. Report to Municipality of Metropolitan Seattle, 1984.
- Brown and Caldwell Engineers and R.R. Horner. Moses Lake Clean Lake Project, Phase I. Report to Moses Lake Irrigation and Rehabilitation District, 1984.
- Mar, B.W., D.P. Lettenmaier, J.S. Richey, R.R. Horner, R.N. Palmer, S.P. Millard, and G.L. Thomas. Sampling Design for Aquatic Ecological Monitoring, Phase II--Methods Development, Vol. 1-2. Report to Electric Power Research Institute, 1984.
- Horner, R.R. Highway Runoff Water Quality Technology Transfer Workshop Handbook. Prepared for Washington State Department of Transportation, 1983.
- Pedersen, E.R., R.R. Horner, and G.L. Portele. SR 528 - 4th Street Extension, Marysville, Snohomish County, Washington: Draft Environmental Impact Statement. Prepared for City of Marysville, 1983.
- Horner, R.R., B.W. Mar, B. Chaplin, and F. Conroy. Implementation Plan for Highway Runoff Water Quality Research Results. Report to Washington State Department of Transportation, 1983.
- Little, L.M., R.R. Horner, and B.W. Mar. Assessment of Pollutant Loadings and Concentrations in Highway Stormwater Runoff, FHWA WA-RD-39.17. Report to Washington State Department of Transportation, 1983.
- Horner, R.R., and E.B. Welch. Velocity-Related Critical Phosphorus Concentrations in Flowing Water. Final Report to National Science Foundation for award number (CME) 79-18514, 1982.
- Horner, R.R., and E.B. Welch. Impacts of Channel Reconstruction on the Pilchuck River, FHWA WA-RD-39.15. Report to Washington State Department of Transportation, 1982.
- Mar, B.W., R.R. Horner, J.F. Ferguson, D.E. Spyridakis, and E.B. Welch. Summary - Highway Runoff Water Quality, 1977-1982, FHWA WA-RD-39.16. Report to Washington State Department of Transportation, 1982.
- Horner, R.R. and B.W. Mar. Guide for Water Quality Assessment of Highway Operations and Maintenance, FHWA WA-RD-39.14. Report to Washington State Department of Transportation, 1982.

- Mar, B.W., D.P. Lettenmaier, R.R. Horner, D.M. Eggers, R.N. Palmer, G.J. Portele, J.S. Richey, E.B. Welch, G. Wiens, and J. Yearsley. Sampling Design for Aquatic Ecological Monitoring, Phase 1. Report to Electric Power Research Institute, 1982.
- Portele, G.J., B.W. Mar, R.R. Horner, and E.B. Welch. Effects of Seattle, Area Highway Stormwater Runoff on Aquatic Biota, FHWA WA-RD-39.11. Report to Washington State Department of Transportation, 1982.
- Wang, T.S., D.E. Spyridakis, B.W. Mar, and R.R. Horner. Transport, Deposition, and Control of Heavy Metals in Highway Runoff, FHWA WA-RD-39.10. Report to Washington State Department of Transportation, 1982.
- Chui, T.W., B.W. Mar, and R.R. Horner. Highway Runoff in Washington State: Model Validation and Statistical Analysis, FHWA WA-RD-39.12. Report to Washington State Department of Transportation, 1981.
- Mar, B.W., J.F. Ferguson, D.E. Spyridakis, E.B. Welch, and R.R. Horner. Year 4, Runoff Water Quality, August 1980-August 1981, FHWA WA-RD-39.13. Report to Washington State Department of Transportation, 1981.
- Horner, R.R. and S.M. Grason. An Ecological Study of the Monocacy Creek and its Groundwater Sources in the Vicinity of Camels Hump. Report to the Monocacy Creek Watershed Association, Bethlehem, Pennsylvania, 1981.
- Horner, R.R. and E.B. Welch. Background Conditions in the Lower Pilchuck River Prior to SR-2 Construction. Report to Washington State Department of Transportation, 1979.
- Horner, R.R. and B.W. Mar. Highway Runoff Monitoring: The Initial Year, FHWA WA-RD-39.3. Report to Washington State Department of Transportation, 1979.
- Horner, R.R. and E.B. Welch. Effects of Velocity and Nutrient Alterations on Stream Primary Producers and Associated Organisms, FHWA WA-RD-39.2. Report to Washington State Department of Transportation, 1978.
- Horner, R.R., T.J. Waddle, and S.J. Burges. Review of the Literature on Water Quality Impacts of Highway Operations and Maintenance. Report to Washington State Department of Transportation, 1977.
- Horner, R.R. A Method of Defining Urban Ecosystem Relationships Through Consideration of Water Resources. U.S. Man and the Biosphere Project 11 Report, 1977.
- Horner, R.R. and R. Gilliom. Bear Lake: Current Status and the Consequences of Residential Development. Report to Bear Lake Residents' Association, Kitsap County, Washington, 1977.

PRESENTATIONS AND DISCUSSIONS

*Presented by a co-author. In all other cases, I presented the paper.

Stormwater Runoff Flow Control Benefits of Urban Drainage System Reconstruction According to Natural Principles. Puget Sound/Georgia Strait Research Meeting; Vancouver, British Columbia; April 2003.

Structural and Non-Structural Best Management Practices (BMPs) for Protecting Streams. Invited presentation at the Engineering Foundation Conference on Linking Stormwater BMP Designs and Performance to Receiving Water Impact Mitigation; Snowmass, Colorado; August 2001.

Performance of a Perimeter (“Delaware”) Sand Filter in Treating Stormwater Runoff from a Barge Loading Terminal. Invited presentation at the Comprehensive Stormwater and Aquatic Ecosystem Management Conf.; Auckland, New Zealand; February 1999.

Regional Study Supports Natural Land Cover Protection as Leading Best Management Practice for Maintaining Stream Ecological Integrity. Invited presentation at the Comprehensive Stormwater and Aquatic Ecosystem Management Conf.; Auckland, New Zealand; February 1999.

Watershed Determinants of Ecosystem Functioning. Invited presentation at the Engineering Foundation Conference on Effects of Watershed Development on Aquatic Ecosystems Urban Runoff and Receiving Systems; Snowbird, Utah; August 1996.

Overview of the Puget Sound Wetlands and Stormwater Management Research Program. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995.

Guidelines for Managing Urban Wetlands. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995.

Urbanization Effects on Wetland Hydrology and Water Quality. Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1995 (prepared with B. Taylor and K. Ludwa).*

Constructed Wetlands for Urban Runoff Water Quality Control. Invited presentation at National Conf. on Urban Runoff Management; Chicago, Illinois; March 1993.

Training for Construction Site Erosion Control and Stormwater Facility Inspection. Invited presentation at National Conf. on Urban Runoff Management; Chicago, Illinois; March 1993.

Toward Ecologically Based Urban Runoff Management. Invited presentation at The Engineering Foundation Conference on Urban Runoff and Receiving Systems; Crested Butte, Colorado; August 1991.

How Stormwater Harms Shellfish. Invited presentation at the Pacific Rim Shellfish Sanitation Conference; Seattle, Washington; May 1991.

Environmental Evaluation of Calcium Magnesium Acetate for Highway Deicing Applications. Invited presentation at Conference on Calcium Magnesium Acetate, An Emerging Chemical for Environmental Applications; Boston, Massachusetts; May 1991.

Issues in Stormwater Management. Statement to State Senate Environment and Natural Resources Committee; Olympia, Washington; January 1991.

Urban Stormwater Impacts on the Hydrology and Water Quality of Palustrine Wetlands in the Puget Sound Region. Invited presentation at Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; January 1991 (prepared with L.E. Reinelt).

The Impact of Nonpoint Source Pollution on River Ecosystems. Invited presentation at the Northwest Rivers Conference; Seattle, Washington; November 1990.

Research Program Overview and Discussion of Hydrologic and Water Quality Studies. Presented at the Puget Sound Wetlands and Stormwater Management Research Program Workshop; Seattle, Washington; October 1990.

Control of Urban Runoff Water Quality. Invited presentations at American Society of Civil Engineers Urban Stormwater Short Courses; Bellevue, Washington; April, 1990; Portland, Oregon; July 1990.

Various Aspects of Erosion Prevention and Control. Invited presentations at University of Wisconsin Erosion Control Short Course; Seattle, Washington; July 1990.

Examination of the Hydrology and Water Quality of Wetlands Affected by Urban Stormwater. Presented at the Society of Wetland Scientists Annual Meeting; Breckenridge, Colorado, June 1990 (prepared with L.E. Reinelt).*

Analysis of Plant Communities of Wetlands Affected by Urban Stormwater. Presented at the Society of Wetland Scientists Annual Meeting; Breckenridge, Colorado; June 1990 (prepared with S.S. Cooke).*

Environmental Evaluation of Calcium Magnesium Acetate. Invited presentation at the Symposium on the Environmental Impact of Highway Deicing; Davis, California; October 1989.

Application of Wetland Science Principles in the Classroom and Community. Invited presentation at the Annual Meeting of the Association of Collegiate Schools of Planning; Portland, Oregon; October 1989.

Structural Controls for Urban Storm Runoff Water Quality. Invited presentation at the Northwest Regional Meeting of the North American Lake Management Society; Seattle, Washington; September 1989.

The Puget Sound Wetlands and Stormwater Management Research Program. Invited presentation at the U.S. Environmental Protection Agency Workshop on Wetlands and Stormwater; Seattle, Washington; September 1989.

An Overview of Storm Runoff Water Quality Control. Invited presentation at the American Water Resources Association Workshop on Forest Conversion; LaGrande, Washington; November 1988.

Progress in Wetlands Research. Invited presentation at the Pacific Northwest Pollution Control Association Annual Meeting; Coeur d'Alene, Idaho; October 1988.

Long-Term Effects of Urban Stormwater on Wetlands. Invited presentation at the Engineering Foundation Conference on Urban Stormwater; Potosi, Missouri; July 1988.

Highway Construction Site Erosion and Pollution Control: Recent Research Results. Invited presentation at the 39th Annual Road Builders' Clinic; Moscow, Idaho; March 1988.

Urban Stormwater and Puget Trough Wetlands. Presented at the 1st Annual Puget Sound Water Quality Authority Research Meeting; Seattle, Washington; March 1988 (prepared with F.B. Gutermuth, L.L. Conquest, and A.W. Johnson).

Preliminary Comparative Risk Assessment for Hanford Waste Sites. Presented at Waste Management 88; Tucson, Arizona; February 1988 (prepared with R.F. Weiner and J. Kettman).*

What Goes on at the Hanford Nuclear Reservation? Invited presentation at the Northwest Association for Environmental Studies Annual Meeting; Western Washington University, Bellingham, WA; November 1987.

The Puget Sound Wetlands and Stormwater Management Research Program. Invited presentation at the Pacific Northwest Pollution Control Association Annual Meeting; Spokane, Washington; October 1987.

Design of Cost-Effective Monitoring Programs for Nonpoint Source Water Pollution Problems. Invited presentation at the American Water Resources Association, Puget Sound Chapter, Annual Meeting; Bellevue, Washington; November 1986.

A Review of Wetland Water Quality Functions. Invited plenary presentation at the Conference on Wetland Functions, Rehabilitation, and Creation in the Pacific Northwest: The State of Our Understanding; Port Townsend, Washington; May 1986.

- Nonpoint Discharge and Runoff session leader. American Society of Civil Engineers Spring Convention; Seattle, Washington; April 1986.
- Prevention of Lake Sammamish Degradation from Future Development. Invited presentation at the American Society of Civil Engineers Spring Convention; Seattle, Washington; April 1986.
- Design of Monitoring Programs for Nonpoint Source Water Pollution Problems. Invited presentation at the American Society of Civil Engineers Spring Convention; Seattle, Washington, April 1986 (prepared with L.E. Reinelt, B.W. Mar, and J.S. Richey).*
- Nonpoint Pollution Control Strategies for Moses Lake, Washington. Presented at the Fifth Annual Meeting of the North American Lake Management Society; Lake Geneva, Wisconsin; November 1985 (prepared with R.C. Bain, Jr., and L. Nelson).
- Response of Lake Sammamish to Urban Runoff Control. Presented at the Fifth Annual Meeting of the North American Lake Management Society; Lake Geneva, Wisconsin; November 1985 (prepared with J.I. Shuster, E.B. Welch, and D.E. Spyridakis).*
- A General Approach to Designing Environmental Monitoring Programs. Invited presentation at the Pacific Section AAAS Symposium on Biomonitoring, Bioindicators, and Bioassays of Environmental Quality; Missoula, Montana; June 1985 (prepared with J.S. Richey and B.W. Mar).
- Panel Discussion on the Planning Process for Non-point Pollution Abatement Programs. Non-point Pollution Abatement Symposium; Milwaukee, Wisconsin; April 1985.
- Nutrient Transport Processes in an Agricultural Watershed. Presented at the Fourth Annual Meeting of the North American Lake Management Society; McAfee, New Jersey; October 1984 (prepared with E.B. Welch, M.M. Wineman, M.J. Adolfson, and R.C. Bain Jr.).*
- Nutrient Transport Processes in an Agricultural Watershed. Presented at the American Society of Limnology and Oceanography Annual Meeting; Vancouver, British Columbia; June 1984 (prepared with M.M. Wineman, M.J. Adolfson, and R.C. Bain, Jr.).
- Factors Affecting Periphytic Algal Biomass in Six Swedish Streams. Presented at the American Society of Limnology and Oceanography Annual Meeting; Vancouver, British Columbia; June 1984 (prepared with J.M. Jacoby and E.B. Welch).*
- A Conceptual Framework to Guide Aquatic Monitoring Program Design for Thermal Electric Power Plants. Presented at the American Society for Testing and Materials Symposium on Rationale for Sampling and Interpretation of Ecological Data in the Assessment of Freshwater Ecosystems; Philadelphia, Pennsylvania; November 1983 (prepared with J.S. Richey, and G.L. Thomas).

Panel Discussion. Public Forum: Perspectives on Cumulative Effects; Institute for Environmental Studies; University of Washington; Seattle, Washington; August 1983.

A Guide for Assessing the Water Quality Impacts of Highway Operations and Maintenance. Presented at the Transportation Research Board Annual Meeting; Washington, D.C.; January 1983 (prepared with B.W. Mar).

Assessment of Pollutant Loadings and Concentrations in Highway Stormwater Runoff. Presented at the Pacific Northwest Pollution Control Association Annual Meeting; Vancouver, British Columbia; November 1982 (prepared with B.W. Mar and L.M. Little).

Phosphorus and Velocity as Determinants of Nuisance Periphytic Biomass. Presented at the International Workshop on Freshwater Periphyton (SIL); Vaxjo, Sweden; September 1982 (prepared with E.B. Welch and R.B. Veenstra).*

The Development of Nuisance Periphytic Algae in Laboratory Streams in Relation to Enrichment and Velocity. Presented at the American Society of Limnology and Oceanography Annual Meeting; Raleigh, North Carolina; June 1982 (prepared with R.B. Veenstra and E.B. Welch).

A Predictive Model for Highway Runoff Pollutant Concentrations and Loadings. Presented at the Stormwater and Water Quality Model Users' Group Meeting; Alexandria, Virginia; March 1982 (prepared with B.W. Mar).

Stream Periphyton Development in Relation to Current Velocity and Nutrients. Presented at American Society of Limnology and Oceanography Winter Meeting; Corpus Christi, Texas; January 1979 (prepared with E.B. Welch).

A Comparison of Discrete Versus Composite Sampling of Storm Runoff. Presented at the Northwest Pollution Control Association Annual Meeting; Victoria, British Columbia; October 1978 (prepared with B.W. Mar and J.F. Ferguson).*

A Method of Defining Urban Ecosystem Relationships Through Consideration of Water Resources. Presented at UNESCO International Man and the Biosphere Project 11 Conference; Poznan, Poland; September 1977.

GRADUATE AND UNDERGRADUATE COURSES TAUGHT (University of Washington)

Civil and Environmental Engineering 552, Environmental Regulations; 8 quarters.

Landscape Architecture 590, Urban Water Resources Seminar; 3 quarters.

Landscape Architecture 522/523, Watershed Analysis and Design; 15 quarters.

Engineering 260, Thermodynamics; 1 quarter.

Engineering 210, Engineering Statics; 2 quarters.

Civil Engineering/Water and Air Resources 453, Water and Wastewater Treatment; 1 quarter.

Civil Engineering/Water and Air Resources 599, Analyzing Urbanizing Watersheds; 1 quarter.

CONTINUING EDUCATION SHORT COURSES TAUGHT (University of Washington; multiple offerings)

Infiltration Facilities for Stormwater Quality Control

Wetlands Ecology, Protection, and Restoration

Storm and Surface Water Monitoring

Fundamentals of Urban Surface Water Management

Applied Stormwater Pollution Prevention Planning Techniques

Construction Site Erosion and Pollution Control Problems and Planning

Construction Site Erosion and Pollution Control Practices

Construction Site Erosion and Sediment Control Inspector Training

Inspection and Maintenance of Permanent Stormwater Management Facilities

Biofiltration for Stormwater Runoff Quality Control

Constructed Wetlands for Stormwater Runoff Quality Control

LOCAL COMMITTEES

Stormwater Panel advising Puget Sound Partnership, 2007.

Technical Advisory Committee, City of Seattle Environmental Priorities Project, 1990-91.

Environmental Toxicology Graduate Program Planning Committee, University of Washington, 1990.

Habitat Modification Technical Work Group, Puget Sound Water Quality Authority, 1987.

Underground Injection Control of Stormwater Work Group, Washington State Department of Ecology, 1987.

Nonpoint Source Pollution Conference Advisory Committee, 1986-87.

Puget Sound Wetlands and Stormwater Management Research Committee, 1986-90.

Accreditation Review, University of Washington Department of Landscape Architecture, 1986.

Planning Committee for University of Washington Institute for Environmental Studies Forum on Perspectives on Cumulative Environmental Effects, 1983.

CONSULTING

Equity Legal Services, Inc., Fairview Heights, Illinois; Technical assistance in a legal case seeking injunctive relief and damages for repeated, widespread neighborhood flooding; 2023-2024.

U.S. Department of Justice; Technical assistance in Clean Water Act legal cases; 2017-2018 and 2022-2024.

Food and Water Watch, Washington, D.C.; development of a water quality monitoring program for confined animal feeding operations; 2022.

Brinnon Group, Brinnon, Washington; development of a water quality and aquatic ecological monitoring program for the local watershed and marine waters; 2021-2022.

Kampmeier & Knutsen PLLC, Portland, Oregon; Technical assistance in Clean Water Act legal cases; 2017 and 2021-2023.

Chesapeake Legal Alliance; Annapolis, Maryland; Assessment of and comment on Maryland's draft Municipal Separate Storm Sewer Discharge Permits and Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated; 2020-2021.

Gonzaga University Legal Assistance; Spokane, Washington; Review of technical documents supporting a proposal for a PCB water quality variance for the Spokane River; 2020.

City of Monrovia, California; Recommendations for improving a watershed management plan; 2020.

Columbia Riverkeeper; Portland Oregon; Assessment of a port industrial development; 2020.

Columbia Riverkeeper and Northwest Environmental Defense Center; Portland Oregon; Assessment of Oregon Department of Environmental Quality's actions regarding setting Water Quality-Based Effluent Limits; 2020.

Coast Law Group, Encinitas, California; Technical assistance in Clean Water Act legal cases and assessments of submissions required by consent decrees; 2019-present.

Monterey County District Attorney, Monterey, California; Assessment of pollution issues at two construction company yards; 2019-2020.

Seneca Lake Guardian, Seneca Falls, New York; Assessment of potential water quality problems associated with an industrial plant; 2019.

Endangered Habitats League, Los Angeles, California; Assessment of stormwater management systems proposed for a large residential development; 2018-2019.

Ziontz Chestnut Law Firm, Seattle, Washington; Assistance with implementation of a court order on a settled case; 2018.

Black Warrior Riverkeeper, Birmingham, Alabama; Review and comment on a total maximum daily load assessment for the Black Warrior River; 2017.

King County, Washington, Seattle, Washington; Participant in a regional stormwater infrastructure assessment project; member of technical advisory committees for stormwater hydrologic and water quality modeling studies; 2012-present.

DeLano and DeLano, Escondido, California; Assessment of stormwater management systems proposed for residential and commercial developments; 2012-present.

Salmon-Safe, Inc.; assessment of sites for possible certification representing practices that protect salmon; 2004-present.

Puget Soundkeeper Alliance and Smith and Lowney, PLC, Seattle, Washington; Technical assistance in Clean Water Act legal cases and expert testimony; 1996, 2002-present.

Natural Resources Defense Council, Los Angeles, California; Technical and program analysis and expert testimony on legal cases involving municipal and industrial stormwater NPDES permit compliance and assistance in reacting to California municipal stormwater permits; 1993-present.

Santa Monica Baykeeper (now Los Angeles Waterkeeper); Technical and program analysis and expert testimony on legal cases involving municipal and industrial stormwater NPDES permit compliance; 1993-present.

Orange County Coastkeeper; Assistance with legal cases involving industrial and construction site pollution control and monitoring and expert testimony; 2001-present.

Lawyers for Clean Water and successor Sycamore Law; Assistance with legal cases involving stormwater discharges and expert testimony; 2004-present.

Earthjustice; Report and testimony regarding Washington state municipal stormwater permit before Pollution Control Hearing Board; 2008, 2013; assessment of Washington, DC combined sewer overflow control plan; 2015.

Tulane Environmental Law Clinic; Assessment and declaration on a legal case involving discharge under an industrial stormwater permit and expert testimony; 2015.

San Diego Coastkeeper, San Diego, California; Technical and program analysis and expert testimony on potential legal cases involving municipal and industrial stormwater NPDES permit compliance; liaison with City of San Diego; 1996-2011 and 2019-present.

Stillwater Science and Washington Department of Ecology; Water quality modeling for Puget Sound Characterization, Phase 2; 2010-2011.

City of Seattle Public Utilities; Analysis of technical aspects of stormwater management program; 2000-2008.

Ventura Coastkeeper; Technical and program analysis and expert testimony on legal cases involving municipal and industrial stormwater NPDES permit compliance; 2010-2015.

San Diego Airport Authority; Peer review of consultant products, training; 2004-2006.

U. S. Federal Court, Central District of California; Special master in Clean Water Act case; 2001-2002.

Storm Water Pollution Prevention Program, City of San Diego; Advising on response to municipal stormwater NPDES program; 2001-2002.

Kerr Wood Leidel, North Vancouver, B.C.; subconsultant for Stanley Park (Vancouver, B.C.) Stormwater Constructed Wetland Design; 1997-1998.

Clean South Bay, Palo Alto, California; Technical and program analysis and expert testimony on potential legal cases involving municipal and industrial stormwater NPDES permit compliance; 1996.

Resource Planning Associates, Seattle, Washington; Assistance with various aspects of monitoring under Seattle-Tacoma International Airport's stormwater NPDES permit; 1995-1997.

Watershed Management Institute, Crawfordville, Florida; Writing certain chapters of guides for stormwater program development and implementation and maintenance of stormwater facilities; 1995-2003.

King County Roads Division, Seattle, Washington; Teaching two courses on construction erosion and sediment control; 1995.

Snohomish County Roads Division, Seattle, Washington; Teaching a course on construction erosion and sediment control; 1995.

Alaska Marine Lines, Seattle, Washington; Performance test of a sand filter stormwater treatment system; 1994-95.

Economic and Engineering Services, Inc., Bellevue, Washington; Assessment of the potential for water quality benefits through modifying existing stormwater ponds; technical advice on remedying operating problems at infiltration ponds; 1994-96.

Washington State Department of Transportation, Olympia, Washington; Teaching courses on construction erosion and sediment control; 1994.

City of Bellevue, Washington; Peer review of documents on potential erosion associated with a road project; analysis of stormwater quality data; 1993-95.

City of Kelowna, B. C., Canada; Teaching short courses on constructed wetlands and erosion and sediment control; 1993.

Oregon Department of Environmental Quality, Portland, Oregon; Technical review of Willamette River Basin Water Quality Study reports; 1992-93.

Whatcom County, Bellingham, Washington; Mediation on lakeshore development moratorium among county, water district, and local community representatives; 1993.

Boeing Commercial Airplane Company, Renton, Washington and Sverdrup Corporation, Kirkland, Washington (at request of City of Renton); Review of stormwater control system design; design of performance monitoring study for system; 1992-94.

Golder Associates, Redmond, Washington; Technical advisor for study of stormwater infiltration; 1992.

Smith, Smart, Hancock, Tabler, and Schwensen Attorneys, Seattle, Washington; Technical advice on a legal case involving a stormwater detention pond; 1992.

PIPE, Inc., Tacoma, Washington; Teaching a course on the stormwater NPDES permit; 1992.

CH2M-Hill, Inc., Bellevue, Washington and Portland, Oregon; Technical seminar on constructing wetlands for wastewater treatment; literature review on toxicant cycling in arid-region wetlands constructed for wastewater treatment; literature and data review on lake nutrient input reduction; expert panel on TMDL analysis for Chehalis River; 1989-1995.

Kramer, Chin and Mayo, Inc., Seattle, Washington; Watershed analysis in Washington County and Lake Oswego, Oregon; literature review in preparation for stormwater infiltration system design; literature review and contribution to design of constructed wetland for municipal wastewater treatment; 1989-1995.

Woodward-Clyde Consultants, Portland, Oregon and Oakland, California; Analysis of wetland capabilities for receiving urban stormwater; design of a constructed wetland for urban stormwater treatment; technical advisor on Washington Department of Ecology and City of Portland stormwater manual updates; 1989-1995.

R.W. Beck and Associates, Seattle, Washington; Assessment of pollutant loadings and their reduction for one master drainage planning and two watershed planning efforts; 1989-92.

Boeing Computer Services Corporation, Bellevue, Washington; mediation among Boeing, citizens' group, and City of Bellevue on stormwater control system design; 1990.

Parametrix, Inc., Bellevue, Washington; Review of Kitsap County Drainage Ordinance; 1990.

U.S. Environmental Protection Agency, Duluth Laboratory; Review of certain provisions of WET 2.0 wetland functional assessment model; 1989.

King County Council, Seattle, Washington; Review of King County Surface Water Design Manual; 1989.

Port of Tacoma, Washington; Assessment of stormwater control strategies; 1989.

Municipality of Metropolitan Seattle, Seattle, Washington; Assessment of land treatment systems for controlling urban storm runoff water quality; 1988-1992.

Impact Assessment, Inc., La Jolla, California (contractor to Washington State Department of Ecology); Socioeconomic impact assessment of the proposed high-level nuclear waste repository at Hanford, Washington; 1987.

Technical Resources, Inc., Rockville, Maryland (contractor to U. S. Environmental Protection Agency); assessment of water treatment waste disposal at pulp and paper plants; 1987-88.

Dames and Moore, Seattle, Washington; analysis of the consequences of a development to Martha Lake; 1987.

Harper-Owes, Seattle, Washington; project oversight, data analysis, and review of limnological aspects for Lake Chelan Water Quality Assessment Study; 1986-88.

URS Corporation, Seattle, Washington and Columbus, Ohio; presentation of a workshop on nonpoint source water pollution monitoring program design; analysis of innovative and alternative wastewater treatment for Columbus; development of a stormwater utility for Puyallup, Washington; watershed analysis for Edmonds, Washington; 1986-88.

Entranco Engineers, Bellevue, Washington; environmental impact assessment of proposed highway construction; technical review of Lake Sammamish watershed management project; technical review of Capital Lake wetland development; 1981-82; 1987-88; 1990.

Washington State Department of Ecology, Olympia, Washington; review of literature on wetland water quality, preparation of conference plenary paper, and leading discussion group at conference; analysis in preparation for a Shoreline Hearing Board case; 1986-87.

Richard C. Bain, Jr., Engineering Consultant, Vashon Island, Washington; analysis of watershed data and development of a policy for septic tank usage near Moses Lake, Washington; 1984-87.

University of Washington Friday Harbor Laboratory; analysis of adjacent port development and preparation of testimony for Shoreline Hearing Board; 1986.

Washington State Department of Transportation and Morrison-Knudsen Company, Inc./H.W. Lochner, Inc., Joint Venture, Mercer Island, Washington; environmental assessment of disposal of excavated material by capping a marine dredge spoil dumping site; 1984.

Foster, Pepper, and Riviera Attorneys, Seattle, Washington; analysis and testimony on provisions to reduce pollutants in stormwater runoff from a site proposed for development; 1983.

Williams, Lanza, Kastner, and Gibbs Attorneys, Seattle, Washington; collection and analysis of water quality data to support a legal case and preparation of testimony; 1982.

Herrera Environmental Consultants, Seattle, Washington; lake data analysis and report preparation; 1982-83.

Brown and Caldwell Engineers, Seattle, Washington; data collection and analysis for watershed study; 1982-83.

City of Marysville, Washington; environmental impact assessment of proposed bridge construction; 1982-83.

F.X. Browne Associates, Inc., Lansdale, Pennsylvania; contributions to manual on lake restoration for U.S. Environmental Protection Agency; preparation of funding proposals and permits for lake restoration; lake data analysis; literature reviews and analysis of septic tank contributions to lake nutrient loading and availability of different forms of nutrients; 1980-83.

Reston Division of Prentice-Hall, Inc., Reston, Virginia; review of and contributions to texts on environmental technology; 1978-79.

Butterfield, Joachim, Brodt, and Hemphill Attorneys, Bethlehem, Pennsylvania; analysis of environmental impact statements; expert witness; 1973.

Robby Eckroth

From: Jan Edelstein <jmeten@comcast.net>
Sent: Tuesday, July 22, 2025 11:02 AM
To: Lisa Janicki; Peter Browning; Ron Wesen
Cc: Jack Moore; Robby Eckroth; Andy Wargo
Subject: CAO Update: Supplemental Comment - Require Notice of Critical Areas Decisions to Support Public's Right to Appeal, etc.
Attachments: JME Comment2 Notice of CA Decisions Required 7.22.2025.pdf

Good Morning Commissioners,

I attach an additional comment for the upcoming hearing on the CAO update.

Did you know that the County Code Type 1 Review of project permits “Director Decision Without Notice” as implemented by the Planning Department, thwarts the public’s right to appeal a Critical Areas decision? (This right is provided by SCC 14.06.150-1.) This also violates a number of GMA provisions regarding permit processing which are described in the attached comment.

Hopefully you will obtain input from Mr. Honea.

Regards,
Jan Edelstein

Jan M. Edelstein
17173 West Big Lake Blvd.
Mt. Vernon, WA 98274
jmeten@comcast.net

July 22, 2025

Skagit County Commissioners
Via e-mail
Cc: Jack Moore, Robby Eckroth, Andy Wargo

RE: CAO Update – Supplemental Comment
Require Notice of CAO Review to Support
Public’s Right to Appeal and Comply with GM

Dear Commissioners,

I offer the following supplemental comment.

Please clarify that Type 1 Review of Critical Areas Decisions MUST be conducted in a manner that complies with the Growth Management Act’s requirements for notice to the public and opportunity to participate.

Very truly yours,

s/

Jan M. Edelstein

Supplemental Comment – Revise Critical Area Ordinance

**REQUIRE PLANNING DEPT. TO GIVE NOTICE TO PUBLIC OF CAO REVIEW DECISIONS
TO (1) ENABLE THE PUBLIC’S RIGHT TO APPEAL AND (2) COMPLY WITH GMA.**

- 1. PUBLIC’S RIGHT TO APPEAL CAO DECISIONS: The Planning Department says “no notice” to public, or parties of record is required for CAO Decisions.**

.RCW 36.70B.110 Administrative appeals.

(9)If provided, an administrative appeal of the project decision and of any environmental determination issued at the same time as the project decision, shall be filed within fourteen days **after the notice of the decision or after other notice that the decision has been made and is appealable....** [Emphasis added.]¹

¹ See Also: RCW 36.70B.130 Notice of Decision-Distribution

“...shall provide a notice of decision... The notice of decision may be a copy of the report or decision on the project permit application. **The notice shall be provided to the applicant and to any person who, prior to the rendering of the decision, requested notice of the decision or submitted substantive comments on the application...**

SCC 14.24.730 Appeals from the Director.

[Appeals](#) may be taken to the [Hearing Examiner](#) by any aggrieved party affected by any decision of the Director under this Chapter [Critical Areas Ordinance]. Such [appeals](#) shall be filed and processed consistent with the provisions of Chapter [14.06 SCC](#).

SCC 14.06.410 Local appeal.

(3) Time to File. An [appeal](#) is timely only if it is:

(a) Filed with the [Department](#) within 14 [days](#) (five working [days](#) for shoreline permits) **after the written notice of decision is mailed or the building permit is issued**; [Emphasis Added.]

The Planning and Development Services Department (PDS) asserts that NO NOTICE TO THE PUBLIC is required for any project permit application, nor for the resulting decision, which is processed under review procedure Type 1 – Director Decision Without Notice. SCC 14.06.150-1.

Critical Area Ordinance Decisions are but one of the many PDS decisions on project permit applications that are reviewed as “Type 1 - Director Decision Without Notice.”

The PDS says that Type 1 Review decisions are NOT required to be made in writing or even simply made publicly available as an “issued permit.”

Contrary to RCW 36.70B.110(9) and .130, PDS takes the position that one begins to count the 14 days within which to file a timely appeal, not from either the time the party of record is given notice of the decision, or even from the time notice of the decision is publicly available, but from some earlier time if the Director says he made the decision some many days before he gives a party of record notice of the decision or posts it on-line. See HE Apl 2025-0007.

2. GMA REQUIRES NOTICE TO THE PUBLIC OF ALL APPLICATIONS and NOTICE TO INTERESTED PARTIES OF DECISIONS FOR “PROJECT PERMITS”

RCW 36.70B.020 Definitions – Project Permit

(4) "Project permit" or "project permit application" means any land use or environmental permit or license required from a local government for a project action, including but not limited to subdivisions ... **permits or approvals required by critical area ordinances**, site-specific rezones which do not require a comprehensive plan amendment ...

RCW 36.70B.060 (2) as described in .110 and (7)

RCW 36.70B.110(2) Notice of application [Timeliness]

(2) “The notice of application shall be provided within 14 days after the determination of completeness...”

RCW 36.70B.110(2) Notice of application [Method of Notice-Minimum Requirement]

(4) A local government shall use reasonable methods to **give the notice of application to the public** and agencies with jurisdiction and may use its existing notice procedures. A local government may use different types of notice for different categories of project permits or types of project actions. **If a local government by resolution or ordinance does not specify its method of public notice, the local government shall use the methods provided for in (a) and (b) of this subsection....**

(a) Posting the property for site-specific proposals;

(b) Publishing notice, including at least the project location, description, type of permit(s) required, comment period dates, and location where the notice of application required by subsection (2) of this section and the complete application may be reviewed, in the newspaper of general circulation in the general area where the proposal is located or in a local land use newsletter published by the local government;

(c) – (g) [omitted.]

RCW 36.70B.130 Notice of Decision-Distribution

“...shall provide a notice of decision... The notice of decision may be a copy of the report or decision on the project permit application. **The notice shall be provided to the applicant and to any person who, prior to the rendering of the decision, requested notice of the decision or submitted substantive comments on the application...**

Robby Eckroth

From: Commissioners
Sent: Thursday, July 24, 2025 8:39 AM
To: PDS comments
Subject: FW: Critical Areas Ordinance Update

From: Andrea Xaver <dancer@fidalgo.net>
Sent: Thursday, July 24, 2025 8:36 AM
To: Lisa Janicki <ljanicki@co.skagit.wa.us>; Peter Browning <pbrowning@co.skagit.wa.us>; Ron Wesen <ronw@co.skagit.wa.us>
Cc: Commissioners <commissioners@co.skagit.wa.us>
Subject: Critical Areas Ordinance Update

(Note: I sent "twice" – once to each of you individually, and then as a group email. I 'm not sure who gets whatever is sent.)

I'm chiming in again with the concerned citizens around Big Lake, as sometimes county "planning" can affect my small farms nearby.

I quote, in part, from Big Lake Informed:

"...county code allows new development to send polluted stormwater to Big lake and other critical areas without treatment or scientific review.

This is contrary to state law."

"...Big Lake is a Critical Area where the water quality has continued to degrade over the years."

Assessments for the off-site impacts of developments need to include any areas regardless of distance.

Big lake and adjacent areas, such as farms and creeks, need to be protected from polluted runoff. Another concern is the possibility of

increased water volume in the lake, or other areas, that could back up onto or run into surrounding lands and nearby creeks and ditches.

I don't want flooding or lingering water-soaked farmland.

Andrea Xaver (360-202-9533)
19814 State Route 9
Mount Vernon, Wa 98274

Robby Eckroth

From: Commissioners
Sent: Thursday, July 24, 2025 12:15 PM
To: PDS comments
Subject: FW: Commissioner Meeting Monday, July 28, 2025

From: kristinejohnso@gmail.com <kristinejohnso@gmail.com>
Sent: Thursday, July 24, 2025 12:12 PM
To: Commissioners <commissioners@co.skagit.wa.us>
Subject: Commissioner Meeting Monday, July 28, 2025

*Kristine M Johnson
16936 Lake View Blvd
Mount Vernon, WA 98274
360-708-8867
kristinejohnso@gmail.com - email address
johnsongk2@gmail.com -Gary's email address*

Skagit County Commissioners
July 22, 2025

RE: Commissioner Meeting Monday, July 28, 2025

Dear Commissioners,

We are deeply concerned about degradation to the waters in Skagit County. We are not experts on any of these matters, but we have lived in Big Lake for 47 years and have seen the improvement after the sewer went through and the continued deterioration of the Lake with more algae and even dead fish. I think we all want the same thing—to have a water that can be enjoyed by people for boating and fishing and animals.

We understand that stormwater delivered through ditches bypasses whatever effect a buffer could have.

Furthermore, stormwater is leading cause of pollution.

Therefore, we urge you to remove the 200' limitation on critical areas site assessments.

It seems imperative to remove the 200' limitation and implement an expert professional opinion. It should always be the case to have the developer provide expert opinion on impact of stormwater pollutants on the waters of Skagit County.

Sincerely,

Gary and Kris Johnson

Gary and Kristine Johnson

16936 Lake View Blvd

Mount Vernon, WA 98274

360-708-8867

kristinejohnso@gmail.com

johnsongk2@gmail.com

Robby Eckroth

From: Commissioners
Sent: Thursday, July 24, 2025 1:22 PM
To: PDS comments
Subject: Big Lake (critical areas ordinance)

Skagit County Commissioners' Office
1800 Continental Place, Suite 100
Mount Vernon, WA 98273
Telephone: (360) 416-1300

From: Celia Miller <celiarmiller@hotmail.com>
Sent: Thursday, July 24, 2025 12:27 PM
To: Commissioners <commissioners@co.skagit.wa.us>
Subject: Possible Spam: Big Lake

Hello,

My name is Cecilia Miller and I live on Biglake. My address is 17201 West Biglake Blvd. I am writing you to ask that you reconsider developments that dump water and debris into Biglake without more scrutiny and advice. Please reconsider this for the residence of the area. Thank you. Biglake has also degraded over the years and it looks pretty nasty to go swimming in already. please help in this matter thank you.

Get [Outlook for iOS](#)

Robby Eckroth

From: Commissioners
Sent: Thursday, July 24, 2025 1:22 PM
To: PDS comments
Subject: Protect Big Lake (critical areas ordinance)

Skagit County Commissioners' Office
1800 Continental Place, Suite 100
Mount Vernon, WA 98273
Telephone: (360) 416-1300

From: DAVE REKEVICS <rekevics@comcast.net>
Sent: Thursday, July 24, 2025 12:55 PM
To: Commissioners <commissioners@co.skagit.wa.us>
Subject: Possible Spam: Protect Big Lake

I have a big concern with the proposed Overlook Crest development near Big Lake, where the stormwater run off is going to go directly into the lake. My family has owned property on Big Lake since 1963. We have a family home there and have enjoyed the lake throughout the years. I have witnessed the development around the lake and as a result have seen changes to the health of the lake. The changes have not been positive. Other than the County spraying the lake annually to help kill the seaweed, you have done nothing to ensure and promote the safety of the lake. The stormwater runoff needs to be treated and an environmental plan in place before approving the development.

Not knowing the politics involved I do understand that the developer and the commissioner are related. That definitely raises a red flag in terms of a conflict of interest here.

I look forward to hear what the lake protection plan will be.

Thank you,
Dave Rekevics
17143 W Big Lake Blvd.

Robby Eckroth

From: Commissioners
Sent: Thursday, July 24, 2025 4:24 PM
To: PDS comments
Subject: FW: Critical Areas Ordinance Update

Skagit County Commissioners' Office
1800 Continental Place, Suite 100
Mount Vernon, WA 98273
Telephone: (360) 416-1300

From: Jan Schuirman <schuirman@wavecable.com>
Sent: Thursday, July 24, 2025 3:02 PM
To: Commissioners <commissioners@co.skagit.wa.us>
Subject: Critical Areas Ordinance Update

Hello

My name is Janet Schuirman and I own property at 18279 W. Big Lake Blvd, Mt. Vernon, WA. Big Lake is a Critical Area where the water quality has continued to degrade over the years. I ask you to require developers to provide Critical Areas Site Assessments for the off-site impacts of their developments to critical areas beyond the 200 ft that is currently required. Big Lake and other critical areas should be protected from further degradation caused by stormwater pollution. The health of the Big Lake watershed needs to be improved, not further challenged by the potential of large amounts of runoff during storms

Thank you for your consideration to this matter

Janet Schuirman
23170 Mosier Rd
Sedro Woolley WA 98284

Sent from my iPad

Robby Eckroth

From: Jenna Friebel <jfriebel@skagitdidc.org>
Sent: Monday, July 28, 2025 7:43 AM
To: Robby Eckroth
Cc: PDS comments
Subject: RE: CAO Comments
Attachments: 2025_CAO_Consortium_FNL 07252025.docx

Sorry about that!

From: Robby Eckroth <reckroth@co.skagit.wa.us>
Sent: Monday, July 28, 2025 7:41 AM
To: Jenna Friebel <jfriebel@skagitdidc.org>
Subject: RE: CAO Comments

Hi Jenna,

Your PDF is not showing the redlines. Can you please send again?

Thanks!



Robby Eckroth, AICP
Senior Planner

Planning and Development Services
1800 Continental Place
Mount Vernon, WA 98273
Direct (360) 416-1328 | Main (360) 416-1320

Email communications with county employees are public records and may be subject to disclosure, pursuant to RCW 42.56.

From: Jenna Friebel <jfriebel@skagitdidc.org>
Sent: Friday, July 25, 2025 2:57 PM
To: PDS comments <pdscomments@co.skagit.wa.us>
Subject: CAO Comments

Thanks!

Jenna Friebel, Executive Director

Skagit Drainage and Irrigation Districts Consortium LLC
2017 Continental Place Suite 4
Mount Vernon, WA 98273
360-708-0344

July 25, 2025

Via email (pdscomments@co.skagit.us)

Skagit County Planning & Development Services
1800 Continental Place
Mount Vernon, WA 98273

RE: Skagit County 2025 Critical Areas Ordinance Update

Dear Planning Department,

The Skagit Drainage and Irrigation District Consortium, LLC (“Consortium”) submits the following comments with respect to the redline version of the Skagit County 2nd Draft Critical Area Ordinance Update filed on-line <https://www.skagitcounty.net/Departments/PlanningAndPermit/2025CPA.htm>

The Consortium appreciates this opportunity to provide public comment and welcomes an opportunity to meet with staff to provide additional context with respect to our comments and for the proposed redlines.

Sincerely,



Jenna Friebel
Executive Director, Skagit County Drainage and Irrigation District Consortium, LLC

Cc:

Skagit Dike District 3
Skagit Dike, Drainage and Irrigation Improvement District 5
Skagit Dike, Drainage and Irrigation Improvement District 12
Skagit Drainage and Irrigation Improvement District 14
Skagit Drainage and Irrigation Improvement District 15
Skagit Drainage and Irrigation Improvement District 16
Skagit Drainage and Irrigation Improvement District 17
Skagit Drainage and Irrigation Improvement District 18
Skagit Drainage and Irrigation Improvement District 19
Skagit Drainage and Irrigation Improvement District 22
Skagit Consolidated Dike, Drainage and Irrigation Improvement District 22
Skagit Dike, Drainage and Irrigation Improvement District 25

Comment #1

14.24.120 Ongoing Agriculture (1)

Purpose and Intent. The purpose of this Section is to address 2 mandates under the Growth Management Act (GMA): (a) to protect the existing functions and values of fish and wildlife habitat conservation areas (FWHCAs) in and adjacent to natural, managed watercourses with headwaters and managed watercourses without headwaters ~~and artificial watercourses~~ as defined in SCC 14.04.020 ~~(collectively “watercourses”)~~, and (b) to conserve and protect agricultural lands of long-term commercial significance, specifically those lands in ongoing agricultural activity as defined by SCC 14.04.020 that are located adjacent to these watercourses.

Comment #2

14.24.120 Ongoing Agriculture (4.d)

Operation and Maintenance of Public and Private Agricultural Drainage Infrastructure. The following practices apply to any natural or any managed watercourse with headwaters that is part of a drainage infrastructure system, ~~except those practices performed pursuant to a fully executed Drainage Fish Initiative or Tidegate Fish Initiative agreement:~~

- ~~(i) Regularly scheduled agricultural drainage infrastructure maintenance that includes dredging or removal of accumulated sediments in any natural or managed watercourse with headwaters ~~watercourse must be conducted between June 15th and October 31st. If a Washington Department of Fish and Wildlife or managed watercourse without headwaters must comply with WDFW issued hydraulics project approval provides for a different work windows, those requirements control. If presence of fall or over winter crops prevents regularly scheduled maintenance during this time period, then the maintenance may be conducted outside this work window; provided, that the person or entity proposing to conduct the maintenance outside the work window can demonstrate that the presence of crops prevents maintenance within the work window and provided the maintenance is conducted using best management practices to minimize sediment or other impacts to water quality.~~~~
- ~~(ii)(i) Owners or operators must consult with districts conducting drainage maintenance to schedule their crop rotations for crops that may still be in the field after October 31st so that, to the maximum extent possible, such drainage maintenance can occur in a year when the fall crops are not being raised in the field adjacent to the drainage infrastructure scheduled _____ for _____ drainage _____ maintenance.~~
- ~~(iii) Unless there is no feasible alternative, regularly scheduled maintenance that includes dredging or removal of accumulated sediments in any watercourse should be conducted at those times when there is no or minimal water flow in the watercourse being maintained to minimize potential for distributing sediments to salmonid bearing waters.~~

~~(iv)~~(ii) Excavation spoils must be placed so as not to cause bank failures and so that ~~drainage seepage~~ from such spoils will not contribute sediment to the watercourse.

~~(iv)~~(iii) Mowing or cutting of vegetation located within a managed watercourse with headwaters or managed watercourse without headwaters that is part of a drainage ~~infrastructure system~~ may be conducted at any time; provided, that the cutting is above the ground surface within the channel and in a manner that does not disturb the soil or sediments; and provided, that the cut vegetation does not block water flow. Watercourse bank vegetation must be preserved or allowed to reestablish as soon as practicable after drainage construction and maintenance are completed to stabilize earthen ditch banks.

~~(vi)~~(iv) Districts subject to this Section, operating pursuant to authority in RCW Title 85 or 86, which are conducting drainage activities must ~~complete and submit a~~maintain a drainage maintenance plan. ~~maintenance checklist to the County by June 1st of each year. The checklist must describe the intent of the district to comply with the drainage maintenance requirements of Subsection (4)(d) of this Section. The districts may seek assistance from NRCS, SCD and/or the County in completing the checklist or addressing the requirements of this Subsection. The checklist will be available from Skagit County Planning and Development Services, mailed to any entity conducting drainage activities, and must be submitted to Planning and Development Services when completed. The districts may submit modifications to the information in the checklist, if circumstances affecting district maintenance change after the initial submittal.~~

~~(A) The County must send a written notice to any district not submitting this completed checklist by June 1st of each year, stating that the County has not received the required checklist and that the district is not authorized to conduct drainage maintenance activity until the district has submitted the completed checklist evidencing intent to comply with this Subsection.~~

~~(B) Subsequent commencement of drainage maintenance work without submitting a completed checklist will be subject to enforcement pursuant to Chapter 14.44 SCC.~~

Comment #3

The report on Best Available Science has not been updated. We request that that the following revisions be made.

Best Available Science (BAS). Section 3. Frequently Flooded Areas. 3.2 Functions and Values pPage 10. The Consortium's comments with respect to BAS, Section 3, include the following:

A. Revisions to Section 3.2 ~~should be revised to discuss the differences~~differentiating between coast flooding, deltas, and river floodplains as they were each formed by different processes and function somewhat differently. In addition, the Consortium sees a need to revise ~~the~~is following sentence, included on ~~{page 10,}~~ as follows: ~~needs to be revised.~~

“Floodplains have been used for agriculture, residential development, and urbanization for centuries because the geographic locations tend to be well-suited for development during periods between floods.”

B. BAS supports the statement that Skagit County’s floodplains ~~in Skagit County, and~~ specifically those in the Skagit delta, ~~are~~ have been, and continue to be, used for agricultural purposes because of the extremely high quality of the soils ~~— s~~ Soils of global significance. Soils are a natural resource, often associated with floodplains and deltas, and ~~these is needs~~ significant attributes should be properly characterized.

C. In addition, ~~the is~~ review of BAS should include references from ~~a~~ purely a hydrologic perspective, floodplains provide storage for water during floods – largely independent ~~ee~~ of land ~~-~~ use. By way of example, the Nookachamps, ~~— which is comprised of~~ mostly agricultural land use, floods frequently, however, ~~but~~ little or no damage results from ~~the is~~ flooding. Maintaining farmland in floodplain areas is a very sound policy objective. ~~As currently~~ written, this BAS review does not adequately characterize the functions of floodplains, independent ~~ee~~ of their land use.

Robby Eckroth

From: Victoria Hattersley <hattersv@gmail.com>
Sent: Saturday, July 26, 2025 8:44 AM
To: PDS comments
Subject: "Skagit County 2025 Critical Areas Ordinance Update"

Hello - my name is Victoria Hattersley and I live at 18779 W Big Lake Blvd, Mount Vernon, WA 98274. My phone number is 781-956-3354.

Please note that I am NOT anti-development - development is good for the community, and I am not one to 'pull the ladder up behind me' now that I live on Big Lake :-). I want smart development that protects our critical areas, like Big Lake.

I would like add my voice to all those others who speak in favor of amending the Critical Areas Ordinance section [14.24.080 Standard critical areas review and site assessment procedures](#). We need to address the issue of stormwater impacting bodies of water and other critical areas that are further than 200', perhaps by adding a requirement that the Director assess the potential areas of impact regardless of distance. For example, The Overlook Development is more than 200' and therefore could be considered as exempt; however, there seems to be an option for the Director (hello Jack Moore!) to make a decision about looking beyond the 200'. I actually suggest that the 200' feet either be eliminated or drastically increased, and have the process require a proper assessment of potential impact.

In addition, I highly recommend that the town, with residents' help, implement a more public deliberative process in this sort of circumstance to ensure that the voice of the residents is heard. Many don't feel heard, and other don't have the time to track these things - it is mostly us retired folks - and it would be best to implement a process that allows us to bring in more voices and, even more essentially, to have a proper discussion vs. just sending in our comments without being able to collectively deliberate.

Thank you, and I'll see you on Monday, possibly with my grandchildren who are visiting on their annual pilgrimage to Big Lake. They experienced lake 'closure' due to toxic algae last year and we need to get our arms around that immediately because it will only get worse with more storm water pollutants. We also need to urgently put a plan in place for clean-up, and some of us are working on how to work with you and the LMD on that, but that is for another meeting :-)

Cheers!

Victoria Hattersley
[Better Together America](#)
I Chose Democracy!
Mount Vernon, WA
781-956-3354

Robby Eckroth

From: Ellen Bynum <skye@cnw.com>
Sent: Monday, July 28, 2025 8:09 AM
To: PDS comments; Lisa Janicki; Peter Browning; Ron Wesen
Cc: Randy & Aileen Good, FOSC.; Andrea Xaver; Lori Scott; FOSC Office
Subject: Comments on the 2025 Critical Areas Ordinance update

July 28, 2025

TO: Skagit County Board of County Commissioners
1800 Continental Place
Mount Vernon, WA 98273

FROM: Ellen Bynum, 3998 Windcrest Lane, Anacortes, WA 98221, on behalf of myself and for
Friends of Skagit County
PO Box 2632
Mount Vernon, WA 98273-2632

RE: Comments on the 2025 Critical Areas Ordinance (CAO) update

Thank you Commissioners for the opportunity to comment concerning the 2025 CAO update.

RCW 36.70A, the WA State Growth Management Act, required those counties and cities required to plan to first inventory, designate, and conserve agriculture, forest and mineral lands and critical areas (CAs). Then the planning counties and cities were to consider the modification or adoption of comprehensive land use plans, and development regulations to implement the plans. Implementation of these plans and rules began on or before July 1, 1990. Critical areas play a primary role in plans and regulations and Skagit County's initial CAO and its subsequent updates adopted best available science (BAS) in 2010 as the primary standard for review of CAs.

The GMA requires the protection of the function and values of critical areas. GMHB rulings have stated that some CAs may constitute ecosystems or parts of ecosystems that transcend individual parcels and jurisdictions, so that protection of their functions and values should be considered on a larger scale to protect the hydrologic cycles and to ensure no net loss of ecosystem functions and values. *Ann Aggard, Judy Fisher, Bob Fisher, Glen Conley, and Save a Valuable Environment (SAVE) v. City of Bothell*, Case No. 15-3-0001, Final Decision and Order (July 21, 2015) at 23-25.

Challenge to unchanged provisions of a CAO is time-barred except where required by a recent GMA legislative amendment, new population forecast, or changed science concerning protection of critical area functions and values. *John Postman v. Snohomish County*, Case No. 15-3-0011, FDO (April 8, 2016) at 6.

RCW 36.70A.172 describes critical areas designation and protection and the best available science to be used. Section (1) says "In addition, cities and counties shall give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries."

PDS review of the steps staff have taken to review the CAO, including BAS, shows the CAO update to be in compliance with GMA. There does not appear to be references to policy and development regulations changes that required the standards and BAS be applied to development projects.

We do not know whether the County has inventoried, analyzed and evaluated the cumulative effects of all developments on CAs in ecosystems in Skagit County. Has there been any pause in permitting to reconsider the cumulative loss of CA functions and values in any ecosystem? The CAO does not contain a plan for doing this work in the future. We recommend Skagit County create and execute an analysis of developments' effects on CA functions and values by ecosystem.

Friends of Skagit County's participation in an appeal to the GMHB in 1996, subsequent settlement and current participation in appeals of various aspects of the proposed Overlook Crest project reveal a number of issues of concern.

Skagit has no process to evaluate the off-site impacts of stormwater runoff from nearby developments. The review does not appear to address how off-site stormwater may effect functions and values of critical areas and how mitigation will occur in ecosystems, rather than on-site and parcel by parcel. The Department of Ecology recommends this analysis be conducted as an additional protective measure. We request that this requirement be incorporated in the CAO update.

We also ask that the CAO update retain the criteria in Skagit County Code 14.24.080(2). Review Procedures that says "...the Director shall use the following method to determine whether critical areas or their required buffers are within 200 feet or a distance otherwise specified in this Chapter or **may be affected by the proposed activity.** ". **Emphasis added.** We read the last criteria to be applicable to off-site effects that are not addressed in current review checklists and permits.

Skagit County has no current data concerning pollution in Big Lake. The last time phosphorus levels were sampled was 1999 and the reporting has been updated using a statistical estimation.

Skagit County has no standards of evaluation for the Director to decide which level of review will be used in a permit review. We assume Level 1 was envisioned as addressing minor administrative changes, not complete redesigns of large subdivisions like Overlook Crest. we ask that the County add standards and procedures for Level 1 appeals of developments so that the Planning Director has better guidance. Level 1 appeals have no public notice or hearing and limits the public's right to appeal. We recommend the BOCC look at performance standards for these decisions as part of a review of whether Level 1 decisions have been used as originally intended - to speed up permitting - or not.

Please add a link or reference to SCC14.16.310 Rural Village Residential (RVR) (7) Special Provisions - Big Lake Rural Village Overlook Golf Course Property section in the development regulations (from the FOSC settlement agreement) into the CAO.

Thank you for your time and public service.

Ellen Bynum, Executive Director
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JUL 25 2025

SKAGIT COUNTY PDS

Ruth Aven

P.O. Box 68

Bow, WA 98232

gandraven@yahoo.com

July 25, 2025

Skagit County Commissioners

RE: Critical Areas *update 2025 ordinance*

Sirs/Madam

This suit was brought by the Pacific Legal Foundation. There is another case pending.

The recent suit being brought by the DOE in Whatcom County Superior Court will be another cause. The current overreach of the DOE includes lands in Skagit County that cannot by any stretch of any imaginings be connected to the Nooksack Basin. (WRIA 1) The Nooksack and Samish Rivers are both under Federal Jurisdiction and therefore will be subject to the enclosed Suit.

While we were able to claim non-significance a neighbor directly to the south is impacted "because they are at a seven-hundred foot elevation". We are at nine-hundred feet. All the water coming through our property and theirs is intermittent and therefore dries up with the rain season. All the wells are shallow.

I hope you will take this information into consideration as pertaining to the critical areas element at hand.

Respectfully Submitted,

Ruth Aven

Ruth A. Aven

[Justia](#) › [U.S. Law](#) › [U.S. Case Law](#) › [U.S. Supreme Court](#) › [Opinions by Volume](#) › [Volume 598](#) › Sackett v. Environmental Protection Agency

Sackett v. Environmental Protection Agency, 598 U.S. ____ (2023)

Docket No.21-454

Granted:January 24, 2022

Argued:October 3, 2022

Decided:May 25, 2023

Justia Summary

Sackett began backfilling an Idaho lot with dirt to build a home. The Environmental Protection Agency informed Sackett that the property contained wetlands and that the backfilling violated the Clean Water Act, which prohibits discharging pollutants into “the waters of the United States,” 33 U.S.C. 1362(7). The EPA ordered Sackett to restore the site, threatening penalties of over \$40,000 per day. The EPA classified the Sackett wetlands as “waters of the United States” because they were near a ditch that fed into a creek, which fed into Priest Lake, a navigable, intrastate lake. The Ninth Circuit affirmed summary judgment in favor of the EPA.

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Annotation
Primary Holding

Supreme Court limits Clean Water Act jurisdiction over "adjacent wetlands" to those having a continuous surface connection to bodies that are "waters of the United States" in their own right, with no clear demarcation between the "waters" and wetlands.

Syllabus

SUPREME COURT OF THE UNITED STATES

Syllabus

SACKETT et ux. v. ENVIRONMENTAL PROTECTION AGENCY et al.

certiorari to the united states court of appeals for the ninth circuit

No. 21–454. Argued October 3, 2022—Decided May 25, 2023

Petitioners Michael and Chantell Sackett purchased property near Priest Lake, Idaho, and began backfilling the lot with dirt to prepare for building a home. The Environmental Protection Agency informed the Sacketts that their property contained wetlands and that their backfilling violated the Clean Water Act, which prohibits discharging pollutants into “the waters of the United States.” 33 U. S. C. §1362(7). The EPA ordered the Sacketts to restore the site, threatening penalties of over \$40,000 per day. The EPA classified the wetlands on the Sacketts’ lot as “waters of the United States” because they were near a ditch that fed into a creek, which fed into Priest Lake, a navigable, intrastate lake. The Sacketts sued, alleging that their property was not “waters of the United States.” The District Court entered summary judgment for the EPA. The Ninth Circuit affirmed, holding that the CWA covers wetlands with an ecologically significant nexus to traditional navigable waters and that the Sacketts’ wetlands satisfy that standard.

Held: The CWA’s use of “waters” in §1362(7) refers only to “geographic[al] features that are described in ordinary parlance as ‘streams, oceans, rivers, and lakes’ ” and to adjacent wetlands that are “indistinguishable” from those bodies of water due to a continuous surface connection. *Rapanos v. United States*, 547 U.S. 715, 755, 742, 739 (plurality opinion). To assert jurisdiction over an adjacent wetland under the

CWA, a party must establish “first, that the adjacent [body of water constitutes] . . . ‘water[s] of the United States’ (*i.e.*, a relatively permanent body of water connected to traditional interstate navigable waters); and second, that the wetland has a continuous surface connection with that water, making it difficult to determine where the ‘water’ ends and the ‘wetland’ begins.” *Ibid.* Pp. 6–28.

(a) The uncertain meaning of “the waters of the United States” has been a persistent problem, sparking decades of agency action and litigation. Resolving the CWA’s applicability to wetlands requires a review of the history surrounding the interpretation of that phrase. Pp. 6–14.

(1) During the period relevant to this case, the two federal agencies charged with enforcement of the CWA—the EPA and the Army Corps of Engineers—similarly defined “the waters of the United States” broadly to encompass “[a]ll . . . waters” that “could affect interstate or foreign commerce.” 40 CFR §230.3(s)(3). The agencies likewise gave an expansive interpretation of wetlands adjacent to those waters, defining “adjacent” to mean “bordering, contiguous, or neighboring.” §203.3(b). In *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121, the Court confronted the Corps’ assertion of authority under the CWA over wetlands that “actually abut[ted] on a navigable waterway.” *Id.*, at 135. Although concerned that the wetlands fell outside “traditional notions of ‘waters,’” the Court deferred to the Corps, reasoning that “the transition from water to solid ground is not necessarily or even typically an abrupt one.” *Id.*, 132–133. Following *Riverside Bayview*, the agencies issued the “migratory bird rule,” extending CWA jurisdiction to any waters or wetlands that “are or would be used as [a] habitat” by migratory birds or endangered species. 53 Fed. Reg. 20765. The Court rejected the rule after the Corps sought to apply it to several isolated ponds located wholly within the State of Illinois, holding that the CWA does not “exten[d] to ponds that are not adjacent to open water.” *Solid Waste Agency of Northern Cook Cty. v. Army Corps of Engineers*, 531 U.S. 159, 168 (SWANCC) (emphasis deleted). The agencies responded by instructing their field agents to determine the scope of the CWA’s jurisdiction on a case-by-case basis. Within a few years, the agencies had “interpreted their jurisdiction over ‘the waters of the United States’ to cover 270-to-300 million acres” of wetlands and “virtually any parcel of land containing a channel or conduit . . . through which rainwater or drainage may occasionally or intermittently flow.” *Rapanos*, 547 U. S., at 722 (plurality opinion).

Against that backdrop, the Court in *Rapanos* vacated a lower court decision that had held that the CWA covered wetlands near ditches and drains that emptied into navigable waters several miles away. As to the rationale for vacating, however, no

position in *Rapanos* commanded a majority of the Court. Four Justices concluded that the CWA's coverage was limited to certain relatively permanent bodies of water connected to traditional interstate navigable waters and to wetlands that are "as a practical matter indistinguishable" from those waters. *Id.*, at 755 (emphasis deleted). Justice Kennedy, concurring only in the judgment, wrote that CWA jurisdiction over adjacent wetlands requires a "significant nexus" between the wetland and its adjacent navigable waters, which exists when "the wetlands, either alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity" of those waters. *Id.*, at 779–780. Following *Rapanos*, field agents brought nearly all waters and wetlands under the risk of CWA jurisdiction by engaging in fact-intensive "significant-nexus" determinations that turned on a lengthy list of hydrological and ecological factors.

Under the agencies' current rule, traditional navigable waters, interstate waters, and the territorial seas, as well as their tributaries and adjacent wetlands, are waters of the United States. See 88 Fed. Reg. 3143. So too are any "[i]ntrastate lakes and ponds, streams, or wetlands" that either have a continuous surface connection to categorically included waters or have a significant nexus to interstate or traditional navigable waters. *Id.*, at 3006, 3143. Finding a significant nexus continues to require consideration of a list of open-ended factors. *Ibid.* Finally, the current rule returns to the agencies' longstanding definition of "adjacent." *Ibid.* Pp. 6–12.

(2) Landowners who even negligently discharge pollutants into navigable waters without a permit potentially face severe criminal and civil penalties under the Act. As things currently stand, the agencies maintain that the significant-nexus test is sufficient to establish jurisdiction over "adjacent" wetlands. By the EPA's own admission, nearly all waters and wetlands are potentially susceptible to regulation under this test, putting a staggering array of landowners at risk of criminal prosecution for such mundane activities as moving dirt. Pp. 12–14.

(b) Next, the Court considers the extent of the CWA's geographical reach. Pp. 14–22.

(1) To make sense of Congress's choice to define "navigable waters" as "the waters of the United States," the Court concludes that the CWA's use of "waters" encompasses "only those relatively permanent, standing or continuously flowing bodies of water 'forming geographic[al] features' that are described in ordinary parlance as 'streams, oceans, rivers, and lakes.'" *Rapanos*, 547 U. S., at 739 (plurality opinion). This reading follows from the CWA's deliberate use of the plural "waters," which refers to those bodies of water listed above, and also helps to align the meaning of "the waters of the United States" with the defined term "navigable

waters." More broadly, this reading accords with how Congress has employed the term "waters" elsewhere in the CWA—see, e.g., 33 U. S. C. §§1267(i)(2)(D), 1268(a)(3)(I)—and in other laws—see, e.g., 16 U. S. C. §§745, 4701(a)(7). This Court has understood CWA's use of "waters" in the same way. See, e.g., *Riverside Bayview*, 474 U. S., at 133; *SWANCC*, 531 U. S., at 168–169, 172.

The EPA's insistence that "water" is "naturally read to encompass wetlands" because the "presence of water is 'universally regarded as the most basic feature of wetlands'" proves too much. Brief for Respondents 19. It is also tough to square with *SWANCC*'s exclusion of isolated ponds or *Riverside Bayview*'s extensive focus on the adjacency of wetlands to covered waters. Finally, it is difficult to see how the States' "responsibilities and rights" in regulating water resources would remain "primary" if the EPA had such broad jurisdiction. §1251(b). Pp. 14–18.

(2) Statutory context shows that some wetlands nevertheless qualify as "waters of the United States." Specifically, §1344(g)(1), which authorizes States to conduct certain permitting programs, specifies that discharges may be permitted into any waters of the United States, except for traditional navigable waters, "including wetlands adjacent thereto," suggesting that at least some wetlands must qualify as "waters of the United States." But §1344(g)(1) cannot define what wetlands the CWA regulates because it is not the operative provision that defines the Act's reach. Instead, the reference to adjacent wetlands in §1344(g)(1) must be harmonized with "the waters of the United States," which is the operative term that defines the CWA's reach. Because the "adjacent" wetlands in §1344(g)(1) are "includ[ed]" within "waters of the United States," these wetlands must qualify as "waters of the United States" in their own right, *i.e.*, be indistinguishably part of a body of water that itself constitutes "waters" under the CWA. To hold otherwise would require implausibly concluding that Congress tucked an important expansion to the reach of the CWA into convoluted language in a relatively obscure provision concerning state permitting programs. Understanding the CWA to apply to wetlands that are distinguishable from otherwise covered "waters of the United States" would substantially broaden §1362(7) to define "navigable waters" as "waters of the United States *and adjacent wetlands*." But §1344(g)(1)'s use of the term "including" makes clear that it does not purport to do any such thing. It merely reflects Congress's assumption that certain "adjacent" wetlands are part of the "waters of the United States."

To determine when a wetland is part of adjacent "waters of the United States," the Court agrees with the *Rapanos* plurality that the use of "waters" in §1362(7) may be fairly read to include only wetlands that are "indistinguishable from waters of the

United States." This occurs only when wetlands have "a continuous surface connection to bodies that are 'waters of the United States' in their own right, so that there is no clear demarcation between 'waters' and wetlands." 547 U. S., at 742.

In sum, the CWA extends to only wetlands that are "as a practical matter indistinguishable from waters of the United States." This requires the party asserting jurisdiction to establish "first, that the adjacent [body of water constitutes] . . . 'water[s] of the United States' (i.e., a relatively permanent body of water connected to traditional interstate navigable waters); and second, that the wetland has a continuous surface connection with that water, making it difficult to determine where the 'water' ends and the 'wetland' begins." *Rapanos*, 547 U. S., at 755, 742. Pp. 18–22.

(c) The EPA asks the Court to defer to its most recent rule providing that "adjacent wetlands are covered by the [CWA] if they 'possess a significant nexus to' traditional navigable waters" and that wetlands are "adjacent" when they are "neighboring" to covered waters. Brief for Respondents 32, 20. For multiple reasons, the EPA's position lacks merit. Pp. 22–27.

(1) The EPA's interpretation is inconsistent with the CWA's text and structure and clashes with "background principles of construction" that apply to the interpretation of the relevant provisions. *Bond v. United States*, 572 U.S. 844, 857. First, "exceedingly clear language" is required if Congress wishes to alter the federal/state balance or the Government's power over private property. *United States Forest Service v. Cowpasture River Preservation Assn.*, 590 U. S. ___, ___. The Court has thus required a clear statement from Congress when determining the scope of "the waters of the United States." Second, the EPA's interpretation gives rise to serious vagueness concerns in light of the CWA's criminal penalties, thus implicating the due process requirement that penal statutes be defined " 'with sufficient definiteness that ordinary people can understand what conduct is prohibited.' " *McDonnell v. United States*, 579 U.S. 550, 576. Where penal statutes could sweep broadly enough to render criminal a host of what might otherwise be considered ordinary activities, the Court has been wary about going beyond what "Congress certainly intended the statute to cover." *Skilling v. United States*, 561 U.S. 358, 404. Under these two principles, the judicial task when interpreting "the waters of the United States" is to ascertain whether clear congressional authorization exists for the EPA's claimed power. Pp. 22–25.

(2) The EPA claims that Congress ratified the EPA's regulatory definition of "adjacent" when it amended the CWA to include the reference to "adjacent"

wetlands in §1344(g)(1). This argument fails for at least three reasons. First, the text of §§1362(7) and 1344(g) shows that “adjacent” cannot include wetlands that are merely nearby covered waters. Second, EPA’s argument cannot be reconciled with this Court’s repeated recognition that §1344(g)(1) “ ‘does not conclusively determine the construction to be placed on . . . the relevant definition of “navigable waters.” ’ ” *SWANCC*, 531 U. S., at 171. Third, the EPA falls short of establishing the sort of “overwhelming evidence of acquiescence” necessary to support its argument in the face of Congress’s failure to amend §1362(7). Finally, the EPA’s various policy arguments about the ecological consequences of a narrower definition of “adjacent” are rejected. Pp. 25–27.

8 F. 4th 1075, reversed and remanded.

Alito, J., delivered the opinion of the Court, in which Roberts, C. J., and Thomas, Gorsuch, and Barrett, JJ., joined. Thomas, J., filed a concurring opinion, in which Gorsuch, J., joined. Kagan, J., filed an opinion concurring in the judgment, in which Sotomayor and Jackson, JJ., joined. Kavanaugh, J., filed an opinion concurring in the judgment, in which Sotomayor, Kagan, and Jackson, JJ., joined.

Notes

[1](#)

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Opinions

- [Opinion \(Alito\)](#)

- [Concurrence \(Thomas\)](#)

- [Concurrence \(Kagan\)](#)

- [Concurrence \(Kavanaugh\)](#)

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SUPREME COURT OF THE UNITED STATES

No. 21–454

MICHAEL SACKETT, et ux., PETITIONERS v. ENVIRONMENTAL PROTECTION AGENCY, et al.

on writ of certiorari to the united states court of appeals for the ninth circuit

[May 25, 2023]

Justice Alito delivered the opinion of the Court.

This case concerns a nagging question about the outer reaches of the Clean Water Act (CWA), the principal federal law regulating water pollution in the United States.^[1] By all accounts, the Act has been a great success. Before its enactment in 1972, many of the Nation’s rivers, lakes, and streams were severely polluted, and existing federal legislation had proved to be inadequate. Today, many formerly fetid bodies of water are safe for the use and enjoyment of the people of this country.

There is, however, an unfortunate footnote to this success story: the outer boundaries of the Act’s geographical reach have been uncertain from the start. The Act applies to “the waters of the United States,” but what does that phrase mean? Does the term encompass any backyard that is soggy enough for some minimum period of time? Does it reach “mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, [or] playa lakes?”^[2] How about ditches, swimming pools, and puddles?

For more than a half century, the agencies responsible for enforcing the Act have wrestled with the problem and adopted varying interpretations. On three prior occasions, this Court has tried to clarify the meaning of “the waters of the United States.” But the problem persists. When we last addressed the question 17 years ago, we were unable to agree on an opinion of the Court.[3] Today, we return to the problem and attempt to identify with greater clarity what the Act means by “the waters of the United States.”

I

A

For most of this Nation’s history, the regulation of water pollution was left almost entirely to the States and their subdivisions. The common law permitted aggrieved parties to bring nuisance suits against polluters. But as industrial production and population growth increased the quantity and toxicity of pollution, States gradually shifted to enforcement by regulatory agencies.[4] Conversely, federal regulation was largely limited to ensuring that “traditional navigable waters”—that is, interstate waters that were either navigable in fact and used in commerce or readily susceptible of being used in this way—remained free of impediments. See, e.g., Rivers and Harbors Act of 1899, 30Stat. 1151; see also *United States v. Appalachian Elec. Power Co.*, 311 U.S. 377, 406–407 (1940); *The Daniel Ball*, 10 Wall. 557, 563 (1871).

Congress’s early efforts at directly regulating water pollution were tepid. Although the Federal Water Pollution Control Act of 1948 allowed federal officials to seek judicial abatement of pollution in interstate waters, it imposed high hurdles, such as requiring the consent of the State where the pollution originated. See 62Stat. 1156–1157. Despite repeated amendments over the next two decades, few actions were brought under this framework.[5]

Congress eventually replaced this scheme in 1972 with the CWA. See 86Stat. 816. The Act prohibits “the discharge of any pollutant” into “navigable waters.” 33 U. S. C. §§1311(a), 1362(12)(A). It broadly defines the term “ ‘pollutant’ ” to include not only contaminants like “chemical wastes,” but also more mundane materials like “rock, sand,” and “cellar dirt.” §1362(6).

The CWA is a potent weapon. It imposes what have been described as “crushing” consequences “even for inadvertent violations.” *Army Corps of Engineers v. Hawkes Co.*, 578 U.S. 590, 602 (2016) (Kennedy, J., concurring). Property owners who negligently discharge “pollutants” into covered waters may face severe criminal penalties including imprisonment. §1319(c). These penalties increase for knowing violations. *Ibid.* On the civil side, the CWA imposes over \$60,000 in fines per day for each violation. See Note following 28 U. S. C. §2461; 33 U. S. C. §1319(d); 88 Fed. Reg. 989 (2023) (to be codified in 40 CFR §19.4). And due to the Act’s 5-year statute

of limitations, 28 U. S. C. §2462, and expansive interpretations of the term “violation,” these civil penalties can be nearly as crushing as their criminal counterparts, see, e.g., *Borden Ranch Partnership v. United States Army Corps of Engineers*, 261 F.3d 810, 813, 818 (CA9 2001) (upholding Agency decision to count each of 348 passes of a plow by a farmer through “jurisdictional” soil on his farm as a separate violation), aff’d by an equally divided Court, 537 U.S. 99 (2002) (*per curiam*).

The Environmental Protection Agency (EPA) and the Army Corps of Engineers (Corps) jointly enforce the CWA. The EPA is tasked with policing violations after the fact, either by issuing orders demanding compliance or by bringing civil actions. §1319(a). The Act also authorizes private plaintiffs to sue to enforce its requirements. §1365(a). On the front end, both agencies are empowered to issue permits exempting activity that would otherwise be unlawful under the Act. Relevant here, the Corps controls permits for the discharge of dredged or fill material into covered waters. See §1344(a). The costs of obtaining such a permit are “significant,” and both agencies have admitted that “the permitting process can be arduous, expensive, and long.” *Hawkes Co.*, 578 U. S., at 594–595, 601. Success is also far from guaranteed, as the Corps has asserted discretion to grant or deny permits based on a long, nonexclusive list of factors that ends with a catchall mandate to consider “in general, the needs and welfare of the people.” 33 CFR §320.4(a)(1) (2022).

Due to the CWA’s capacious definition of “pollutant,” its low *mens rea*, and its severe penalties, regulated parties have focused particular attention on the Act’s geographic scope. While its predecessor encompassed “interstate or navigable waters,” 33 U. S. C. §1160(a) (1970 ed.), the CWA prohibits the discharge of pollutants into only “navigable waters,” which it defines as “the waters of the United States, including the territorial seas,” 33 U. S. C. §§1311(a), 1362(7), (12)(A) (2018 ed.). The meaning of this definition is the persistent problem that we must address.

B
Michael and Chantell Sackett have spent well over a decade navigating the CWA, and their voyage has been bumpy and costly. In 2004, they purchased a small lot near Priest Lake, in Bonner County, Idaho. In preparation for building a modest home, they began backfilling their property with dirt and rocks. A few months later, the EPA sent the Sacketts a compliance order informing them that their backfilling violated the CWA because their property contained protected wetlands. The EPA demanded that the Sacketts immediately “ ‘undertake activities to restore the Site’ ” pursuant to a “ ‘Restoration Work Plan’ ” that it provided. *Sackett v. EPA*, 566 U.S. 120, 125 (2012). The order threatened the Sacketts with penalties of over \$40,000 per day if they did not comply.

At the time, the EPA interpreted “the waters of the United States” to include “[a]ll . . . waters” that “could affect interstate or foreign commerce,” as well as “[w]etlands adjacent” to those waters. 40 CFR §§230.3(s)(3), (7) (2008). “[A]djacent” was defined to mean not just “bordering” or “contiguous,” but also “neighboring.” §230.3(b). Agency guidance instructed officials to assert jurisdiction over wetlands “adjacent” to non-navigable tributaries when those wetlands had “a significant nexus to a traditional navigable water.”^[6] A “significant nexus” was said to exist when “ ‘wetlands, either alone or in combination with *similarly situated lands* in the region, *significantly affect* the chemical, physical, and biological integrity’ ” of those waters. 2007 Guidance 8 (emphasis added). In looking for evidence of a “significant nexus,” field agents were told to consider a wide range of open-ended hydrological and ecological factors. See *id.*, at 7.

According to the EPA, the “wetlands” on the Sacketts’ lot are “adjacent to” (in the sense that they are in the same neighborhood as) what it described as an “unnamed tributary” on the other side of a 30-foot road. App. 33. That tributary feeds into a non-navigable creek, which, in turn, feeds into Priest Lake, an intrastate body of water that the EPA designated as traditionally navigable. To establish a significant nexus, the EPA lumped the Sacketts’ lot together with the Kalispell Bay Fen, a large nearby wetland complex that the Agency regarded as “similarly situated.” According to the EPA, these properties, taken together, “significantly affect” the ecology of Priest Lake. Therefore, the EPA concluded, the Sacketts had illegally dumped soil and gravel onto “the waters of the United States.”

The Sacketts filed suit under the Administrative Procedure Act, 5 U. S. C. §702 *et seq.*, alleging that the EPA lacked jurisdiction because any wetlands on their property were not “waters of the United States.” The District Court initially dismissed the suit, reasoning that the compliance order was not a final agency action, but this Court ultimately held that the Sacketts could bring their suit under the APA. See *Sackett*, 566 U. S., at 131. After seven years of additional proceedings on remand, the District Court entered summary judgment for the EPA. 2019 WL 13026870 (D Idaho, Mar. 31, 2019). The Ninth Circuit affirmed, holding that the CWA covers adjacent wetlands with a significant nexus to traditional navigable waters and that the Sacketts’ lot satisfied that standard. 8 F. 4th 1075, 1091–1093 (2021). We granted certiorari to decide the proper test for determining whether wetlands are “waters of the United States.” 595 U. S. ___ (2022).

II

A

In defining the meaning of “the waters of the United States,” we revisit what has been “a contentious and difficult task.” *National Assn. of Mfrs. v. Department of Defense*, 583 U. S. ___, ___ (2018) (slip op., at 1). The phrase has sparked decades of

agency action and litigation. In order to resolve the CWA's applicability to wetlands, we begin by reviewing this history.

The EPA and the Corps initially promulgated different interpretations of "the waters of the United States." The EPA defined its jurisdiction broadly to include, for example, intrastate lakes used by interstate travelers. 38 Fed. Reg. 13529 (1973). Conversely, the Corps, consistent with its historical authority to regulate obstructions to navigation, asserted jurisdiction over only traditional navigable waters. 39 Fed. Reg. 12119 (1974). But the Corps' narrow definition did not last. It soon promulgated new, much broader definitions designed to reach the outer limits of Congress's commerce power. See 42 Fed. Reg. 37144, and n. 2 (1977); 40 Fed. Reg. 31324–31325 (1975).

Eventually the EPA and Corps settled on materially identical definitions. See 45 Fed. Reg. 33424 (1980); 47 Fed. Reg. 31810–31811 (1982). These broad definitions encompassed "[a]ll . . . waters" that "could affect interstate or foreign commerce." 40 CFR §230.3(s)(3) (2008). So long as the potential for an interstate effect was present, the regulation extended the CWA to, for example, "intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds." *Ibid.* The agencies likewise took an expansive view of the CWA's coverage of wetlands "adjacent" to covered waters. §230.3(s)(7). As noted, they defined "adjacent" to mean "bordering, contiguous, or neighboring" and clarified that "adjacent" wetlands include those that are separated from covered waters "by man-made dikes or barriers, natural river berms, beach dunes and the like." §230.3(b). They also specified that "wetlands" is a technical term encompassing "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." §230.3(t). The Corps released what would become a 143-page manual to guide officers when they determine whether property meets this definition.[7]

This Court first construed the meaning of "the waters of the United States" in *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985). There, we were confronted with the Corps' assertion of authority under the CWA over wetlands that "actually abut[ted] on a navigable waterway." *Id.*, at 135. Although we expressed concern that wetlands seemed to fall outside "traditional notions of 'waters,'" we nonetheless deferred to the Corps, reasoning that "the transition from water to solid ground is not necessarily or even typically an abrupt one." *Id.*, at 132–133. The agencies responded to *Riverside Bayview* by expanding their interpretations even further. Most notably, they issued the "migratory bird rule," which extended jurisdiction to any waters or wetlands that "are or would be used as [a] habitat" by

migratory birds or endangered species. See 53 Fed. Reg. 20765 (1988); 51 Fed. Reg. 41217 (1986). As the Corps would later admit, “nearly all waters were jurisdictional under the migratory bird rule.”^[8]

In *Solid Waste Agency of Northern Cook Cty. v. Army Corps of Engineers*, 531 U.S. 159 (2001) (*SWANCC*), this Court rejected the migratory bird rule, which the Corps had used to assert jurisdiction over several isolated ponds located wholly within the State of Illinois. Disagreeing with the Corps’ argument that ecological interests supported its jurisdiction, we instead held that the CWA does not “exten[d] to ponds that are not adjacent to open water.” *Id.*, at 168 (emphasis deleted).

Days after our decision, the agencies issued guidance that sought to minimize *SWANCC*’s impact. They took the view that this Court’s holding was “strictly limited to waters that are ‘nonnavigable, isolated, and intrastate’ ” and that “field staff should continue to exercise CWA jurisdiction to the full extent of their authority” for “any waters that fall outside of that category.”^[9] The agencies never defined exactly what they regarded as the “full extent of their authority.” They instead encouraged local field agents to make decisions on a case-by-case basis. What emerged was a system of “vague” rules that depended on “locally developed practices.” GAO Report 26. Deferring to the agencies’ localized decisions, lower courts blessed an array of expansive interpretations of the CWA’s reach.

See, e.g., *United States v. Deaton*, 332 F.3d 698, 702 (CA4 2003) (holding that a property owner violated the CWA by piling soil near a ditch 32 miles from navigable waters). Within a few years, the agencies had “interpreted their jurisdiction over ‘the waters of the United States’ to cover 270-to-300 million acres” of wetlands and “virtually any parcel of land containing a channel or conduit . . . through which rainwater or drainage may occasionally or intermittently flow.” *Rapanos v. United States*, 547 U.S. 715, 722 (2006) (plurality opinion).

It was against this backdrop that we granted review in *Rapanos v. United States*. The lower court in the principal case before us had held that the CWA covered wetlands near ditches and drains that eventually emptied into navigable waters at least 11 miles away, a theory that had supported the petitioner’s conviction in a related prosecution. *Id.*, at 720, 729. Although we vacated that decision, no position commanded a majority of the Court. Four Justices concluded that the CWA’s coverage did not extend beyond two categories: first, certain relatively permanent bodies of water connected to traditional interstate navigable waters and, second, wetlands with such a close physical connection to those waters that they were “as a practical matter indistinguishable from waters of the United States.” *Id.*, at 742, 755 (emphasis deleted). Four Justices would have deferred to the Government’s determination that the wetlands at issue were covered under the CWA. *Id.*, at 788 (Stevens, J., dissenting). Finally, one Justice concluded that jurisdiction under the

CWA requires a “significant nexus” between wetlands and navigable waters and that such a nexus exists where “the wetlands, either alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity” of those waters. *Id.*, at 779–780 (Kennedy, J., concurring in judgment).

In the decade following *Rapanos*, the EPA and the Corps issued guidance documents that “recognized larger grey areas and called for more fact-intensive individualized determinations in those grey areas.”^[10] As discussed, they instructed agency officials to assert jurisdiction over wetlands “adjacent” to non-navigable tributaries based on fact-specific determinations regarding the presence of a significant nexus. 2008 Guidance 8. The guidance further advised officials to make this determination by considering a lengthy list of hydrological and ecological factors. *Ibid.* Echoing what they had said about the migratory bird rule, the agencies later admitted that “almost all waters and wetlands across the country theoretically could be subject to a case-specific jurisdictional determination” under this guidance. 80 Fed. Reg. 37056 (2015); see, e.g., *Hawkes Co.*, 578 U. S., at 596 (explaining that the Corps found a significant nexus between wetlands and a river “some 120 miles away”).

More recently, the agencies have engaged in a flurry of rulemaking defining “the waters of the United States.” In a 2015 rule, they offered a muscular approach that would subject “the vast majority of the nation’s water features” to a case-by-case jurisdictional analysis.^[11] Although the rule listed a few examples of “waters” that were excluded from regulation like “[p]uddles” and “swimming pools,” it categorically covered other waters and wetlands, including any within 1,500 feet of interstate or traditional navigable waters. 80 Fed. Reg. 37116–37117. And it subjected a wider range of other waters, including any within 4,000 feet of indirect tributaries of interstate or traditional navigable waters, to a case-specific determination for significant nexus. *Ibid.*

The agencies repealed this sweeping rule in 2019. 84 Fed. Reg. 56626. Shortly afterwards, they replaced it with a narrower definition that limited jurisdiction to traditional navigable waters and their tributaries, lakes, and “adjacent” wetlands. 85 Fed. Reg. 22340 (2020). They also narrowed the definition of “[a]djacent,” limiting it to wetlands that “[a]but” covered waters, are flooded by those waters, or are separated from those waters by features like berms or barriers. *Ibid.* This rule too did not last. After granting the EPA’s voluntary motion to remand, a District Court vacated the rule. See *Pascua Yaqui Tribe v. EPA*, 557 F. Supp. 3d 949, 957 (D Ariz. 2021).

The agencies recently promulgated yet another rule attempting to define waters of the United States. 88 Fed. Reg. 3004 (2023) (to be codified in 40 CFR §120.2). Under

that broader rule, traditional navigable waters, interstate waters, and the territorial seas, as well as their tributaries and adjacent wetlands, are waters of the United States. 88 Fed. Reg. 3143. So are any “[i]ntrastate lakes and ponds, streams, or wetlands” that either have a continuous surface connection to categorically included waters or have a significant nexus to interstate or traditional navigable waters. *Id.*, at 3006, 3143. Like the post-*Rapanos* guidance, the rule states that a significant nexus requires consideration of a list of open-ended factors. 88 Fed. Reg. 3006, 3144. Finally, the rule returns to the broad pre-2020 definition of “adjacent.” *Ibid.*; see *supra*, at 7. Acknowledging that “[f]ield work is often necessary to confirm the presence of a wetland” under these definitions, the rule instructs local agents to continue using the Corps’ Wetlands Delineation Manual. 88 Fed. Reg. 3117.

B

With the benefit of a half century of practice under the CWA, it is worth taking stock of where things stand. The agencies maintain that the significant-nexus test has been and remains sufficient to establish jurisdiction over “adjacent” wetlands. And by the EPA’s own admission, “almost all waters and wetlands” are potentially susceptible to regulation under that test. 80 Fed. Reg. 37056. This puts many property owners in a precarious position because it is “often difficult to determine whether a particular piece of property contains waters of the United States.” *Hawkes Co.*, 578 U. S., at 594; see 40 CFR §230.3(t) (2008). Even if a property appears dry, application of the guidance in a complicated manual ultimately decides whether it contains wetlands. See 88 Fed. Reg. 3117; Wetlands Delineation Manual 84–85 (describing “not . . . atypical” examples of wetlands that periodically lack wetlands indicators); see also *Hawkes Co. v. United States Army Corps of Engineers*, 782 F.3d 994, 1003 (CA8 2015) (Kelly, J., concurring) (“This is a unique aspect of the CWA; most laws do not require the hiring of expert consultants to determine if they even apply to you or your property”). And because the CWA can sweep broadly enough to criminalize mundane activities like moving dirt, this unchecked definition of “the waters of the United States” means that a staggering array of landowners are at risk of criminal prosecution or onerous civil penalties. What are landowners to do if they want to build on their property? The EPA recommends asking the Corps for a jurisdictional determination, which is a written decision on whether a particular site contains covered waters. Tr. of Oral Arg. 86; see Corps, Regulatory Guidance Letter No. 16–01, at 1 (2016) (RGL 16–01); 33 CFR §§320.1(a)(6), 331.2. But the Corps maintains that it has no obligation to provide jurisdictional determinations, RGL 16–01, at 2, and it has already begun announcing exceptions to the legal effect of some previous determinations, see 88 Fed. Reg. 3136. Even if the Corps is willing to provide a jurisdictional determination, a

property owner may find it necessary to retain an expensive expert consultant who is capable of putting together a presentation that stands a chance of persuading the Corps.^[12] And even then, a landowner's chances of success are low, as the EPA admits that the Corps finds jurisdiction approximately 75% of the time. Tr. of Oral Arg. 110.

If the landowner is among the vast majority who receive adverse jurisdictional determinations, what then? It would be foolish to go ahead and build since the jurisdictional determination might form evidence of culpability in a prosecution or civil action. The jurisdictional determination could be challenged in court, but only after the delay and expense required to exhaust the administrative appeals process. See 33 CFR §331.7(d). And once in court, the landowner would face an uphill battle under the deferential standards of review that the agencies enjoy. See 5 U. S. C. §706. Another alternative would be simply to acquiesce and seek a permit from the Corps. But that process can take years and cost an exorbitant amount of money. Many landowners faced with this unappetizing menu of options would simply choose to build nothing.

III

With this history in mind, we now consider the extent of the CWA's geographical reach.

A

We start, as we always do, with the text of the CWA. *Bartenwerfer v. Buckley*, 598 U.S. 69, 74 (2023). As noted, the Act applies to "navigable waters," which had a well-established meaning at the time of the CWA's enactment. But the CWA complicates matters by proceeding to define "navigable waters" as "the waters of the United States," §1362(7), which was decidedly not a well-known term of art. This frustrating drafting choice has led to decades of litigation, but we must try to make sense of the terms Congress chose to adopt. And for the reasons explained below, we conclude that the *Rapanos* plurality was correct: the CWA's use of "waters" encompasses "only those relatively permanent, standing or continuously flowing bodies of water 'forming geographic[al] features' that are described in ordinary parlance as 'streams, oceans, rivers, and lakes.'" 547 U. S., at 739 (quoting Webster's New International Dictionary 2882 (2d ed. 1954) (Webster's Second); original alterations omitted).

This reading follows from the CWA's deliberate use of the plural term "waters." See 547 U. S., at 732–733. That term typically refers to bodies of water like those listed above. See, e.g., Webster's Second 2882; Black's Law Dictionary 1426 (5th ed. 1979) ("especially in the plural, [water] may designate a body of water, such as a river, a lake, or an ocean, or an aggregate of such bodies of water, as in the phrases 'foreign waters,' '*waters of the United States*,' and the like" (emphasis added));

Random House Dictionary of the English Language 2146 (2d ed. 1987) (Random House Dictionary) (defining “waters” as “a. flowing water, or water moving in waves: The river’s mighty waters. b. the sea or seas bordering a particular country or continent or located in a particular part of the world” (emphasis deleted)). This meaning is hard to reconcile with classifying “ ‘lands,” wet or otherwise, as “waters.” ’ ’ *Rapanos*, 547 U. S., at 740 (plurality opinion) (quoting *Riverside Bayview*, 474 U. S., at 132).

This reading also helps to align the meaning of “the waters of the United States” with the term it is defining: “navigable waters.” See *Bond v. United States*, 572 U.S. 844, 861 (2014) (“In settling on a fair reading of a statute, it is not unusual to consider the ordinary meaning of a defined term, particularly when there is dissonance between that ordinary meaning and the reach of the definition”).

Although we have acknowledged that the CWA extends to more than traditional navigable waters, we have refused to read “navigable” out of the statute, holding that it at least shows that Congress was focused on “its traditional jurisdiction over waters that were or had been navigable in fact or which could reasonably be so made.” *SWANCC*, 531 U. S., at 172; see also *Appalachian Electric*, 311 U. S., at 406–407; *The Daniel Ball*, 10 Wall., at 563. At a minimum, then, the use of “navigable” signals that the definition principally refers to bodies of navigable water like rivers, lakes, and oceans. See *Rapanos*, 547 U. S., at 734 (plurality opinion).

More broadly, this reading accords with how Congress has employed the term “waters” elsewhere in the CWA and in other laws. The CWA repeatedly uses “waters” in contexts that confirm the term refers to bodies of open water. See 33 U. S. C. §1267(i)(2)(D) (“the waters of the Chesapeake Bay”); §1268(a)(3)(I) (“the open waters of each of the Great Lakes”); §1324(d)(4)(B)(ii) (“lakes and other surface waters”); §1330(g)(4)(C)(vii) (“estuarine waters”); §1343(c)(1) (“the waters of the territorial seas, the contiguous zone, and the oceans”); §§1346(a)(1), 1375a(a) (“coastal recreation waters”); §1370 (state “boundary waters”). The use of “waters” elsewhere in the U. S. Code likewise correlates to rivers, lakes, and oceans.^[13]

Statutory history points in the same direction. The CWA’s predecessor statute covered “interstate or navigable waters” and defined “interstate waters” as “all rivers, lakes, and other waters that flow across or form a part of State boundaries.” 33 U. S. C. §§1160(a), 1173(e) (1970 ed.) (emphasis added); see also Rivers and Harbors Act of 1899, 30Stat. 1151 (codified, as amended, at 33 U. S. C. §403) (prohibiting unauthorized obstructions “to the navigable capacity of any of the waters of the United States”).

This Court has understood the CWA’s use of “waters” in the same way. Even as *Riverside Bayview* grappled with whether adjacent wetlands could fall within the CWA’s coverage, it acknowledged that wetlands are not included in “traditional

notions of ‘waters.’ ” 474 U. S., at 133. It explained that the term conventionally refers to “hydrographic features” like “rivers” and “streams.” *Id.*, at 131. SWANCC went even further, repeatedly describing the “waters” covered by the Act as “open water” and suggesting that “the waters of the United States” principally refers to traditional navigable waters. 531 U. S., at 168–169, 172. That our CWA decisions operated under this assumption is unsurprising. Ever since *Gibbons v. Ogden*, 9 Wheat. 1 (1824), this Court has used “waters of the United States” to refer to similar bodies of water, almost always in relation to ships. *Id.*, at 218 (discussing a vessel’s “conduct in the waters of the United States”).^[14] The EPA argues that “waters” is “naturally read to encompass wetlands” because the “presence of water is ‘universally regarded as the most basic feature of wetlands.’ ” Brief for Respondents 19. But that reading proves too much. Consider puddles, which are also defined by the ordinary presence of water even though few would describe them as “waters.” This argument is also tough to square with SWANCC, which held that the Act does not cover isolated ponds, see 531 U. S., at 171, or *Riverside Bayview*, which would have had no need to focus so extensively on the adjacency of wetlands to covered waters if the EPA’s reading were correct, see 474 U. S., at 131–135, and n. 8. Finally, it is also instructive that the CWA expressly “protect[s] the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution” and “to plan the development and use . . . of land and water resources.” §1251(b). It is hard to see how the States’ role in regulating water resources would remain “primary” if the EPA had jurisdiction over anything defined by the presence of water. See *County of Maui v. Hawaii Wildlife Fund*, 590 U. S. ___, ___ (2020) (slip op., at 7); *Rapanos*, 547 U. S., at 737 (plurality opinion).

B

Although the ordinary meaning of “waters” in §1362(7) might seem to exclude all wetlands, we do not view that provision in isolation. The meaning of a word “may only become evident when placed in context,” *FDA v. Brown & Williamson Tobacco Corp.*, 529 U.S. 120, 132 (2000), and statutory context shows that some wetlands qualify as “waters of the United States.”

In 1977, Congress amended the CWA and added §1344(g)(1), which authorizes States to apply to the EPA for permission to administer programs to issue permits for the discharge of dredged or fill material into some bodies of water. In simplified terms, the provision specifies that state permitting programs may regulate discharges into (1) any waters of the United States, (2) except for traditional navigable waters, (3) “including wetlands adjacent thereto.”^[15]

When this convoluted formulation is parsed, it tells us that at least some wetlands must qualify as “waters of the United States.” The provision begins with a broad category, “the waters of the United States,” which we may call category A. The

provision provides that States may permit discharges into these waters, but it then qualifies that States cannot permit discharges into a subcategory of A: traditional navigable waters (category B). Finally, it states that a third category (category C), consisting of wetlands "adjacent" to traditional navigable waters, is "includ[ed]" within B. Thus, States may permit discharges into A minus B, which includes C. If C (adjacent wetlands) were not part of A ("the waters of the United States") and therefore subject to regulation under the CWA, there would be no point in excluding them from that category. See *Riverside Bayview*, 474 U. S., at 138, n. 11 (recognizing that §1344(g) "at least suggest[s] strongly that the term 'waters' as used in the Act does not necessarily exclude 'wetlands' "); *Rapanos*, 547 U. S., at 768 (opinion of Kennedy, J.). Thus, §1344(g)(1) presumes that certain wetlands constitute "waters of the United States."

But what wetlands does the CWA regulate? Section 1344(g)(1) cannot answer that question alone because it is not the operative provision that defines the Act's reach. See *Riverside Bayview*, 474 U. S., at 138, n. 11. Instead, we must harmonize the reference to adjacent wetlands in §1344(g)(1) with "the waters of the United States," §1362(7), which is the actual term we are tasked with interpreting. The formulation discussed above tells us how: because the adjacent wetlands in §1344(g)(1) are "includ[ed]" within "the waters of the United States," these wetlands must qualify as "waters of the United States" in their own right. In other words, they must be indistinguishably part of a body of water that itself constitutes "waters" under the CWA. See *supra*, at 14.

This understanding is consistent with §1344(g)(1)'s use of "adjacent." Dictionaries tell us that the term "adjacent" may mean either "contiguous" or "near." Random House Dictionary 25; see Webster's Third New International Dictionary 26 (1976); see also Oxford American Dictionary & Thesaurus 16 (2d ed. 2009) (listing "adjoining" and "neighboring" as synonyms of "adjacent"). But "construing statutory language is not merely an exercise in ascertaining 'the outer limits of a word's definitional possibilities,'" *FCC v. AT&T Inc.*, 562 U.S. 397, 407 (2011) (alterations omitted), and here, "only one . . . meanin[g] produces a substantive effect that is compatible with the rest of the law," *United Sav. Assn. of Tex. v. Timbers of Inwood Forest Associates, Ltd.*, 484 U.S. 365, 371 (1988). Wetlands that are separate from traditional navigable waters cannot be considered part of those waters, even if they are located nearby.

In addition, it would be odd indeed if Congress had tucked an important expansion to the reach of the CWA into convoluted language in a relatively obscure provision concerning state permitting programs. We have often remarked that Congress does not "hide elephants in mouseholes" by "alter[ing] the fundamental details of a regulatory scheme in vague terms or ancillary provisions." *Whitman v. American*

Trucking Assns., Inc., 531 U.S. 457, 468 (2001). We cannot agree with such an implausible interpretation here.

If §1344(g)(1) were read to mean that the CWA applies to wetlands that are not indistinguishably part of otherwise covered “waters of the United States,” see *supra*, at 14, it would effectively amend and substantially broaden §1362(7) to define “navigable waters” as “waters of the United States *and adjacent wetlands.*” But §1344(g)(1)’s use of the term “including” makes clear that it does not purport to do—and in fact, does not do—any such thing. See *National Assn. of Home Builders v. Defenders of Wildlife*, 551 U.S. 644, 662–664, and n. 8 (2007) (recognizing that implied amendments require “‘clear and manifest’” evidence of congressional intent). It merely reflects Congress’s assumption that certain “adjacent” wetlands are *part of* “waters of the United States.”

This is the thrust of observations in decisions going all the way back to *Riverside Bayview*. In that case, we deferred to the Corps’ decision to regulate wetlands actually abutting a navigable waterway, but we recognized “the inherent difficulties of defining precise bounds to regulable waters.” 474 U. S., at 134; see also *id.*, at 132 (noting that “the transition from water to solid ground is not necessarily or even typically an abrupt one” due to semi-aquatic features like shallows and swamps). In such a situation, we concluded, the Corps could reasonably determine that wetlands “adjoining bodies of water” were part of those waters. *Id.*, at 135, and n. 9; see also *SWANCC*, 531 U. S., at 167 (recognizing that *Riverside Bayview* “held that the Corps had . . . jurisdiction over wetlands that actually abutted on a navigable waterway”).

In *Rapanos*, the plurality spelled out clearly when adjacent wetlands are part of covered waters. It explained that “waters” may fairly be read to include only those wetlands that are “as a practical matter indistinguishable from waters of the United States,” such that it is “difficult to determine where the ‘water’ ends and the ‘wetland’ begins.” 547 U. S., at 742, 755 (emphasis deleted). That occurs when wetlands have “a continuous surface connection to bodies that are ‘waters of the United States’ in their own right, so that there is no clear demarcation between ‘waters’ and wetlands.” *Id.*, at 742; cf. 33 U. S. C. §2802(5) (defining “coastal waters” to include wetlands “having unimpaired connection with the open sea up to the head of tidal influence”). We agree with this formulation of when wetlands are part of “the waters of the United States.” We also acknowledge that temporary interruptions in surface connection may sometimes occur because of phenomena like low tides or dry spells.^[16]

In sum, we hold that the CWA extends to only those wetlands that are “as a practical matter indistinguishable from waters of the United States.” *Rapanos*, 547 U. S., at 755 (plurality opinion) (emphasis deleted). This requires the party asserting

jurisdiction over adjacent wetlands to establish “first, that the adjacent [body of water constitutes] . . . ‘water[s] of the United States,’ (i.e., a relatively permanent body of water connected to traditional interstate navigable waters); and second, that the wetland has a continuous surface connection with that water, making it difficult to determine where the ‘water’ ends and the ‘wetland’ begins.” *Id.*, at 742.

IV

The EPA resists this reading of §1362(7) and instead asks us to defer to its understanding of the CWA’s jurisdictional reach, as set out in its most recent rule defining “the waters of the United States.” See 88 Fed. Reg. 3004. This rule, as noted, provides that “adjacent wetlands are covered by the Act if they ‘possess a “significant nexus” to’ traditional navigable waters.” Brief for Respondents 32 (quoting *Rapanos*, 547 U. S., at 759 (opinion of Kennedy, J.)); see 88 Fed. Reg. 3143. And according to the EPA, wetlands are “adjacent” when they are “neighboring” to covered waters, even if they are separated from those waters by dry land. Brief for Respondents 20; 88 Fed. Reg. 3144.

A

For reasons already explained, this interpretation is inconsistent with the text and structure of the CWA. Beyond that, it clashes with “background principles of construction” that apply to the interpretation of the relevant statutory provisions. *Bond*, 572 U. S., at 857. Under those presumptions, the EPA must provide clear evidence that it is authorized to regulate in the manner it proposes.

1

First, this Court “require[s] Congress to enact exceedingly clear language if it wishes to significantly alter the balance between federal and state power and the power of the Government over private property.” *United States Forest Service v. Cowpasture River Preservation Assn.*, 590 U. S. ___, ___-___ (2020) (slip op., at 15–16); see also *Bond*, 572 U. S., at 858. Regulation of land and water use lies at the core of traditional state authority. See, e.g., *SWANCC*, 531 U. S., at 174 (citing *Hess v. Port Authority Trans-Hudson Corporation*, 513 U.S. 30, 44 (1994)); *Tarrant Regional Water Dist. v. Herrmann*, 569 U.S. 614, 631 (2013). An overly broad interpretation of the CWA’s reach would impinge on this authority. The area covered by wetlands alone is vast—greater than the combined surface area of California and Texas. And the scope of the EPA’s conception of “the waters of the United States” is truly staggering when this vast territory is supplemented by all the additional area, some of which is generally dry, over which the Agency asserts jurisdiction. Particularly given the CWA’s express policy to “preserve” the States’ “primary” authority over land and water use, §1251(b), this Court has required a clear statement from Congress when determining the scope of “the waters of the United States.” *SWANCC*, 531 U. S., at 174; accord, *Rapanos*, 547 U. S., at 738 (plurality opinion).

The EPA, however, offers only a passing attempt to square its interpretation with the text of §1362(7), and its “significant nexus” theory is particularly implausible. It suggests that the meaning of “the waters of the United States” is so “broad and unqualified” that, if viewed in isolation, it would extend to all water in the United States. Brief for Respondents 32. The EPA thus turns to the “significant nexus” test in order to reduce the clash between its understanding of “the waters of the United States” and the term defined by that phrase, *i.e.*, “navigable waters.” As discussed, however, the meaning of “waters” is more limited than the EPA believes. See *supra*, at 14. And, in any event, the CWA never mentions the “significant nexus” test, so the EPA has no statutory basis to impose it. See *Rapanos*, 547 U. S., at 755–756 (plurality opinion).

2

Second, the EPA’s interpretation gives rise to serious vagueness concerns in light of the CWA’s criminal penalties. Due process requires Congress to define penal statutes “ ‘with sufficient definiteness that ordinary people can understand what conduct is prohibited’ ” and “ ‘in a manner that does not encourage arbitrary and discriminatory enforcement.’ ” *McDonnell v. United States*, 579 U.S. 550, 576 (2016) (quoting *Skilling v. United States*, 561 U.S. 358, 402–403 (2010)). Yet the meaning of “waters of the United States” under the EPA’s interpretation remains “hopelessly indeterminate.” *Sackett*, 566 U. S., at 133 (Alito, J., concurring); accord, *Hawkes Co.*, 578 U. S., at 602 (opinion of Kennedy, J.).

The EPA contends that the only thing preventing it from interpreting “waters of the United States” to “conceivably cover literally every body of water in the country” is the significant-nexus test. Tr. of Oral Arg. 70–71; accord, Brief for Respondents 32. But the boundary between a “significant” and an insignificant nexus is far from clear. And to add to the uncertainty, the test introduces another vague concept—“similarly situated” waters—and then assesses the aggregate effect of that group based on a variety of open-ended factors that evolve as scientific understandings change. This freewheeling inquiry provides little notice to landowners of their obligations under the CWA. Facing severe criminal sanctions for even negligent violations, property owners are “left ‘to feel their way on a case-by-case basis.’ ” *Sackett*, 566 U. S., at 124 (quoting *Rapanos*, 547 U. S., at 758 (Roberts, C. J., concurring)). Where a penal statute could sweep so broadly as to render criminal a host of what might otherwise be considered ordinary activities, we have been wary about going beyond what “Congress certainly intended the statute to cover.” *Skilling*, 561 U. S., at 404.

Under these two background principles, the judicial task when interpreting “the waters of the United States” is to ascertain whether clear congressional

authorization exists for the EPA's claimed power. The EPA's interpretation falls far short of that standard.

B

While mustering only a weak textual argument, the EPA justifies its position on two other grounds. It primarily claims that Congress implicitly ratified its interpretation of "adjacent" wetlands when it adopted §1344(g)(1). Thus, it argues that "waters of the United States" covers any wetlands that are "bordering, contiguous, or neighboring" to covered waters. 88 Fed. Reg. 3143. The principal opinion concurring in the judgment adopts the same position. See *post*, at 10–12 (Kavanaugh, J., concurring in judgment). The EPA notes that the Corps had promulgated regulations adopting that interpretation before Congress amended the CWA in 1977 to include the reference to "adjacent" wetlands in §1344(g)(1). See 42 Fed. Reg. 37144. This term, the EPA contends, was "'obviously transplanted from'" the Corps' regulations and thus incorporates the same definition. Brief for Respondents 22 (quoting *Taggart v. Lorenzen*, 587 U. S. ___, ___ (2019) (slip op., at 5)).

This argument fails for at least three reasons. First, as we have explained, the text of §§1362(7) and 1344(g)(1) shows that "adjacent" cannot include wetlands that are not part of covered "waters." See *supra*, at 22.

Second, this ratification theory cannot be reconciled with our cases. We have repeatedly recognized that §1344(g)(1) "'does not conclusively determine the construction to be placed on . . . the relevant definition of 'navigable waters.'" *SWANCC*, 531 U. S., at 171 (quoting *Riverside Bayview*, 474 U. S., at 138, n. 11); accord, *Rapanos*, 547 U. S., at 747–748, n. 12 (plurality opinion).

Additionally, *SWANCC* rejected the closely analogous argument that Congress ratified the Corps' definition of "waters of the United States" by including "'other . . . waters'" in §1344(g)(1). 531 U. S., at 168–171. And yet, the EPA's argument would require us to hold that §1344(g)(1) actually did amend the definition of "navigable waters" precisely for the reasons we rejected in *SWANCC*.

Third, the EPA cannot provide the sort of "overwhelming evidence of acquiescence" necessary to support its argument in the face of Congress's failure to amend §1362(7). *Id.*, at 169–170, n. 5. We will infer that a term was "'transplanted from another legal source' . . . only when a term's meaning was 'well-settled' before the transplantation." *Kemp v. United States*, 596 U. S. ___, ___–___ (2022) (slip op., at 9–10).

Far from being well settled, the Corps' definition was promulgated mere months before the CWA became law, and when the Corps adopted that definition, it candidly acknowledged the "rapidly changing nature of [its] regulatory programs." 42 Fed. Reg. 37122. Tellingly, even the EPA would not adopt that definition for several more years. See 45 Fed. Reg. 85345 (1980). This situation is a far cry from any in which we have found ratification. See, e.g., *George v. McDonough*, 596 U. S.

___, ___ (2022) (slip op., at 5) (finding ratification when “Congress used an unusual term that had a long regulatory history in [the] very regulatory context” at issue). The EPA also advances various policy arguments about the ecological consequences of a narrower definition of adjacent. But the CWA does not define the EPA’s jurisdiction based on ecological importance, and we cannot redraw the Act’s allocation of authority. See *Rapanos*, 547 U. S., at 756 (plurality opinion). “The Clean Water Act anticipates a partnership between the States and the Federal Government.” *Arkansas v. Oklahoma*, 503 U.S. 91, 101 (1992). States can and will continue to exercise their primary authority to combat water pollution by regulating land and water use. See, e.g., Brief for Farm Bureau of Arkansas et al. as *Amici Curiae* 17–27.

V

Nothing in the separate opinions filed by Justice Kavanaugh and Justice Kagan undermines our analysis. Justice Kavanaugh claims that we have “rewrit[ten]” the CWA, *post*, at 12 (opinion concurring in judgment), and Justice Kagan levels similar charges, *post*, at 3–4 (opinion concurring in judgment). These arguments are more than unfounded. We have analyzed the statutory language in detail, but the separate opinions pay no attention whatsoever to §1362(7), the key statutory provision that limits the CWA’s geographic reach to “the waters of the United States.” Thus, neither separate opinion even attempts to explain how the wetlands included in their interpretation fall within a fair reading of “waters.” Textualist arguments that ignore the operative text cannot be taken seriously.

VI

In sum, we hold that the CWA extends to only those “wetlands with a continuous surface connection to bodies that are ‘waters of the United States’ in their own right,” so that they are “indistinguishable” from those waters. *Rapanos*, 547 U. S., at 742, 755 (plurality opinion) (emphasis deleted); see *supra*, at 22. This holding compels reversal here. The wetlands on the Sacketts’ property are distinguishable from any possibly covered waters.

* * *

We reverse the judgment of the United States Court of Appeals for the Ninth Circuit and remand the case for further proceedings consistent with this opinion.

It is so ordered.

Notes

1 86Stat. 816, as amended, 33 U. S. C. §1251 *et seq.*

2 40 CFR §230.3(s)(3) (2008).

3 See *Rapanos v. United States*, 547 U.S. 715 (2006). Neither party contends that any opinion in *Rapanos* controls. We agree. See *Nichols v. United States*, 511 U.S. 738, 745–746 (1994).

[4](#) See N. Hines, *Nor Any Drop To Drink: Public Regulation of Water Quality*, 52 Iowa L. Rev. 186, 196–207 (1966).

[5](#) See Hearings on Activities of the Federal Water Pollution Control Administration before the Subcommittee on Air and Water Pollution of the Senate Committee on Public Works, 90th Cong., 1st Sess., 674 (1967) (reporting only one abatement suit between 1948 and 1967).

[6](#) EPA & Corps, *Clean Water Act Jurisdiction Following the U. S. Supreme Court's Decision in Rapanos v. United States & Carabell v. United States* 7–11 (2007) (2007 Guidance).

[7](#) See Corps, *Wetlands Delineation Manual* (Tech. Rep. Y-87-1, 1987) (*Wetlands Delineation Manual*); see also, e.g., Corps, *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Alaska Region* (Version 2.0) (ERDC/EL Tr-07-24, 2007).

[8](#) GAO, *Waters and Wetlands: Corps of Engineers Needs To Evaluate Its District Office Practices in Determining Jurisdiction* 26 (GAO-04-297, 2004) (GAO Report).

[9](#) EPA & Corps, *Memorandum, Supreme Court Ruling Concerning CWA Jurisdiction Over Isolated Waters* 3 (2001) (alteration omitted).

[10](#) N. Parrillo, *Federal Agency Guidance and the Power To Bind: An Empirical Study of Agencies and Industries*, 36 *Yale J. on Reg.* 165, 231 (2019); see 2007 Guidance 7–11; EPA & Corps, *Clean Water Act Jurisdiction Following the U. S. Supreme Court's Decision in Rapanos v. United States & Carabell v. United States* 8–12 (2008) (2008 Guidance).

[11](#) EPA & Dept. of the Army, *Economic Analysis of the EPA-Army Clean Water Rule* 11 (2015).

[12](#) See 88 Fed. Reg. 3134; Corps, *Questions and Answers for Rapanos and Carabell Decision* 16 (2007); J. Finkle, *Jurisdictional Determinations: An Important Battlefield in the Clean Water Act Fight*, 43 *Ecology L. Q.* 301, 314–315 (2016); K. Gould, *Drowning in Wetlands Jurisdictional Determination Process: Implementation of Rapanos v. United States*, 30 *U. Ark. Little Rock L. Rev.* 413, 440 (2008).

[13](#) See, e.g., 16 U. S. C. §745 (“the waters of the seacoast . . . the waters of the lakes”); §4701(a)(7) (“waters of the Chesapeake Bay”); 33 U. S. C. §4 (“the waters of the Mississippi River and its tributaries”); 43 U. S. C. §390h–8(a) (“the waters of Lake Cheraw, Colorado . . . the waters of the Arkansas River”); 46 U. S. C. §70051 (allowing the Coast Guard to take control of particular vessels during an emergency in order to “prevent damage or injury to any harbor or waters of the United States”).

[14](#) See, e.g., *United States v. Alvarez-Machain*, [504 U.S. 655](#), 661, n. 7 (1992) (discussing a treaty “to allow British passenger ships to carry liquor while in the

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Robby Eckroth

From: Rosann Wuebbels <rwuebbels@yahoo.com>
Sent: Sunday, July 27, 2025 5:29 AM
To: Commissioners; Lisa Janicki; Ron Wesen
Subject: Big lake proposed development and pollution

Dear commissioners

I want you to ensure the current CAO and the proposed CAO update will send no pollution to Big Lake from the Overlook project.

And I ask that the County does not delete the SCC 14.24.080(2) language "**...or may be affected by the proposed activity...**" from SCC 14.23.080 (3)(a), (4)(b) and any other place it was deleted, as the language is the only protection for critical areas that may be outside of a development and may be affecting the lake.

Sincerely, Rosann Wuebbels

11134 O Ave

Anacortes, WA 98221

[Yahoo Mail: Search, Organize, Conquer](#)

Robby Eckroth

From: John and Beth <verose@usa.net>
Sent: Sunday, July 27, 2025 12:32 PM
To: Commissioners
Cc: John and Beth
Subject: Big Lake

Hello, my name is John Verdoes and I live at 18870 Sulfer Springs Road, Mount Vernon, 98274(Big Lake).

Big Lake is a Critical Area where the water quality has continued to degrade over the years. I ask you to require developers to provide Critical Areas Site Assessments for the off-site impacts of their developments to critical areas without regard to distance.

Big Lake and other critical areas should be protected from further degradation caused by stormwater pollution.

Thank you for your consideration of this important element of development.

Skagit County Commissioners
Mt. Vernon Wa. 98273

RECEIVED

JUL 28 2025

SKAGIT COUNTY
PDS

July 26, 2025

Comments on Skagit County Critical Areas Ordinance Update July 2025:

It's very important to keep everyone informed on Skagit County Ongoing Agriculture CAO. In early 2000's county ag associations, farmers, landowners and citizens combined to protect and preserve agriculture here in Skagit. By providing best available science (BAS) that meets all criteria of BAS, -WAC 365-195-900-925 real true, field tested on the ground and replicable in development of Skagit County Ongoing Agriculture CAO. (attach)¹ This was essential in Washington State Supreme Courts ruling that Skagit County is adequately protecting County's On-going agriculture ordinance. (attach)²

Skagit County Cattlemen's found that EPA, DOE, and F&W shade theory lacks proof that a buffer will in fact cool water. Farmers and landowners need to get involved in a private property water monitoring program just as cattlemen's did. Methods used by EPA, DOE & F&W to investigate water quality issues are not the proper methodology required for science investigations nor are they assessing natural background conditions due to local climate conditions. There are water temperatures collected in sagebrush country without shade that are cooler than streams on west side with 80% shade. Why after 26 years, 138 million dollars wasted relying on assumptions, grant driven political science using computer modeling are there no good results? Time to get back to common sense, real true on the ground field tested science.

The Cattlemen's provided to the Court a 96 page literature review manual of scientific literature that is "best science" of what is available for review. The shade theory can be debunked in a single season of monitoring using proper methods and a statistical analysis. It's predicted it will take up to 65 years to grow a buffer that will have no influence on water temperature or water quality. (attach.)³

The Skagit County Cattlemen's Study 2001-2002 found adequate buffers, trees in critical areas and temperature problems agriculture were being blamed for were not problems at all, it was just natural conditions of Skagit. (Index, Summary and Conclusion attach.)⁴

Skagit County 2010 GIS A study shows 80% forested natural buffer canopy at 75 feet for streams in all Skagit County Ag/NRL zoned lands. (copy attach)⁵

What's really polluting? Fecal output loading rate 1 skunk is equal to 23 cows. Avian (water fowl) the major pollution contributors. DNA is needed before enforcement.

(attach) 6

2000 Voice of the Valley by Bill Reinard who served on a fisheries enhancement group and biology teacher expressed ocean conditions is the reason for less fish numbers.

(attach) 7

With the Courts Ruling, Cattlemen's Literature Review Manual and Cattlemen's two year Study, Skagit County and the agriculture community has accomplished all required goals in protecting critical areas and agriculture in the On-going Ag Zone.

Randy Good President Friends of Skagit County

35482 State Route 20

Sedro Woolley Wa. 98284

360-856-1199

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Book 4			

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Book 4	06/25/02	Public Meeting Submittals (cont)	<p>8) <u>Patricia A. Larson</u>: Letter to Skagit County Commissioners, from Ecosystem Research and Analysis Science and Natural Resource Advisor, with attachments;</p> <p>a) A copy of Skagit County Cattlemen Stream Study Final Report 2001 Data; Science & Data Booklet. A Quick Reference Handbook for Landowners (1998), Distributed in Cooperation with the Oregon Cattlemen's Association;</p> <p>c) White Paper, <i>What is Science?</i> Oregon Cattlemen's Association;</p> <p>9) <u>Annie Lohman</u>: Letter to Skagit County Public Works Dept from Skagit County Farm Bureau suggesting considerations and objectives in writing a new ordinance. Also submitted:</p> <p>a) <i>Watershed Agricultural Program for New York City's Water Supply Watershed and Whole Farm Planning and Management</i>;</p> <p>b) Watershed Agricultural Council, New York, <i>Watershed Protection: A Better Way</i>, Richard I. Coombe, Chair, October 21, 1994;</p> <p>c) A White Paper: <i>Skagit County Critical Area Ordinance Triggers State and Federal Constitutional Property Rights and Due Process Protection</i>;</p> <p>10) <u>William Porter</u>: <i>A Farmer's Opinion of BUFFER ZONES</i>;</p> <p>11) <u>Bill Reinard</u>: <i>The Responsible Alternative to Excessive Buffer Demands and Over Harvest Still Prevents Salmon Recovery</i>;</p> <p>12) <u>Tam Mower</u>: Web articles on global environment;</p> <p>13) <u>Thomas H. Solberg</u>: Letter to Skagit County Commissioners re Rewrite of CAO on ongoing agriculture;</p> <p>14) <u>Randy Good</u>: Letter to Skagit County Commissioners with comments for SCC 14.24.120 rewrite, with submittals:</p> <p>a) <i>Economic Farm Value Lost-Result of Skagit County's 75 Foot Buffers On Ag Lands</i>, compiled by Randy Good;</p> <p>b) Woody Debris Destructive Consequences, Roger A. Lowe;</p> <p>c) Pictures and statistics regarding Manser Creek;</p> <p>15) <u>Carol Ehlers</u>: Public comment sought on 303(d) listing policy, May, 2002;</p> <p>16) <u>Tipton Hudson</u>: Letter to Board of County Commissioners from Washington Cattlemen's Association;</p>

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Exhibit Location	Date	Title / Type of Document	Description
Book 4	06/25/02	Public Meeting Submittals (cont)	<p>17) <u>Dana Jones Studebaker</u>: Letter to Skagit County Commissioners from Woolly Prairie Buffalo Company;</p> <p>18) <u>Glenn Tenneson</u>: Opinion re Skagit County's Flawed Buffer Plan;</p> <p>19) <u>Ruth Thomas</u>: Comment sheet submitted at meeting;</p> <p>20) <u>Other</u>:</p> <p>a) <u>Sherman Creek Implementation Project SCIP (September 2001)</u>;</p> <p>b) Delisting Petition to D. Robert Lohn, Regional Administrator for Nation Marine Fisheries Service, from James L. Buchal, to remove two "species" of Pacific Northwest salmon from the "threatened" status under the ESA;</p> <p>c) Court's Memorandum Decision in Whatcom County Superior Court Case No. 99-2-00334-3, Island County and WEAN v. WWGMHB;</p> <p>d) Contract Documents <u>Harvestable Salmon Carcasses and Eggs-Fall, (August 1997)</u>;</p> <p>e) Part nine, Best Available Science, WAC 365-195-900</p> <p>21) Letter to Chal Martin, Public Works Department, from Sakuma Brothers Holding Company dated 6/16/02 with comments on Ag buffer Ordinance rewrite. Also includes e-mail comments from Dave Brookings and Chal Martin in response to letter.</p>
Book 5	06/26/02	Letter and articles submitted by Bill Reinard (Updated version 6/26/02)	<p><i>The Responsible Alternative to Excessive Buffer Demands</i>, previously submitted on 6/25/02 by Bill Reinard (see 6/25/02, Sub 11) including the following attachments:</p> <p>1) <i>Pacific Salmon and Wildlife, Ecological Context, Relationships, and Implications for Management</i>, Johnson and O'Neil 2000;</p> <p>2) <i>The Responsible Alternative to Excessive Buffer Demands</i>, June, 2002, with bibliography;</p> <p>3) "Works Not Cited"-listing newspaper and other articles of interest, with articles attached;</p> <p>4) <i>Fish Habitat Rehabilitation Procedures</i>, Watershed Restoration Technical Circular No. 9;</p> <p>5) <i>Fishes and the Forest, Expanding perspectives on fish-wildlife interactions</i>, Mary F. Willson and others;</p>

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Exhibit Location	Date	Title / Type of Document	Description
Book 5	06/26/02	Letter and articles submitted by Bill Reinard (Updated version 6/26/02) (continued)	<p>6) <i>An Estimation of Historic and Current Levels of Salmon production in the Northeast Pacific Ecosystem, Evidence of a Nutrient Deficit in the Freshwater Systems of the Pacific Northwest</i>, Ted Gresh, Jim Lichatowich and Peter Schoonmaker;</p> <p>7) <i>Inverse Production Regimes: Alaska and West Coast Pacific Salmon</i>, Steven R. Hare, Nathan J. Mantua and Robert C. Francis;</p> <p>8) <i>Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the past 300 Years</i>; Bruce P. Finney, and others.</p> <p>9) Other: Miscellaneous newspaper and other articles.</p>
Book 5	06/26/02	Letter to "Interested Parties" from Lew Atkins, Assistant Director, Fish Program; Letter to "U.S. Fraser Panel convention Area Fishers" from Rich Lincoln, Fraser River Panel, WDFW	Re regulations applying to non-treaty Puget Sound commercial salmon fisheries, with attachments from 2002 Puget Sound All-citizen Commercial Salmon Fisheries
Book 5	07/2002	Riparian Zone Bibliography	<i>Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances</i> , an Annotated and Indexed Bibliography of the world literature including buffer strips, and interactions with hyporheic zones and floodplains, by Dave Correll, July 2002
Book 5	07/02/02	Letter to Governor Gary Locke from Senator Mary Margaret Haugen, 10 th Legislative District	Requesting Governor Locke to tour Skagit County, meet the farmers involved in county agriculture and assist by providing leadership in resolving the tide-gate and dike and drainage issues.
Ex 478 (0033c)	07/12/02	Letter to Matthew Ojennus, Asst Planner, Growth Mgt Program, from Chal Martin, Skagit County Public Works Director	Transmitting the 2 nd quarter 2002 status report of activities under block grant agreement S01-63200-004, with request to extend termination date of contract to 12/31/03. (Copy of Status Report attached)
Ex 485 (0033c)	07/23/02	Interim Ordinance No. R20020263	An Interim Ordinance Repealing Skagit County Code (SCC) 14.24.130, Strategic Plan to Protect Wild Salmonids and Amending SCC 14.24.120 of the Critical Area Ordinance.

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Exhibit Location	Date	Title / Type of Document	Description
Book 6	09/11/02	Memo to Planning Commission Members from Patti Chamber, Planning and Permit Center	Re: Correspondence for Deliberations on September 24 th , Invitation to September 17 th BCC Agenda Item
Book 6	09/11/02	Skagit County Public Works News Release	<i>County Seeks Input For New Critical Areas Ordinance</i> , announcing public meeting on 9/23/02.
Book 6	09/13/02	Memo to Ric Boge, Public Works from Rod Hamilton, CREP Program Specialist, FSA	Response to inquiry on land eligibility under CREP
Book 6	09/17/02	Board of County Commissioners Agenda and Record of Proceedings	<u>Planning and Permit Center</u> – Discussion/Possible Approval-Issue a Request for Proposals for Development of a Programmatic Environmental Impact Statement for Skagit County's Critical Areas Ordinance.
Book 6	09/19/02	Letter to WWGMHB from Senator Mary Margaret Haugen, 10 th Legislative District	Expressing concern of continuing litigation affecting Skagit County and the impact on agricultural land.
Book 6	09/19/02	BAS literature for Skagit County Cattlemen submitted by Randy Good	Best Available Science Index: Grazing and Livestock Management: 1) <i>Field evaluation of furrow irrigation performance, sediment loss, and bromide transport in a highly erosive silt loam soil</i> , Ashraf, M.S., et al, 1999; 2) <i>Grazing systems, pasture size, and cattle grazing behavior, distribution and gains</i> , Hart, R.H., et al, 1993; 3) <i>Upland erosion under a simulated most damaging storm</i> , Linse, S.J., et al, 2001; 4) <i>Influence of intensive rotational grazing on bank erosion, fish habitat quality, and fish communities in Southwestern Wisconsin trout streams</i> , Lyons, J., et al, 2001; 5) <i>Economic and environmental impacts of alternative practices on dairy farms in an agricultural watershed</i> , Osei, E., et al, 2000; 6) <i>Nitrogen fertilization, botanical composition and biomass production on mixed grass rangeland</i> , Samuel, Marilyn J., et al, 1998; 7) <i>Nitrate abatement practices, farm profits, and lake water quality: a central Illinois case study</i> , Shankar, B., et al, 2000; 8) <i>Seasonal grazing affects soil physical properties of a montane riparian community</i> , Wheeler, Melinda A., et al, 2002; 9) <i>Pasture management influences on soil properties in the northern Great Plains</i> , Wienhold, B.J., et al, 2001

Skagit County v. ...
litigation.
Court Case, Wash. State
Supreme Court, No 76339-9
Ruling - County adequately
protecting C40 without
mandated buffers

IN THE SUPREME COURT OF THE STATE OF WASHINGTON

**SWINOMISH INDIAN TRIBAL
COMMUNITY and WASHINGTON
ENVIRONMENTAL COUNCIL,**

Petitioners,

v.

**WESTERN WASHINGTON GROWTH
MANAGEMENT HEARINGS BOARD;
SKAGIT COUNTY, a municipal
corporation of the State of Washington;
SKAGIT COUNTY FARM BUREAU;
SKAGITONIANS TO PRESERVE
FARMLAND; WESTERN WASHINGTON
AGRICULTURAL ASSOCIATION;
SKAGIT COUNTY DIKING DISTRICT
NO. 3; SKAGIT COUNTY DIKING
DISTRICT NO. 12; SKAGIT COUNTY
DRAINAGE DISTRICT NO. 17; and
SKAGIT COUNTY CONSOLIDATED
DIKING DISTRICT NO. 22,**

Respondents.

**SKAGIT COUNTY, a municipal
corporation of the State of Washington;
SKAGIT COUNTY FARM BUREAU;
SKAGITONIANS TO PRESERVE
FARMLAND; WESTERN WASHINGTON
AGRICULTURAL ASSOCIATION;
SKAGIT COUNTY DIKING DISTRICT
NO. 3; SKAGIT COUNTY DIKING
DISTRICT NO. 12; SKAGIT COUNTY
DRAINAGE DISTRICT NO. 17; and**

No. 76339-9

En Banc

Science Skagit County
put into Court record
meets all six criteria
in WAC 763-195-900-925
was deciding factor

Filed September 13, 2007

3.

**LITERATURE REVIEW
OF
BEST AVAILABLE SCIENCE**

ACCORDING TO WAC.-365-195-905 through 925 Criteria

Prepared by:

Pat Larson
Science and Natural Resource Advisor

Skagit County Cattlemen in cooperation with
Oregon Cattlemen's Association

2007

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OVERVIEW

The Earth is two-thirds water and one third land. Oceans surround the continents that have formed throughout geologic time and continue to form and erode as time continues. Members of both the Plant and Animal Kingdoms have evolved and become extinct as shifts in their habitat changed or were destroyed due to climatic or geologic events.

Oceans and atmospheric conditions interact and as air currents move over land various climates form. Throughout time a series of mountains and valleys of variable sizes have developed due to geologic events in combination with localized climate events. As a result mountains and valleys have become areas where precipitation is captured, stored in the soils, and the excess water through paths of least resistance moves off the land and back to the ocean.

Watersheds and river systems are the result of very long periods of events caused by geologic and hydrologic forces influenced by climate. At different scales both are defined areas where time, geologic, hydrologic and climatic events are recorded.

Geologists observe landforms from a perspective of time. Geologic events can be characterized as change over hundreds of years or in some cases a large area may have changed over thousands of years. Geology relies on Physics and Chemistry principles to reconstruct the order and causes of the event that have formed Earth's landscape.

Hydrologists study waterways and river systems in terms of time. Daily and seasonal events of the water cycle are often seen as important or insignificant when compared to periodic effects grouped by decades or centuries. The physical laws are used to describe and predict river and land interactions during changes that take place constantly.

Climatologists study climate in terms of periodic events at large scales. Trends in wet periods or dry periods, cold or warm cycles are viewed from a perspective of patterns established over time. Climate is described using laws in the fields of Physics and Chemistry

In a river system, Hydrologists and Geomorphologists study the time and space where geologic and climatic forces interact. Under the force of gravity the land surface has been sculpted by water, wind, and ice. The time involved in the process may be over hundreds of years and is recognized as a system in constant change.

Excess water from precipitation continues to carve paths through mountains, erode land in one area and depositing the load on another. River form and fluvial processes take place simultaneously and the system adjusts to the volume of water, erosional debris taken on as a load within the water column, and drainage area contributing to the channel.

Excess water from precipitation after saturating land (soil) can enter waterways carrying loose particles of soil and plant material. Natural erosion of soils takes place in this manner. River deposition has played a role in forming new soils where rivers and streams have carried materials from uplands to valley floors.

Soils are biochemical weathered products of nature formed through time and are a habitat for the growth of plants. The soils have been formed from a variable mixture of broken and weathered minerals and organic matter. Soils, with the proper amount of air and water provide a mechanical support and sustenance for plants.

Plant ecologists examine communities of plant life based on boundaries established by water and/or soil formation influenced by local climatic factors. Plants species have adaptive characteristics

placing them in variable spaces across the Earth. Generally ecological studies describe communities in terms of periodic events that have allowed or discouraged species of plants to become established over years, decades and possibly a century. Changes in plant community composition occur continuously due to disruptions of other earth processes such as fire, wind, precipitation in the form of rain, snow or ice, as well as volcano and earthquake activities. These events have prevented landscapes from becoming a monoculture of a single family, genus, or species.

Plant communities are areas where members of the Animal Kingdom exist. Organisms of microscopic size to very large species take advantage of the varying landscapes to find food and shelter. Animal species are usually studied as populations within a habitat in order to examine survival skills within a habitat. Nutrition for growth and reproduction takes place through interactions with plants or other organisms over life spans which can be from a few days, weeks, years or decades.

Different species use different habitat. Specialized fields within the biological sciences have developed, to focus on species that occur on the land or in the water. Wildlife Biologists focus on terrestrial and aquatic animals that use plant communities and display interactions with both the habitat as well as other terrestrial or aquatic life. Fish biologists study aquatic life and specialize in fresh or marine water inhabitants.

The fisheries during the last half century have examined questions of how fish exist and adapt to the variable aquatic habitats. Fresh water habitats of rivers and lakes are of particular interest in North America regarding the group of fish, Salmonids, as they take advantage of a marine environment during their adult, mature lives and seek fresh water to begin the reproduction of the species. Fisheries physiological studies describe internal adaptations that allow the species to make the switch as having formed through many generations during hundreds or thousands of years. In current events, the phenomenon is viewed within the time period of human settlement on the continent into the present day.

It is because of the recognition of scale and interaction that in 1941 H. Jenny (Father of Soil Science) proposed in Factors of Soil Formation that soil formation was the cumulative interaction of parent material, climate, biota topography and time. Similarly A.G. Tansly (Tansly, H. 1936. The use and abuse of vegetational concepts and terms. Ecology 16:284-307) proposed the term ecosystem to describe the structure and interaction of climate, topography soils, plants and animals.

Members of the Animal Kingdom live and use habitat for food and shelter and use adaptive features of the species to nudge nature or seek new habitat favorable to their survival and future existence. Humans and Salmonids exist in different habitats as opportunists with limited abilities to manipulate and control the ecosystem which has been formed at scales of time and force beyond individual capabilities.

It is imperative that man's ability to manipulate a system be viewed with a realistic understanding of scale and the interactions that occur in natural systems. It is equally imperative that Salmonids be viewed with a realistic understanding that their existence is dependent on two very different environments: the ocean and fresh water river systems. Reproduction takes place in fresh water and survival has come about due to both adaptations and mobility which allows the species to relocate when specific water column conditions become unsuitable.

To study Salmonid increases or declines being caused solely by man's manipulation of the terrestrial habitat cannot be done in isolation from all the factors that influence their life cycle. Biological processes and population dynamics require observance of scale in both the time and

events that have resulted in the creation of specific environments.

INTRODUCTION

This literature review is arranged using a literature citation by authors, date, journal name, with volume and page number. A short abstract and summary of the study follows each manuscript reviewed. For most of the literature, the abstract provided in the published manuscript written by the authors has been included. Some manuscript summaries also include reported findings, descriptions of methods, and concluding statements if an abstract was missing or was abbreviated and did not capture detail important to the topic.

Issues currently facing natural resource management are: fish, fish habitat, water temperature, sedimentation of streams due to forest and agriculture non point source erosion from runoff, the role of nitrate in the riparian areas, and riparian buffers. The following questions were used to provide categories as guidance for the selections of literature to be reviewed :

1. What is temperature and what is heat?
2. What governs water temperatures in watersheds?
3. What do we know about the interaction of livestock with salmon in riparian areas?
4. What do we know about livestock use of the plant community of a riparian area?
5. What is the role of nitrogen in the riparian area and stream water?
6. How does a riparian area filter sediments out of runoff from non point source erosion?
7. What do we know about "filter strips" in riparian areas?
8. What water temperatures are important to salmon, and when are water temperatures critical for their survival?

Within each topic, hundreds of published articles (and possibly thousands in some categories) are available in professional scientific journals, government documents, reports, and University extension bulletins. This literature review was conducted using six criteria found in Washington Administrative Code, Growth Management. Act (WAC 365-195-905).

These criteria provided guidance to determine what is "best available science". The criteria are a close representation of the criteria used during manuscript review at professional journals. Reviewed articles that did not include each of the criteria were excluded from this literature list.

1. Peer review. The information has been critically reviewed by other persons who are qualified scientific experts in that scientific discipline. The criticism of the peer reviewers has been addressed by the proponents of the information. Publication in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.
2. Methods. The methods that were used to obtain the information are clearly stated and able to be replicated. The methods are standardized in the pertinent scientific discipline or, if not, the methods have been appropriately peer-reviewed to assure their reliability and validity.

3. Logical conclusions and reasonable inferences. The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.

4. Quantitative analysis. The data have been analyzed using appropriate statistical or quantitative methods.

5. Context. The information is placed in proper context. The assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.

6. References. The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.

Statistics and Science

Snedecor, G.W. and William Cochran. 1967. Statistical methods. Iowa State University Press. Ames, IA.

This text is a standard reference for researchers in designing and analyzing data collected on projects. The theories of math are used to provide an objective result in determining when numbers are different due to patterns occurring within a population that are not due to chance.

Steel, R.G. and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill. New York, NY.

This text is a standard reference for researchers in designing and analyzing data collected on projects. The theories of math are used to provide an objective result in determining when numbers are different due to patterns occurring within a population that are not due to chance.

Romesburg, H.C. 1981. Wildlife science: gaining reliable knowledge. J. Wildl. Manage. 45(2):293-313.

Two scientific methods called induction and retrodution form the basis for almost all wildlife research. Induction is used to establish reliable associations among sets of facts, whereas retrodution is used to establish research hypotheses about the fact-giving processes driving nature. A 3rd method, the hypothetico-deductive (H-D) is a means for testing research hypotheses for gauging their reliability. The H-D method is rarely used in wildlife science. Instead research hypotheses are proposed, and either made into a law through verbal repetition or lose favor and are forgotten.

Knowledge, the set of ideas that agree or are consistent with the facts of nature, is discovered through the application of scientific methods. There is no single all purpose scientific method; instead there are several, each suited to a different purpose. When the set of methods is incomplete, or when one method is used for the purpose better fit by another, or when a given method is applied without paying strict attention the control of extraneous influences, then these errors of misuse cause knowledge to become unreliable.

Unreliable knowledge is the set of false ideas that are mistaken for knowledge. If we let unreliable knowledge in then others accepting these false laws, will build new knowledge on a false foundation. At some point an overload will occur, then a crash, then a retracting to the set of knowledge that existed in the past before the drift toward unreliability started. Every field that loses quality control over its primary product must undergo this kind of tracing if it is to survive. Of course, some unreliable knowledge inevitably creeps in – a researcher makes a systematic error here, or fails to do enough replications there. All science is prone to human error, and minor retracing continually occurs. Part of wildlife science's knowledge bank has become grossly unreliable owing to the misuse of scientific methods, and major retracing is inevitable.

Consider the question of how salmon find their way upstream to their home spawning grounds. The answer, "salmon navigate by vision alone," is a research hypothesis (H), a conjecture about a process of navigation. A test consequence (C) is a "a group of salmon that has been captured and blinded as they begin their upstream migration and will not reach their home tributary spawning grounds in numbers greater than expected by chance, whereas a non blinded control group of equal size that was spawned in the same tributary as the blinded fish will return to their tributary in numbers greater than expected by chance." The fact of the test consequence must then be obtained by experiment, e.g. tagging smolts before their migration to the lake or ocean, recapture of those returning to spawn, and subsequent recapture of blinded and control-group salmon after they have swum upstream.

The more certain a researcher is that the background conditions are indeed true, the more certain he will be in announcing H to be confirmed when C is true, and H to be falsified when C is false.

Hurlbert, Stuart H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs*. Ecological Society of America. 54(2).

Pseudoreplication is defined as the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent. In ANOVA terminology, it is the testing for treatment effects with an error term inappropriate to the hypothesis being consider. Scrutiny of 176 experimental studies published between 1960 and the present revealed that pseudoreplication occurred in 27% of them, or 48% of all such studies that applied inferential statistics.

Some specific actions to take to combat pseudoreplication and related errors are provided as guidance for editors.

Insist that the physical layout of an experiment either be presented in a diagram or be described so that the reader can sketch a diagram for himself.

Determine from the above if the experiment involves true replication and interspersion of treatments.

Question and pass judgment as to the likelihood that the procedures for assigning treatments to experimental units may have introduced bias or generated spurious treatment effects.

Insist that the statistical analysis applied be described in detail. Insist on disclaimers and explicit mention of the weaknesses of the experimental design. Be liberal in accepting good papers that refrain from musing inferential statistics when these cannot validly be applied. Many papers, both descriptive and experimental, fall in this category.

It is often easier to get a paper published if one uses erroneous statistical analysis than if one uses no statistical analysis at all.

On science and planning, discussion is presented separating the science domain and the planning exercise as different kinds of decision-making. Man's imperative to plan is so strong that planning routinely goes on even when scientific knowledge is totally absent from the planner's images. Science on the other hand uses relatively absolute and tight tolerances for deciding which theories and hypotheses should be called law. Planning does not use tolerances for deciding what is the best plan, but instead defines "best" as relative to the set of alternative images.

Computer simulation modeling as a science is discussed also. The model is a hypothesized process and its predictions of the state variables are the test consequences. Modelers call the process of comparing predicted and observed test consequences "verification" or "validation" and a valid model is one whose predictions are within a designated tolerance.

The model is an informed guess, a mixture of knowledge and error about a process of nature. Models are often tuned or calibrated, a process in which some of the model parameters are "fiddled with" to force better agreement between predicted and observed consequences (also Innis 1978, Savia and Roberston 1979). This serves as feedback for what is called model validation which is not the modeler's ability to hypothesize but rather his ability to fiddle.

Modeling was never intended to function as a means to scientific knowledge. Its use in science is limited because it usually cannot predict to within established tolerances. Wildlife science must try the H-D method. Without an ability to detect errors in pronouncement of laws, the self-correcting feature science must have, is lacking. All learning takes place in a feedback system in which ideas and reality interplay. The H-D method is such a feedback system. Uncouple them and the ability to learn, to tell error from truth is hindered, if not destroyed.

Wilson Jr., E. Bright. 1990. An introduction to scientific research. Dover Inc. Mineola, NY.

From a practical standpoint this book is intended to assist scientists in planning and carrying out research. Mathematical treatments have been kept as elementary as possible to make the book accessible to a broad range of scientists. Its principles and rules can be absorbed by most in the physical sciences. The topics include research design, execution of experiments, analysis of experimental data, errors of measurements, and discussions of probability and randomness as well as logic.

Anderson, David R., Kenneth P. Burnham, William R. Gould, and Steve Cherry. 2001.

Concerns about finding effects that are actually spurious. Wildlife Society Bulletin. 29(1):311-316.

during the course of data analysis one must be concerned about 1) failing to detect real effects that are present in the data and 2) finding effects that seem supported by the data but are actually spurious. The paper deals with the latter issue and outlines 5 scenarios in which the probability of finding spurious effects is high. It provides some guidelines to avoid finding and reporting effects that are spurious. It is unfortunate that there seem to be rewards but no penalties for finding and reporting on results that have a high probability of being spurious. the conclusions are that there is a need for more theory to guide empirical studies and warns against analysis strategies that are especially prone to elicit spurious results.

Smith, E., Y. Keying, C. Hughes and L. Shabman. 2001. Statistical assessment of violations of

water quality standards under section 303(d) of the clean water act. Environmental science and Technology 35:606-612.

State testimony indicates that 25% of TMDL will cost \$50,000.00 to \$200,000.00, 65% will cost \$300,000.00 to \$400,000.00 and 10% will run \$600,000.00 to \$1,000,000.00.

Failure to properly identify impaired streams (ie false positive) will result in not only unwarranted planning costs but also the cost of forgone benefits to society.

The challenge is that decisions must be made from limited data, samples are affected by variability in human activity and natural or background conditions, errors in analysis, and accepted tolerances for violations.

Guidelines require a water to be listed only if more than 10% of the samples violate the standard.

Provides discussion of hypothesis testing.

Discussion section provides an interesting example of the cost of a false positive listing for ecoli – should read for discussion ideas if do ecoli on elk creek.

The raw score approach (EPA) yields an unusually high false positive error rate regardless of sample size.

Gibbons, R. 2003. A statistical approach for performing water quality impairment assessments. JAWRA 39:841-849.

Guidelines and rules for water quality assessments lack statistically sound procedures.

Water body classification (violation/no violation) is typically defined as a percentage of exceedances of a numeric water quality criterion (ie no more than 10% of samples can exceed the standard).

The problem with this approach is that the violation decision is based on the observed percentage in the raw data not a true population estimate derived through statistics.

Reliance on a raw data percentage means that the confidence of the classification (violation/no violation) is directly a function of the number of samples. The regulatory guidelines set some sampling requirements as low as 10 samples over a 3-year period.

The fewer the samples the greater the uncertainty in the accuracy of the regulatory classification and the lower the relationship between what is actually present in the water body (true population) and regulatory decisions. For example, a high concentration of a pollutant should be of greater concern and importance than a low level of pollution.

Many regulatory applications involve testing hypotheses regarding the probability that pollution concentrations (within the true population) exceed a regulatory standard. This does not mean a simply an observed measurement or percentage of measurements (see USEPA 1989, 1992; unpublished Unified Guidance document: Statistical Analysis of ground water monitoring Data at RCRA facilities, 2002)

‘A simple tally of the observed percentage of exceedances, based on an arbitrary number of

available samples, does not test this hypothesis! Such an approach provides us with no information regarding the confidence with which a percentage of the true concentration distribution fails to meet a regulatory standard, nor does it provide a sound basis for making impairment determinations.'

River Systems

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology Books. Pagosa Springs, CO.

A companion field book for Rosgen, D. and L. Silvey. 1998.

Rosgen, D. and L. Silvey. 1998 Field Guide for stream classification. Wildland Hydrology Books. Pagosa Springs, CO.

A discussion of prediction--a key to prevention, traditions, natural stability concepts and efforts to improve the river. Emphasis is made to learn from observation of the river response to treatments and understand what caused the problem, how the river responded, determine consequences and ultimately determine how to remedy the problem and prevent the problem from recurring. Control reaches must be used when changes are being made because not all streams respond the same to a given set of imposed changes. "One size fits all" management scenarios are not appropriate for river systems.

It is imperative that management and research intensify their efforts to put research principles into practice. Mathematical relations exist to illustrate a stratification of river systems by unique morphological forms, that provide meaning to an otherwise random appearing, complex set of interrelated variable. Ignoring the rules of the river can cause diverse channel adjustments and damage to property and life.

Rarely do we see rivers with the same set of morphological characteristics. We should not impose common forms and practices to meet site specific objectives. Fish habitat enhancement projects that attempt to change the sequence of pools must recognize that riffle/pool sequences rarely occur in nature at 50-50 or at spacing of convenience. The nature, type, sequence, and function of riffle/pool features are well known among fluvial geomorphologists and they need to be consulted if biologists and others working with the river are unfamiliar with these determinations.

LWD (large woody debris) reintroduction using chainsaws to return debris to the stream must consider how many, how high and in what sequence the woody debris is needed in each stream. Aiming at a "desired future condition" leaves confusion between ecological potential and a natural stable channel form to be achieved. It is critical that prescribed fisheries habitat improvement guidelines such as desired width/depth ratios; riffle/pool and step/pool sequences; and debris spacing be established as functions of slope and stream width. These can be mathematically described for specific morphological stream types.

Leopold, Luna B., M.G. Wolman, J.P. Miller. 1964. Fluvial Processes in Geomorphology. Dover Pub. Inc. New York.

Leopold et al (1964) provides discussions of fluvial processes describes scouring caused by debris in a stream varying by levels of discharge. Debris load is a factor sometimes overlooked in

assessing the scour and fill mechanics. In some cases scour occurs with immediate fill taking place rather than continued transport downstream.

Leopold et al provide basic river morphological principles including water and sediment in channels, fluid force and its relation to debris movement, and hydraulic characteristics. Bankfull discharge in many rivers is one that occurs about every 1.5 years. Leopold et al includes the geologic time involved in all these processes. A flood plain is a depositional feature of a river valley associated with a particular climate or hydrologic regimen of the drainage basin. Sediment is stored and averaged over years and alterations of the conditions of equilibrium through tectonic changes or by changes in the hydrologic regimen results in an alteration of the flood plain to degradation and terrace formation or aggradation. These processes are a result of stream power and forces over geologic time and are not processes that are manipulated on any broad scale through current activities.

Calame, E., G. Holden (compiled). 1981. Hydrometeorological data bank: water year 1978-79. USDA Forest Service. Umatilla National Forest Region 6.

Monitoring of the Umatilla River Barometer Watershed and its sub-basins started 1965.

The objective was to provide a representative instrumented watershed in the Blue Mountains to aid in providing needed information to protect and improve soil water and dependent resources. The harvesting and fuel treatments, erosion control, precipitation and runoff data are presented for the area during the 1978-79 water year. Water temperature, water quality data, sediment loads, and flow data are included for the Mill Creek and High Ridge watersheds. A number of research projects were conducted in this watershed to address grazing impacts and forest management techniques while monitoring of the watershed took place. This paper is fundamental as a basic inventory of the watershed and its environment.

SUMMARY OF WATER SCIENCE AND THE PHYSICAL LAWS

What is temperature and what is heat?

What governs water temperatures in watersheds?

The water science literature reviewed for this document was selected from papers on the topic of water. Many of the papers reviewed discussed streams and stream water heating, but data was absent in the paper that supported the discussions. Some of the popular papers cited in recent government and state agency documents have been excluded if they failed to meet the criteria outlined earlier. Some manuscripts describe mechanistic models without field verification, other speculate about stream heating processes but fail to provide data and analysis to validate discussions. Many contained assumptions about stream water conditions and fail to test the hypothesis using statistical methods. Many papers assumed a cause and effect that shade would cool water, but failed to provide data supporting the theory.

Some papers relied on citations of works that examined fish (salmon, steelhead, trout etc.) physiological responses to warm or cool water in laboratory experiments while reporting results of ocular observations of riparian components on a stream. These papers failed to provide a logical link between the riparian plant community function, the water column heating process, and the fish survival at the study site. Many supplied thermometer records that displayed water temperatures greater than laboratory results cited in other literature, and assumed the temperatures were caused by direct solar radiation on the stream surface. Thermometers record the amount of energy in a

system when the temperature is read. They do not also report what caused the change in temperature. Temperature changes captured by the instruments can only be interpreted as a change in energy and the cause of the change requires other instruments as well as other physical law applications.

This review includes manuscripts that examine the characteristics of water, the physical laws that govern heat, provide onsite applications of the laws, or are basic research describing the physical laws themselves.

The chronological sequence of the publications is provided to put in that context work by one scientist is supported in work conducted by other scientists at a later date. The process of science is not one conducted by an individual, isolated from other work or other studies. The products are the evolution of manuscripts by many scientists that provide a systematic arrangement of our knowledge of the physical or material world.

We know from Physic textbooks that the heat theory described in the Physics literature is the theory that applies to everything in the Universe. Dr. Richard Feynman, a Nobel prize winner delivered a series of lectures at California Institute of Technology that revolutionized the teaching of physics around the world. The lectures are cited as **Feynman, R.P., R. B. Leighton, and M. Sands. 1963.**

Dr. Feynman in one of his lectures on heat, describes the “thermal ratchet” which is a classic description for Physics students during their courses about the Laws of Thermodynamics. Halliday and Resnick as well as Wheeler and Kirkpatrick are basic Physic college textbooks that provide a clear description of these laws and how they apply to our everyday lives.

In 1999 von Baeyer explained the history of the heat theory and how it interacts with other Laws of Physics. The history of heat began with the Greeks who perceived heat as being something that was measured by a human’s response after touching an item that was hot or cold. From there it was examined by many scientists for hundreds of years. Following the history it becomes clear that the scientific principles that govern the Universe have been founded through the work of many and no one individual can be credited for work without recognition that they benefited from discoveries of their predecessors.

The history of the search to understand heat and energy is a chapter in the history of science. The Laws of Thermodynamics were written in the mid 1800s, have been tested through experimentation time and time again always to be confirmed. Faucheux et al (1995) constructed an optical thermal ratchet along the same design as Feynman used to explain to students at Cal Tech. This experiment describes “thermal” noise in the data that previously had not been accounted for but had been estimated. The Laws of Thermodynamics were again confirmed as proper theory and no adjustments to the theory were made.

In natural resource management the issue of stream water heating during the summertime has become a contentious issue between different fish biologists, range and forest managers, landowners, government, and anyone involved in the problem of salmon population declines since the Endangered Species Act listings of the early 1990’s. It has been established in some federal and state regulations that in order to protect fish and other aquatic life, stream water temperatures throughout entire watersheds need to be cooled. The prescription being offered as a way to cool stream waters has been to increase shade over the streams to prevent solar radiation from striking the stream surface directly. Literature citations supporting the concepts are numerous but most fail to meet the criteria described above (see Introduction) to be considered “best available science” for the topic.

Edinger et al. (1968) indicated that the rate of heat exchange is a function of the difference between actual water temperature and an equilibrium temperature at which the net rate of heat exchange would be zero. Cluis (1972) modeled water temperatures from ambient air temperatures rather than using the "heat budget" technique which examines the water in a static environment and make inaccurate predictions for natural streams. Walker et al (1976) described a method to determine water temperatures using the site topographic altitude and ambient air temperatures. Recognition that the natural thermal cycle could be described with these two variables is a proper application of the Thermodynamic Laws.

Bohren (1987) describes heating and cooling events through atmospheric science and gives many examples of "optical" illusions people experience in their lives, and erroneously believe what they see or feel by failing to examine the processes properly. Bohren's work was published for a broad audience and the author explains the fundamentals of solar radiation and how it affects Earth in everyday terms. Coupled with the college Physics textbooks mentioned above, radiation, wavelengths, the importance of following how different wavelengths are absorbed and reflected, and how energy is dispersed on Earth can be established according to the principles of science.

McRae (1994) et al, Larson et al (1996), and Stoneman et al (1996) examine the science of water heating and cooling in watersheds as it occurs in streams and rivers using air temperatures as an influence on the stream water temperature increases and decreases. McRae et al found beaver ponds were responsible for increasing stream water temperatures. Stoneman et al (1996) found streams heated differently as they moved downhill. Larson et al (1996) described the Laws of Thermodynamics and how the law influences the rate of heating and cooling of water. Larson et al (1997) applied physical laws to streams at different elevations to explain the differences between stream temperatures at different locations.

From 1963 to 1996 the Laws of Physics are applied to descriptions of stream water heating and cooling by addressing air temperatures and elevation gradients. The reviewed and selected literature focus on the science of heat when applied to stream temperatures as a natural response of increasing or decreasing due to the physical laws. Each work confirms the findings of previous authors and ultimately are applications of physical law in a watershed. These studies are especially important to natural resource managers as they pursue the issue of stream water temperature increases.

Larson et al (1997) described how to assess water temperatures on streams to identify the natural rates expected in a watershed using air temperature and topographic elevation and stream velocity. Larson et al (2001) provided a mathematical methodology to statistically validate differences between rates of heating and cooling on streams at different topographic locations using the Thermodynamic thermal gradients.

Many of the mythical and factual concepts about heating and cooling are well explained in Bohren (1998) through atmospheric science and the application of the Thermodynamic Laws. Atmospheric science must apply the same laws as other science disciplines to describe air and land thermal cycles as well as water heating and cooling.

Mohseni (1999) provides regression equations that describe the association between air temperature and stream water and equilibrium principles in a stream system. Meays (2001) and Meays et al. (2004) provided an examination of streams in a watershed and how the mean air, water, and soils responded to the adiabatic heating and cooling at each 500 foot drop in elevation.

Zwieniecki et al (1999) studied forested areas that had been clear-cut or thinned and compared

stream segments through the project areas to determine differences and if the forest practices had influenced the stream temperatures. They did not find differences due to forest harvesting treatments.

Larson et al (2001) measured and analyzed data collected in 4 different watersheds in Northeastern Oregon and compared the rates of heating and cooling by examining the data through a gradient analysis between air and water temperature data collected at different elevations. A mathematical methodology is provided for land managers to determine the natural rate of heating and cooling in order to assess the value of revegetation projects intended to cool stream water.

Larson et al (2002) describe the use of FLIR (forward looking infrared) systems currently used in the Pacific Northwest to determine stream heating. FLIR (infrared) photos cannot determine the temperature of a stream and the technology has been misrepresented as a tool to determine the influence of shade across stream channels. The article presents an application of known processes that describe how a stream cools due to the influence of the air mass. Shade, whether viewed on an infrared photo or measured with a thermometer, did not influence the stream temperature.

Statements throughout cited literature during the 1990s published by fish biologists and natural resource disciplines have produced speculative statements such as: streams are warmer today than in historical times, livestock grazing and forest harvesting have reduced riparian vegetation which has caused stream temperatures to increase, and major reasons for fine sediment loading and temperature increases as well as fish habitat declines are due to agriculture development, forest harvesting and road development.

Of particular interest in addressing the question of what governs water temperatures in watersheds is how water temperatures increase or decrease. It cannot be assumed that stream temperatures are currently greater than or less than any other year without approaching a study designed to test the water temperatures. Many studies investigate fish habitat, population densities, or the availability of food within the habitat and either assumed at the onset or speculated at the conclusion that their results were being influenced by human activities and a lack of shade.

These kinds of statements and papers are well described by Romesburg, 1981. What Romesburg noted continues to be a prevalent problem today regarding water temperature literature in the wildlife sciences that describe the decline of fishery habitat and their populations.

No studies were located that in fact measured water temperatures and then linked the study to the salmon population studies. Fish biology and water temperature science are not the same. Fish physiology must be studied and interpreted from the position of how a fish survives through adaptive techniques. A fish body heats internally, they live in a cool water environment, and the questions about water temperature harm to fish is not necessarily a factor human activity can correct outside of obvious point source discharges.

Stream temperatures are best studied from a position that water in a stream is governed by physical laws. The specific heat of water governs how long it takes water to heat and cool and that time is controlled by the thermal gradient that establishes around the body of water within the watershed. Water cannot be assumed to be heating too much or little based on how a fish responds. Stream temperatures cycles are well understood, through the Physics laws. There is nothing about water that is so special or so different from other objects that it responds differently than rocks or trees or paper for that matter when solar radiation is present. The specific heat capacity of each object on earth is what determines the time it takes to increase in temperature and the time it takes to decrease temperatures.

WATER SCIENCE LITERATURE

American Public Health Association, et al. 1971. Standard methods for the examination of water and waste water. American Public Health Association. Washington, D.C. p 874.

This book is a standard handbook used to ensure proper use of methods for water quality testing procedures. Most water quality labs and agencies involved in the work to monitor water quality cite this handbook as their reference for standard testing.

Allen, J. David. 2001. Stream Ecology. Kluwer Academic Publishers. Netherlands. p 23-43.

This book provides some of the basic fundamentals of the physical processes acting on river systems. Chapter 1 and 2 are references for channel flow and stream water chemistry respectively.

Raphael, Jerome M. 1962. Prediction of temperature in rivers and reservoirs. J. of the Power Division, Proceedings of the American Society of Civil Engineers 88:157-181.

Raphael (1962) observed that for most streams in the western United States, water temperatures at their source are nearly at freezing temperature because the flow originates from snow melt at high altitude. As the water moves downstream, whether it flows through a natural channel or through an artificial reservoir, it is affected at its surface by the sun and air mass, which raise the temperature of the water during the summer. Raphael visualized that the greater the temperature difference between air and water, the greater the surface area of the water, and the more slowly it moves, then the greater will be the heating of the water. Raphael's (1962) observations suggest that the thermal environment as well as stream characteristics are important in determining the amount of heating that will occur.

Feynman, R.P., R. B. Leighton, and M. Sands. 1963. The Feynman Lectures on Physics, Volume I. Addison-Wesley Publishing Co. Reading, MA.

Edinger, John E., D.W. Duttweiler, J.C. Geyer. 1968. The response of water temperatures to meteorological conditions. Water Resources Research. 4(3); 1137-1143.

Temperature difference and exposure time influence this process. In the study of water temperature the concept of an equilibrium temperature is used to describe the response of water temperature to meteorological conditions. Edinger et al. (1968) indicated that the rate of heat exchange is a function of the difference between actual water temperature and an equilibrium temperature at which the net rate of heat exchange would be zero. They noted that the equilibrium temperature changes in response to varying meteorological conditions and that water temperature moves continuously toward the equilibrium temperature. Edinger et al. (1968) indicated that a lag time approaching 6 hours can occur between maximum equilibrium temperature and maximum water temperature.

Cluis, Daniel A. 1972. Relationship between stream water temperature and ambient air temperature: a simple auto regressive model for mean daily stream water temperature fluctuations. Nordic Hydrology, 3:65-71.

The water temperature of streams and rivers is required for various practical purposes and is frequently obtained by calculating the heat budget. This method is tedious and yields rather inaccurate values of the water temperature. This paper presents an alternative approach using cheap and simple means to measure air temperatures, which are believed to be a major factor influencing the water temperature. It is demonstrated that a useful separation can be made between the seasonal cyclic variations and the daily stochastic fluctuations of these temperatures.

Walker, J.H. and J.D. Lawson. 1976. Natural stream temperature variations in a catchment. Water Research. Vol 11, pp. 373-377. Pergamon Press 1977. Great Britain.

In order to establish water temperature criteria or limits for reaches of streams downstream from thermal discharges, a knowledge of the natural water temperature is necessary. To overcome the situation where no historical records are available a simple method of predicting natural water temperature in a catchment is presented.

The only data required for computation are the site altitude and the air temperature at a station in the catchment or the natural water temperature in an upstream reach or other tributary in the catchment. The time scale of the predicted water temperature is a function of the frequency of measurement of the independent variables.

Bohren, C.F. 1987. Clouds in a glass of beer. John Wiley and Sons, Inc. New York, NY. Page 81-81

Radiative equilibrium of the earth is described. The planet is bathed in solar radiation and is always bathed as one half of the earth always has sun shining on it. Absorbed radiation gives up its energy to whatever absorbed it, thereby causing its temperature to increase. The earth does not get hotter and hotter because the earth also emits radiation in a spectra distribution different from the incoming solar radiation. Everything emits infrared radiation. If the atmosphere absorbed no infrared radiation the ground would be intolerably cold and so would the air in contact with it.

Halliday, D. and R. Resnick. 1988. Fundamentals of physics. 3rd ed. John Wiley & Sons Inc., New York

Standard college Physics textbook. Chapter 22 covers Entropy and the Second Law of Thermodynamics. The directions in which natural events happen is governed by the second law of thermodynamics. The second law can be expressed in several equivalent forms two of which involve simple statements about heat and work. The Second law--first form states: It is not possible to change heat completely into work, with no other change taking place and the second form states: It is not possible for heat to flow from one body to another body at a higher temperature, with no other change taking place. In a third form in terms of entropy it states: In any thermodynamic process that process from one equilibrium state to another, the entropy of the system + environment either remains unchanged or increases. All three forms are equal.

Many events do not occur even though they would not violate the first law of thermodynamics. The spontaneous flow of heat from a cold to a hot body is an example. The second law of thermodynamics sets up a criterion for identifying such "forbidden" processes.

Kirkpatrick, Larry D., G.F. Wheeler. 1995. Physics a world view. Harcourt Brace College Publishers.

Chapter 9: Thermal Energy. Heat and temperature are not the same thing. Heat is a flow of energy and temperature is a macroscopic property of the object. Two objects can be the same temperature and yet transfer different amounts of energy to a third objects. EXAMPLE: a swimming pool of water and a coffee cup of water at the same temperature can melt very different amounts of ice.

The amount of heat it takes to increase the temperature of 1 gram of any material by 1 °C is known

as the specific heat of the material. This is an intrinsic property of the material and is not dependent on the size or shape of the object made from the material. The specific heat of water is numerically 1. The specific heat of air is 0.24. When two different materials are brought into thermal contact with each other, they reach thermal equilibrium, but do not experience the same changes in temperature because of their different specific heats and masses. The heat lost by the hotter object is equal to the heat gained by the colder object.

The specific heats of the materials on the surface of the earth account for the temperature extremes lagging behind the season changes. The first day of summer in the Northern Hemisphere usually occurs on June 21. On this day the soil receives the largest amount of solar radiation because it is the longest day of the year and the sunlight arrives closest to the vertical. And yet, the hottest days of summer occur several weeks later. It takes time for the ground to warm up because it requires a lot of energy to raise its temperature each degree.

Faucheux, L.P., L.S. Bourdieu, P.D. Kaplan, and A.J. Libchaber. 1995. Optical Thermal Ratchet. *Physical Review Letters*. 74:9: 1504(4)

The authors experimentally demonstrated the principle of a thermal ratchet. They presented an optical realization by directing motion of Brownian particles in water and induced by modulating in time a spatially periodic but asymmetric optical potential. The experimental results agree with a simple theoretical model based on diffusion. Similar models of engines that extract work from random noise have been recently proposed under the denomination of "thermal ratchets" (**Feynman, R.P., R. B. Leighton, and M. Sands. 1963.**) Thermal noise can be a tool rather than a physical limit to the efficiency of motors.

McRae, G. and Clayton J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: implications for brook trout habitat. *Transactions of the American Fisheries Society*. 123-641-656. American Fisheries Society.

Expansion of beaver populations raised concerns of warming water due to the mammal impoundment. Hourly water, air and soil temperatures on four headwater streams occupied by beaver were measured. Stream temperatures followed air temperatures, even near groundwater sources. Removal of beaver dams did not generally reduce the difference between upstream and downstream temperatures. In some cases dam removal increased the warming rate. Direct thermal benefits of dam removal in headwater streams may be outweighed by the potentially disruptive effects on the fish and invertebrate communities downstream.

Larson, L.L. and S.L. Larson. 1996. Riparian shade and stream temperature: a perspective. *Rangelands*, 18(4) 149-152).

The capacity of a stream to buffer against temperature increase is directly influenced by water volume and the size of the surface area that is exposed to the energy source. Overnight low air temperature will modify the daily temperature range of a stream by influencing predawn water temperature.

The specific heat of water allows water to absorb considerable amounts of energy before its temperature will increase. A warmed stream must release significant amounts of energy before cooling can take place. The minimum temperature that water can be cooled will be the lowest temperature in the local environment. It will be difficult to cool a stream in a warm environment

whether the stream is shaded or not. Streamside vegetation can improve bank stability, increase habitat for some species of wildlife, and serve as a component in the system as a whole, but shade does not control stream temperature.

Feynman, R.P. 1996. Six easy pieces. Addison-Wesley Publishing Co. MA. p 64-67.

Dr. Feynman lectures discuss Physics as well as the relationship of Physics to other sciences. He discusses the problem that the analysis of circulating or turbulent fluids, such as water, has not been described satisfactorily using math. He describes the problem in terms of being able to analyze turbulent fluids if water flows very slowly (thick goo like honey) in order for us to describe it. The complexity is enormous. Water running through a pipe cannot be analyzed entirely because of the large number of molecules and their interactions with each other.

Relative to the science of running water, such as a river system, the complexity of the problem is even greater. Modeling efforts to describe a heat budget for stream are weakened due to this problem. Modeling efforts at best use a static lab environment in order to account for a quiet water body reaction to heat input.

Feynman conducted a classic experiment in thermodynamic known as the thermal ratchet problem. Richard Feynman received the Nobel Prize in Physics in 1965 along with Sin-Itaro Tomanaga and Julian Schwinger, for work in quantum electrodynamics. He played a role in the Manhattan Project at Los Alamos during World War II and taught at Cornell and at California Institute of Technology.

Feynman introduced basic new computational techniques and notations into physics, above all the ubiquitous Feynman diagrams that have changed the way in which basic physical processes are conceptualized and calculated. The Feynman Lectures on Physics is the guide for teachers along with his other publications have become classic references for researchers and students.

Richard Feynman was one of the most influential physicist of modern times. The first 7 lectures delivered at Cornell University discuss the Law of Gravitation and the interaction of mathematics and physics. He explores the principles of conservation and symmetry and the irreversibility of time.

Stoneman, C.L. and Michael L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. North American Journal of Fisheries Management 16:128-131.

The relationship between instream water temperature and ambient air temperature at 6 stream sites in southern Ontario was examined. At two sites, maximum summer water temperatures never exceeded 17°C; at two others, temperatures remained below 23°C; and at the remaining two, temperatures reached 28°C. The relationship that best distinguished the three pairs of sites was the regression of water temperature measured at 1600 hours on maximum air temperature. Analysis of covariance indicated that the regression slopes for the first (cold) and second (cool) pairs of sites were non homogeneous; those for the second (cool) and third (warm) pairs were homogeneous, and the adjusted means were significantly different. Where data were available analysis of covariance indicated that the relationship did not differ between years. Graphical analysis of the data indicated little overlap of 95% confidence intervals at air temperatures greater than 25°C. The regression results were used to develop a nomogram to determine the thermal stability of stream sites from a single observation of water temperature at 1600 hours on a warm summer day and a maximum air temperature estimate for the same day.

Larson, L. and P.A. Larson. 1997. The natural heating and cooling of water. Rangelands 19:6-

8.

The ability of woody vegetation to shade a stream for any reason decreases with increasing stream width. Larson and Larson cited basic Physics text and other works addressing thermodynamic principles and demonstrated on a stream at 3000 ft. elevation in northeastern Oregon that water temperature responds to air temperature.

At any point along the stream the gradient between air temperature and water temperature will vary from hour to hour. Maximal heat transfer occurs when the gradient is steepest.

Generally water at higher elevations accumulates energy at a different rate than those at lower elevations. Higher elevations have lower water temperatures at sunrise and greater average gradients during the day. This might suggest that the water temperatures would be higher than a similar body at lower elevations. This is not the case. Water heating at higher elevations is restricted to a short time period. This is due to a rapid thermal cycling of the local environment which results in less energy accumulation. Given this, water temperatures at lower elevations will have a greater increase in temperatures than those at higher elevations.

When all these processes are combined (elevation, rates of heating and cooling, and the difference between air temperature and water temperature) the framework of the thermal environment in which a stream is flowing is described. However, as recognized in the principles of thermodynamics and the examples provided in this paper, modification of one or more of the thermal sources will result in a different rate of heating or cooling.

1. Climates produce weather systems that determine the patterns of heating and cooling within a watershed environment.
2. Water temperatures are influenced by the thermal reservoir that surrounds the water body. Air temperature can be used as an index of that thermal environment. Air and stream temperatures, at a minimum, must be measured at each data collection site to establish the relationship between the stream and its environment.
3. A portion of stream temperature change can be associated with the thermal environment and rates of adiabatic temperature change. The lower elevations not only have warmer water, but they have warmer air temperatures on a daily basis. The adiabatic rates of air mass temperature change is 3.2°F to 5.5°F difference for each 1000 ft. of elevation.
4. The difference between the air temperature and the water temperature influences the rate at which the water will warm or cool. The smaller the differences are between air and water temperature the longer it will take for the water to heat or cool.
5. The rate of flow of a stream must be determined to understand the entire process of how a stream heats and cools. Flow determines how long a body of water is influenced by a particular thermal environment. Downstream air temperatures are warmer than upstream because of lower elevations. Flow rates must be monitored during each sample period, between each monitoring site to establish how long the water is exposed to a thermal environment.
6. Two measurements are required at a minimum to estimate the thermal evolution of a stream: 1) the flow rate and, 2) the gradient between air and water temperature. The rate of flow determines how long the water is exposed to a particular air mass (at a specific temperature). The gradient determines the rate at which heat energy is transferred between the air and water.

Bohren, C.F. 1998. Atmospheric Thermodynamics. Oxford University Press. New York, NY

Page 45 describes temperature scales and thermometers. It discusses the subjectivity of a human's perception of temperature which is not a reliable measure of temperature. Thermometers are based in the Zeroth law of Thermodynamics.

Page 233-237 discusses Henry's Law: air in water. Molecules that strike water from air will be captured by it and retained for at least a brief time before possibly returning to the air. Because of this at the surface of water, their concentration increases above that in the air. This is known as adsorption. Eventually molecules dissolved in water will come into equilibrium with those in the air.

Page 346-347 discusses energy transfer and thermal conductivity in water and gases such as the atmosphere.

Page 381 provides a problem and solution to demonstrate that humans are not reliable thermometers.

Dong, J., J. Chen, K.D. Brosofske and R.J. Naiman. 1998. Modeling air temperature gradients across managed small streams in western Washington. Journal of Environ. Management. 53: 309-321.

J.Dong, et al, 1998 collected air temperatures on 20 buffered stream in western Washington . Five streams were sampled before and after harvesting of the forest. The data were analyzed to examine the effects of harvesting riparian buffer strips. Buffer width was not a significant variable in predicting stream air temperature, suggesting that even a 72 meter buffer was not sufficient to maintain a stream environment due to greater depth of the edge influences. The forest buffers provided minimal protection for stream air temperature during the middle of summer at the stream. Little is known about the degree of protection achieved when buffers are used and the authors state that 70 meter wide buffers do not offer good protection to the stream and efforts to preserve the vegetation are costly because of economic competition for high quality timber. Social assessments are necessary along with ecological assessments to determine the costs of maintaining buffer strips.

Maloney, S.B., A.R. Tiedemann, D.A. Higgins, T.M. Quigley and D.B. Marx. 1999. Influence of stream characteristics and grazing intensity on stream temperatures in eastern Oregon. Gen. Tech. Rep. PNW-GTR-459, Portland, OR :U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 19 p.

Stream temperatures were measured during summer months, 1978-1984, at 23 forested watersheds near John Day, Oregon to determine temperature characteristics and asses effects of three range management strategies of increasing intensity. Maximum temperatures in steams of the 12 watersheds ranged from 12.5 to 27,8 °C. Maximum stream temperatures on four watersheds exceeded 24 °C the recommended short term maximum for rainbow trout. and Chinook salmon. Streams with greater than 75 percent stream shade maintained acceptable stream temperatures for rainbow trout and Chinook salmon. Lowest temperatures were observed in streams from ungrazed watersheds. Although highest temperatures were observed in the most intensely managed watersheds the effect of range management strategy was not definitive. It was confounded by watershed characteristics and about 100 years of grazing use prior to initiation of this study.

Mohseni, O. and H.G. Stefan. 1999. Stream temperature/air temperature relationship: a physical interpretation. Journal of Hydrology 218 (1999) 128-141.

Linear regressions of stream temperature versus air temperature are attractive because they require only one input variable (air temperature) which can be simulated by General Circulation Models. The equilibrium temperature concept introduced by Edinger was used. In stream reaches with large drainage area, stream temperature can be approximated by equilibrium temperature. At elevated air temperature the vapor pressure deficit above a water surface increases drastically causing strong evaporative cooling and hence a flatter stream temperature / air temperature relationship. At low air temperatures, stream temperatures often reach 0°C as an asymptote. If an upstream flow control (dam, reservoir release) or a waste heat input is present, the lower asymptotic value can be larger than 0°C. As a result of these upper and lower constraints for stream temperatures, the stream temperature/air temperature relationship resembles an S-shaped function rather than a straight line.

The authors made a physical interpretation of the relationship between stream and air temperature. They observed a strong association between air and stream temperature and the upper and lower constraints of the relationship tended to form an S-shaped function due to changing factors such as vapor pressure deficit.

von Baeyer, Hans C. 1999. Warmth disperses and time passes: the history of heat. The Modern Library. NY

Today we know that warmth or heat is nothing but motion, a palpable manifestation for the ceaseless, random, chaotic agitation of the invisible atoms and molecules that compose all matter. Temperature, a measure of the intensity of heat, turns out to be related to the speed of those particles - - the faster they jiggle, the hotter they seem to the touch. These insights in turn suggest new more difficult questions. Why doesn't a warm cup ever heat up spontaneously, and come to a rolling boil, while the vast reservoir of motion vested in the air of even a cool kitchen is imperceptibly reduced?

In the middle of the nineteenth century, this question occupied center stage of scientific research. In the language of thermodynamics, the science of heat that was then emerging, the question became: When a hot body is in contact with a cool body, why does heat always flow from hot to cold and never the other way around? Why does heat only flow downhill, which in time led to the theories of universal gravitation and general relativity and today inspires the search for a quantum theory of gravity.

The puzzle of the teacup also affects our lives in a more personal and philosophical way. It turns out that the flow of heat from the tea into the air or from any body into a cooler one for that matter defines the flow of time itself.

In 1995 the Second Law of Thermodynamics was confirmed again in the paper by Faucheaux et al (1995). The Second Law is not in jeopardy. The purpose of the experiment was to demonstrate the fundamental mechanism for detecting thermal noise.

Zwieniecki, M.A. and M. Newton, 1999. Influence of streamside cover and stream features on temperature trends in forested streams of Western Oregon. West. J. Am. For. 14(2) 106-112.

Clear-cut harvesting along low-elevation streams in western Oregon with forest buffers (8.6 to 30.5 m wide) was followed by little direct local effect on water temperature. A study of 14 streams demonstrated that all have a tendency to warm with downstream direction even under full forest cover. After the natural warming trend of the stream water was accounted for, water at slightly higher temperatures within the buffered clear-cut zones cooled to the trend line for temperature by 150 m downstream.

Different levels of buffering were compared and there was no basis for a cumulative effect on temperature from multiple harvest units interspersed with forested stream sections. The warming trend signature occurring within a natural forest cover is a product of the sum radiant energy inputs and exposure to air warmer than water.

Larson, L. and P.A. Larson. 2000. Topographic Classification of stream temperature patterns. SRM. 53rd Annual Meeting.

Discriminant analysis of stream temperature data collected at elevations of 3000 feet to approximately 7000 feet in Northeastern Oregon over a 3 year period indicated that elevations could be used to stratify the data. Elevation was found to be an important factor in determination of the rate of heating and cooling.

Meays, Cynthia L. 2000. Elevation, Thermal Environment, and Stream Temperatures on Headwater Streams in Northeastern Oregon. Master of Science thesis, Oregon State University.

This study showed a strong association between water temperature and atmospheric conditions. Elevation, a factor shown to have a strong association with the thermal environment of this study, represents an indirect measure of vertical atmospheric conditions and its influence on the thermal environment. Similarly, monthly associations represent exposure to annual, monthly, and daily patterns of atmospheric conditions. Stream temperature is a function of the thermal environment to which it is exposed.

Larson, L. and P.A. Larson. 2001. Influence of thermal gradients on the rates of heating and cooling of streams. *Journal of Soil and Water Conservation*. 56:1:38-43

The study addressed the influence of thermal gradients on rates of stream heating and cooling. 4 watersheds in Northeastern Oregon were studied using air temperature as an index of the thermal environment to estimate the rate of stream heating or cooling in different thermal environments. Rates were tested to evaluate a means of quantifying and evaluating rates of water heating through the application of scientific principles. There were no significant differences between rates of heating or cooling at similar elevations between watersheds during any of the study years. Days with similar thermal gradients had similar rates of heating and cooling.

Larson, S.L., L.L. Larson, P.A. Larson. 2002. Perspectives on water flow and the interpretation of FLIR Images. *Journal Rng. Mgmt.* 55 (2): 106-111.

Airborne infrared thermal radiography (infrared photography) has been proposed as a tool which may be used to monitor the water temperature along the network of stream and rivers. The proponents correlate vegetative shadows on a stream channel with the reduced infrared radiation (IR) reception in the data to suggest that the water temperature is reduced in such areas due to the shade on the water surface.

The fundamental principles of thermodynamics are employed and if the stream is in fact flowing, the water affected by any cooling process cannot remain in the vicinity where it was cooled. Second, temperature data taken from a stream channel are used to show that the water flowing in the channel is essentially unaffected by the patterns of vegetative shaded on the surface of the water.

The paper considers the time it takes a body of water to cool, explores how the temperature change should manifest itself in a monitoring system such as FLIR. The effect of the flow rate on water is analyzed to show that the coolest temperatures in the FLIR images should not correspond exactly with the shaded regions when compared to aerial photos. Examples of using the theory are given, data is presented from a partially shaded stream, and speculation is offered as to the cause of the misinterpretation of the FLIR data. A mathematical derivation is also presented.

Larson, P.A. and L.L. Larson. 2003. Landowner monitoring of stream temperature and bottom sediments. *Journal of Soil and Water Conservation*. 58:3:152-157.

A 3-year study was designed to capture the temperature signature and substrate sediments of individual stream segments. The study was conducted with rancher cooperation through the Oregon Cattlemen's Watershed Ecosystem Education and Training (WEST) program. The daily pattern of temperature change (4h periods between 5 am and 5 pm) in both air and water were examined based on elevation and were classified as cold, cool, and warm stream segments. Thermal gradients and heating rates at the study sites were different when compared by elevation. Data compared across elevation showed cold water sites had the greatest temperature changes occurring between 1 and 5 pm and cool and warm water sites changed most between 9 am and 1 pm. Adiabatic stratification of the watershed environment has an influence on the thermal pattern of stream temperature and should be considered when assessing daily maximum water temperatures. Channel substrate measurement of "fines" was between 0.03% and 4% in 2000 and no substrate sediments were found in quantities > 20%. Overall, thermal and sediment pollution were undetected once natural and/or background conditions were established.

Bohren, C.F. 2004. The Freezing of Streams and Ponds: *A Simple—But Uncomfortable—Experiment*. *The Physics Teacher*. 42:12:522-525.

About a year later I opened my copy of the Jan 15-21, 2004 *Guardian Weekly* (U.K.) and came upon the following in Notes and Queries: "In cold weather a pond freezes, presumably when the temperature drops below zero Celsius, while a stream remains liquid. Why?" I immediately responded: "A stream is essentially a drainage ditch that drains the surrounding land, even long after rain has ceased. Stream water originates from under the ground, and hence is insulated by it from cold air. There is always a fresh supply of relatively warm water being fed into a stream, whereas pond water is only slowly or not at all replenished in the depths of winter. At the depth of our well (73 ft) temperatures are high enough even in the coldest winter that the water does not freeze. But this underground water flows through a pipe that emerges from the ground and through an exterior wall of our house, at which juncture it is vulnerable to freezing. One way to prevent this is to leave a tap running very slowly. Turn off the tap, and the still water in the pipe above ground will freeze when the temperature drops sufficiently."

This was duly published in the Feb. 12-18 issue, but as I expected, it was accompanied by two incorrect explanations. A reader in Italy asserted that "water in a moving stream goes downhill and so is lowering its height. The height of an object is associated with potential energy that can be converted into other forms.... The potential energy is converted to kinetic energy, that is, the energy associated with its motion, friction and viscosity eventually convert this form of energy into heat. So as long as the heat generated by the fall in height is at least as great as the heat lost to the surrounding air and earth, the water does not freeze." The other response came from a reader in New Zealand: "Physics teaches us that the world is composed of particles. These particles are constantly active, vibrating against one another. The faster they move, the more heat is produced. Pond water is still whereas water in a stream is always moving, thus the particles rub against one another more quickly, frequently, and vigorously. This causes the water to heat up and explains why a pond would freeze over while a stream remains in a liquid state." These explanations demonstrate

that ignorance of physics is not limited to the United States. In the following sections I present theoretical refutations of these explanations and experimental proof

Meays, Cynthia L., Michael M. Borman, and Larry L. Larson, 2004. Temperatures of Three Headwater Streams in Northeastern Oregon. Northwest Science, 79:4:203:210.

Stream temperature is an important component of water quality for salmon and other organisms. We studied the relationship between water temperature and elevation in three headwater streams in northeastern Oregon. Two streams had very little subsurface addition. One of these watersheds was largely burned over with little vegetation cover. The other was an intact, forested system with substantial vegetation cover. The third watershed was largely intact forest with tributary and subsurface cold-water inputs. Water temperatures were strongly associated with elevation ($P < 0.001$; $R^2 = 0.92$ to 0.99). Averaged across all three streams during July and August 1998 and 1999, mean daily air temperature increased 0.8°C , mean daily soil temperature increased 1.5°C , and mean daily water temperature increased 1.2°C per 150 m drop in elevation, similar to the expected adiabatic lapse rate of 0.9 to 1.5°C per 150 m elevation change. Water temperature diurnal variation increased and mean water and air temperatures trended to convergence with decreasing elevation. Elevation effect was moderated by cool water inputs, discharge, and flow rate, but not vegetation cover. When adjusted for exposure time, all three streams heated at similar rates. Water temperatures should be expected to be higher at lower elevations at approximately the same magnitude as the expected adiabatic lapse rate, with some degree of modification due to discharge, rate of flow (exposure time), and cool water inputs.

Danehy, Robert J., Christopher G. Colson, Kimberly B. Parrette, Steven D. Duke, 2005. Patterns and sources of thermal heterogeneity in small mountain streams within a forested setting. Forest Ecology and Management 208 (2005) 287–302

Spatial thermal patterns and the sources of those patterns were examined in four mountain streams in northeast Oregon and Idaho during hot summer days in 2001. Summer baseflow ranged from <0.007 to 0.22 m³/s. Maximum and minimum temperatures increased in the downstream direction, with the diurnal range decreasing with increasing stream size. Each stream was thermally diverse spatially, diurnally, and seasonally, with unique landform and geologic influences on the daily temperature maxima. Insolation was the most important predictor for maximum temperature at each stream. Minimum daily temperatures were less variable than maxima and followed a seasonal and elevation gradient, with minimum air temperature a more important predictor than either the insolation from the previous day or channel features. Models for each stream using insolation and physical habitat characteristics explain 32 to 67% of maximum temperature and 17 to 51% of minimum temperature variability. Groundwater inputs moderated thermal conditions, particularly local maxima, but did not subsume the predominant temperature range controls of insolation and air temperature.

SUMMARY OF LIVESTOCK AND RIPARIAN COMMUNITY PUBLICATIONS

What do we know about the interaction of livestock with salmon in riparian areas?

What do we know about livestock use of the plant community in a riparian area?

Issues regarding livestock and salmon in riparian areas are generally misrepresented in the current writings by fish biologists and wildlife specialists as well as other natural resource authors. The misquoted and misguided statements about livestock use of riparian vegetation has apparently stemmed from literature reviews that are too narrow in their scoping of the available literature.

To determine if livestock use of riparian areas is harmful to fish, both the fish and the livestock must be studied at the same time. Understanding how livestock use an area is important coupled with identification of whether they are grazing grasslands, sagebrush, forest, or meadow sites. The available best science is ample. Structured science and replicated experimentation have been conducted in the Animal Science profession for many decades. The body of work encompassed through the years establish a firm foundation about the livestock use and misuse of vegetation communities across the country.

Schepers 1982 studied the water chemistry in pastures with and without livestock. The results did not indicate that when chemical composition of water was high that the livestock were a problem, because there were factors such as plant decomposition and wildlife use that contributed to high numbers where cattle weren't present.

Biskie et al 1981 studied fecal coliforms and how they moved in a stream system as flows changed. This study is important to note that the investigators studied fecal coliforms separate from livestock use. The study is focused on a single topic which is relevant in determining how fecal coliforms survive and when they die in a watershed. Many studies associate fecal coliforms with livestock but do not establish whether the coliforms were from the cattle or if they were from wildlife such as deer, beaver, or waterfowl living in the same areas.

Larsen et al 1994 present a study that measured the movement of coliforms across land due to runoff patterns. The analysis of data did not indicate significant differences of bacteria transport in relation to rainfall intensities at distances of less than 1 meter., at 1-37 or 2-13 meters. Any suggestions that speculate that livestock presence adjacent to a stream in fact establishes fecal coliform in water would be in error. Yet, many papers include such statements.

The Larsen et al 1994 paper has not been repeated nor shown to have errors that make it invalid. Based on other research the runoff and fecal coliform in streams have not been found to be a problem across the landscapes. Porath et al 2002 tested for fecal deposits and tracked cattle distance from a riparian meadow stream and documented their use of the area. Grazing activity, fecal deposit distribution, and travel distance of cattle were not found to have a significant affect on the study site. The study indicated that careful management of livestock to ensure uniform distribution throughout grazing areas is a better way of protecting streams and fish than fencing streams or excluding grazing altogether and this is consistent with other studies conducted throughout the last 20-30 years.

Livestock use of grass and shrub browsing is generally misquoted as being a cause of riparian vegetation missing from sites or that livestock have caused damage to riparian plants due to grazing, browsing and trampling. Management of grasslands, shrub communities and forest sites using cattle are well documented and too numerous to list in a single literature review. Silvertown 1993, Shaw 1982, and Heitschmidt and Stuth 1991 are textbooks for reference to establish a foundation of knowledge regarding practices and systems used for livestock management. Assessing the cause of riparian vegetation missing from sites requires an investigation based on site potential analyses that include soil types, rainfall, and plant ecology. Other topics necessary to understand herbivores behavior and eating habits are covered in the citations already mentioned as well as Tiedemann 1987, Smith 1992 & 1993, and Clary 2000 under the topic: River Systems and Riparian Management.

Fisheries studies often claim human activities have caused streams to fail in providing habitat for salmon and trout but they are merely claims. It is not possible from the standpoint of science given the Best available science in the literature using criteria 1-6 (see Introduction), to tie fish

physiological responses in water to all watershed components such as vegetation on the streambank. Many plants have evolved under a grazing/browsing system and respond to use in a beneficial manner. Nutrients and sediments present in a watershed reach the water column through many processes none of which occur in a response to the fish needs, but are chemical and natural events occurring before human activities began. Fish may or may not have physiological responses to different levels of nitrates, phosphates, or sediments. Some adaptations in the fish are due to an ability to adjust to a changing water habitat where they live their entire life. Fish have adaptive physiological responses to varying habitat conditions encountered as they swim up and down river systems and migrate from fresh water to salty ocean conditions.

To determine the impact of human activities or livestock impacts on a stream the scientist must first determine what part of the current stream condition was formed through hundreds or thousands of years of geologic time. They must also account for variability of water volume that under natural climatic events erodes banks and scours stream bottoms. Best available science criteria in this literature review, found no published material where a stream had been measured and data analyzed to be able to qualify as sufficient to make the statements that human activity near streams had caused fish populations to decline. Generally one might observe that within the works of Leopold and Rosgen that the impact from daily human activity is somewhat minimal, simply due to the power of geologic time and the dynamics of water on the formation of river systems. Coupled with the fishery literature selected, the Salmonid species can be seen as a survivor of events most of us were not present to experience while other species of the plant and animal Kingdoms became extinct.

Also important are publications by Leopold 1964, and Rosgen 1996 and 1998. River morphology studies describe a stream's characteristics, through geology and hydrologic responses while applying many of the physical laws that help explain the river systems of the watersheds throughout the world. Leopold and Rosgen are stream specialists who have spent many years studying river systems based on physical laws. Their works are helpful in providing a foundation about the types of mountain and valley terrain where water drains via a river channel and how the river systems can be described using geologic land form as a classification.

Literature, Livestock and Riparian Communities

Dickey, Elbert C., and Dale H. Vanderholm. 1981. Vegetative filter treatment of livestock feedlot runoff. *J. Environ. Qual.* 10:3:279-284.

Four vegetative filters were installed on feedlots in central and northern Illinois. Channelized flow and overland flow configurations were used. Runoff was applied directly to the filters with results reported as influent, effluent, and surface flow. Filters removed as much as 95% of nutrients and oxygen demanding materials from the applied runoff on a weight basis and 80% on a concentration basis. Removal was directly related to flow distance or contact time with the filter. Channelized flow with greater flow depths required greater contact time or flow distance than shallow overland flow to achieve the same level of treatment. Discharge from adequate size vegetation filters occurs only during large runoff events, which coincide with periods of high stream flows. The overall impact of multiple vegetative filter systems on receiving streams appeared to be negligible, but needs to be evaluated in more detail before these can be widely recommended and used. Vegetative filters can provide a satisfactory alternative to zero-discharge systems and result in reduced pollution problems associated with feedlot runoff.

This study provides insight about runoff from an area with 500 confined animals, the use of vegetative filter strips, and the effectiveness as a means of reducing pollution from runoff. Analysis of the data showed no difference in runoff content during periods of runoff due to

rainfall. They found a relationship between the concentrations and the distances developed that provide the overland flow and time for filtration of the discharge. Channelized flow with greater flow depths required greater contact time or flow distance than shallow overland flow to achieve the same level of treatment.

This study uses a "control" plot. The study was conducted over 2 years and plots were replicated. No recommendations were made for size of buffer with trees of any type or height. It is important to understand that while some differences were indicated, the number of bacterial analyses was not large enough to analyze statistically. This suggests no differences were found between the treatment plots and the control plots. The authors stated that additional research is needed to accurately define bacterial quality for agricultural runoff. Other than very large precipitation events or spring high water levels, which were not tested water quality was the same between treatments on 4 feedlots located at 4 different sites.

Schepers, J.S., D.D. Francis. 1982. Chemical water quality of runoff from grazing land in Nebraska: I. Influence of Grazing Livestock. *J. Environ.Qual.* 11(3):351-354.

The chemical quality of runoff water from a 32.5 hectare (81 acres) cow-calf pasture area was determined over a 3 year period. Runoff events from the grazed pasture were separated into those occurring while livestock were grazing and when no livestock were present. Grazing livestock increased by 52% the total solids concentration, but only increased total organic carbon and chemical oxygen demand by 11 and 7% respectively and decreased the nitrogen concentration by 19%.

Concentrations nitrate, ammonia, total phosphate, soluble phosphate, and chlorine were 6, 45, 37, 48 and 78.5% greater, respectively, when livestock were grazing. Runoff from an ungrazed control area within the pasture contained chemical concentrations that ranged from 1.94 and 10.8 times greater than those from an adjacent pasture under ungrazed conditions. These elevated concentrations were attributed to concentrations of wildlife and decomposition of plant material.

Schepers, J.S., D.D. Francis. 1982. Chemical water quality of runoff from grazing land in Nebraska: II. Influence of Grazing Livestock. *J. Environ.Qual.* 11(3):355-358.

The chemical quality of runoff water from a 32.5 hectare (81 acres) cow-calf pasture area was determined over a 3 year period. Precipitation and hydrologic characteristics, stocking rates, and sediment contents in the runoff were used to predict the average concentrations of eight chemical constituents in the water. Predicted concentrations of NH₄-N, total Kjeldahl nitrogen, total phosphorus, total organic carbon, and chemical oxygen demand were directly related to the density of grazing livestock. A combination of one or more hydrologic or rainfall factors significantly improved the prediction. Leachates from the standing plant material, surface litter layer, surface soil, and manure deposits indicated manure and standing plant material were likely sources of most chemical constituents in runoff water. Chloride appeared to be a possible indicator of wildlife or livestock activity.

Tiedemann, A.R., D.A. Higgins, T.M. Ouigley, et al. 1987. Responses of fecal coliform in streamwater to four grazing strategies. *J. Range Management.* 40:322-329.

This study was conducted at the Umatilla River Barometer Watershed. Concentrations of fecal coliform (FC) and fecal streptococcus (FS) were measured weekly during summer 1984 in streamwater of 13 wildland watersheds managed under four range management strategies. The strategies were (A) no grazing; (B) grazing without management for livestock distribution; (C) grazing with management for livestock distribution; and (D) grazing with

management for livestock distribution and with cultural practices to increase forage. Counts were compared to Oregon water quality standards. Data for FS were used for determining the ratio of FC to FS to assess origin of FC organisms. Counts of FC were significantly lower under strategies A and C than under strategy D, but no significant differences were apparent among other strategy comparisons. Two strategy D watersheds violated the Oregon water quality 30-day log₁₀ standard of no more than 200 FC/100 mL; one watershed was in violation for the major part of the sampling period. Ratios of FC to FS indicated that wildlife was the major source of FC bacteria in strategies A, B, and C watersheds. Cattle were the primary source of FC bacteria on strategy D watersheds when combined with the background wildlife contribution.

Biskie, Howard A., Brett A. Sherer, James A. Moore, John C. Buckhouse, and J. Ronald Miner. 1988. Behavior of indicator bacteria in rangeland streams- manure spike experiments. Society of Agriculture Engineers. ASAE. Paper #88-2082.

Cattle grazing on public and private rangelands typically have access to streams as a source of water. The most significant impact of this grazing has been shown to be increased concentrations of indicator organisms of fecal origin (Darling and Cothorp, 1973). The organisms typically measured are fecal coliforms and fecal streptococci. This work documents that when fresh manure enters a rangeland stream under summertime flow conditions, approximately 95% of the indicator organisms settle out of the flow in the first 50 m.

Peak FC and FS could be noted 50 m downstream of a manure slurry injection. The peak arrived at the same time as the plume of a soluble constituent would be expected. Peaks at 100 and 300 m downstream showed a wider distribution. 95% of the FC and FS introduced into a stream did not reach a sampling station 50 m downstream within 20 minutes. Additional settling was noted between 50 and 300 m and between 10 and 300 m. Following the passing of the FC and FS plumes, the bacterial counts returned to near the background levels but generally remained noticeably higher, indicating the continuing resuspension of previously settled microorganisms.

Sherer, Brett M., J. Ronald Miner, James A. Moore, John C. Buckhouse. 1988. Resuspending Organisms from a Rangeland Stream Bottom. ASAE, St. Joseph, Michigan. Transactions of the ASAE. 41:4:1217-1222.

Bacteria from livestock wastes enter streams with run-off and are deposited directly when animals have access to the stream. While the exact fate of all of the organisms is not known, some of the bacteria settle out into the sediment on the stream bottom. This study examined resuspending organisms from the stream bottom. The extent of increases reflects water temperature and recent animal access to streams. Low water temperature may have been responsible for the numbers of viable bacteria that were resuspended in the study. The data suggest that the fecal streptococcus tend to move downstream more freely and survive longer under adverse temperatures than fecal coliforms. Stream velocity appears to play an important role in the equilibrium between the bottom sediments and the overlying water. The magnitude of the resuspension will vary with the intensity of the discharge rate.

Sedgwick, James A., and Fritz L. Knopf. 1991. Prescribed grazing as a secondary impact in a western riparian floodplain. Journal of Range Management 44:4:369-373.

The effect of late-autumn cattle grazing on plant biomass was examined in a western Great Plains cottonwood riparian zone prone to catastrophic flooding every 5-8 years. Five hectare pastures were grazed from 1982-1984 were compared to control pastures within the South Platte River floodplain in northeastern Colorado. At a prescribed grazing level of .46 ha/AUM (1.15 Acre/ AUM), riparian vegetation proved to be resilient to the impacts of grazing. Yearly changes in aboveground

biomass, especially dramatic following a severe flood in 1983, suggest that periodic, catastrophic flooding is a major perturbation to the ecosystem, and in conjunction with our results on grazing impacts, indicate that the dormant season grazing within SCS (Natural Resource Conservation Service) guidelines is comparatively minor impact within the floodplain. Grazing impacts were further mitigated by a major forage supplement of cottonwood leaves which was available at the time of cattle introductions. The local forage supplement ultimately created a lighter grazing treatment than that originally prescribed.

1. Smith, M.A., J.D. Rodgers, J.L. Dodd, O.D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. *J. Range Manage.* 45:385-389.

2. Smith, M.A., J.D. Rodgers, J.L. Dodd, O.D. Skinner. 1993. Habitat selection by cattle along an ephemeral channel. *Rangelands.* 15(3):120122.

Habitat preferences were similar in a small pasture compared to the large allotment. The study emphasized the applicability of small pasture studies versus larger areas of similar vegetation and landforms and the importance of water developments to grazing management. Water location influenced cattle selection of habitats in the large allotment. A slightly greater proportion of cattle selected channel and flood plain habitats near water, and fewer cattle used uplands than in the small seasonal pastures.

Use of the channel where water was present increased in summer and declined in the flood plain. Similar changes did not occur in seasonal pastures. When no water was available at upland reservoirs, cattle reduced selection of uplands from 46% to 14%.

When controlled number of cattle and length of time in the pasture were tested, increased selection of a site did not result in increased utilization in the preferred areas. Limited water distribution in large allotments may influence use of forage closer to water. No season of grazing in this study resulted in more detrimental utilization of channels when water was not limited. Vegetation in or near channels can be best protected by developing water sources in adjacent uplands while monitoring utilization of channel areas.

Larsen, Royce E., J. Ronald Miner, John C. Buckhouse, and James A. Moore. 1994. Water-quality benefits of having cattle manure deposited away from streams. *Bioresource Technology.* 48(1994) 113-118.

A series of runoff and infiltration studies with bovine feces were used to assess effectiveness of vegetative filter strips. Effectiveness was evaluated on the ability of the separation distance to reduce the number of fecal coliform bacteria being transported from the manure to the edge of the plots. 17% of the FC in the manure were present at the edge of the manure pile. The analysis of data did not indicate significant differences of bacteria transport in relation to rainfall intensities at distances of less than 1 meter., at 1-37 meters or 2-13 meters.

Green, Douglas M. and J. Boone Kauffman. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. *Journal of Range Management.* 48:4:307-313.

Comparisons of vegetation dynamics of riparian plant communities under livestock use and exclusions over a 10 year period were quantified in a Northeastern Oregon riparian zone. Livestock grazed from late August until mid September at a rate of 1.3 to 1.8 ha/AUM (3.2-4 acres/ AUM). Ungrazed dry and moist meadow communities had significantly lower species richness and diversity when compared to grazed counterparts. In heavily grazed communities, ruderal and competitive ruderal species were favored by grazing disturbance. In exclosures of the same

communities, competitive or competitive stress tolerant species were favored. Both height and density of woody species were significantly greater in ungrazed gravel bar communities. The results indicate that influences of herbivore on species diversity and evenness varies from 1 community to another and basing management recommendation on 1 component ignores the inherent complexity of riparian ecosystems.

Allen-Diaz, Barbara, R.D. Jackson, J.S. Fehmi. 1998. Detecting channel morphology change in California's hardwood rangeland spring ecosystems. *J.Range Manage.* 51:514-518.

Permanent channel cross-sectional transects perpendicular to flow were used to estimate changes in spring and resultant creek channel morphology. Three cattle grazing treatments (none, light, and moderate) were applied to a 2.5 ha pastures containing a perennial spring and resultant creek cohort for 5 years. Grazing effects on the total change in channel morphology were not detected, nor did our method detect channel morphology change over the 5 year study period. Ungrazed springs and creeks were observed to change more than grazed springs and creeks although these differences were not statistically significant. Observed, but not significant, change over time appears related to rainfall patterns. Permanent channel cross-sections, one of the currently recommended methods for monitoring livestock grazing impacts on stream channels may not be adequate for detecting channel changes in low flow spring/creek systems.

Larsen, R.E., W.C. Krueger, M.R. George, M.R. Barrington, J.C. Buckhouse and D.E. Johnson. 1998 provides a classification for published literature regarding livestock influences on riparian zones and fish habitat. The document uses a similar classification as the one described in criteria 1, 2, 3, 4, 5, and 6 of the Introduction "What is the best science?". They reported that of 2300 stream ecology papers reviewed by the group, only 1/3rd were scientifically based; 2/3rds were the "opinions" of the authors. Many of the opinion articles state that riparian buffers are necessary to shade streams and provide riparian buffers, but the articles do not meet criteria expected for science classification.

The scientifically based articles describe the scientific principles used to determine the best methods of grazing grass and riparian areas for maximum production. The study areas are descriptions of how grazing is used to ensure vigorous growth and production of the grasses and riparian vegetation in order to maintain a plant community as a viable component of the land management opportunities for wildlife and livestock. Fundamentals of "grass species" biology and physiology are incorporated in the articles and prescribe methods of grazing using livestock as a tool to maintain vigorous grass and riparian communities and avoid decadent grass stands and deterioration of winter range for wildlife.

Ballard, T.M. 1999. Interactions of cattle and chinook salmon. M.S. Thesis, OSU, Dept. of Rangeland Resources, Corvallis, OR.

The 2 year study had 3 objectives: determine cattle distribution and behavior within the riparian pasture, determine if cattle disrupt the spawning behavior of salmon by the presence near the redd, and determine the likelihood of a cow coming into direct contact with a redd.

The study took place on a 41 hectare(102 acres) riparian pasture in Eastern Oregon, cattle were stocked at a rate of 0.82 ha/AUM (2 acres/ AUM) with salmon spawning densities of 4.6 redds perimeter in 1996 and 6.1 redds per kilometer in 1997. 2.6 kilometers of stream is in the pasture and 50% of the area had been excluded from cattle since 1978.

Mid August through early September cattle and salmon distribution and behavior were recorded every minute for two out of three four-hour periods per day. 94% of the time, cattle preferred the terrestrial habitats, 5% was observed in the gravel bar habitats, and less than 1% of their time was in direct contact with the aquatic habitat. During observations of active salmon redds, cattle were visible from the redd location an average of 12% of the time. During the period of visibility, cattle spent 96% of the time out of the stream and 84% of the time greater than 3 meters from the redds.

Over the 2 year study period, of 50 cows over 56 days in the pasture a redd was contacted two different times which calculated to be less than 0.01% of the time that contact was made.

When cattle were present during salmon spawning the salmon spent 64% of their time resting in the redd and 26% of their time under cover. Typical behavior found in the literature indicates that salmon in other studies spent 45% of their time resting in the redd and 30% of their time under cover. Salmon carcasses surveyed during both years were 100% spawned which indicated that egg loss from retention due to harassment by cattle was not a problem.

Overall cattle were rarely close to a redd so there was very little opportunity for cattle to interact with salmon or step on redds.

Ballard, Teena M. and William C. Krueger. 2005. Cattle and Salmon I: Cattle Distribution and Behavior in a Northeastern Oregon Riparian Ecosystem. *Rangeland Ecology & Management* 48:3:267–273.

This 2-year study was designed to quantify the influence of terrestrial and stream habitats on cattle distribution and behavior in a riparian pasture with access to active chinook salmon (*Oncorhynchus tshawytscha*) spawning. The active salmon redds accessible to cattle were at a density of 4.6 redds per km in 1996 and 6.1 redds per km in 1997. The stocking rate was maintained at 0.82 ha·AUM⁻¹ for 28 days. Cattle spent approximately 94% of their time in the terrestrial habitats (meadow, disturbance, low shrub, tall shrub, and trees) that supported herbivory-type activities (travel, graze, and rest), the remaining time was spent in stream habitats, which consisted of gravel bar (5%) and in aquatic (<1%) habitats. Cattle spent approximately 88% of their time on nonherbivory-type activities while in the aquatic habitat. Individual cows were observed during the daylight hours for 18 of 28 days each year they were in the pasture and were never observed in direct contact with a redd. Cattle spent over half of their time drinking and <0.01% of their time defecating while they were in the aquatic habitat. Defecation was proportional to time spent in each habitat; so about 2% of the manure was directly deposited in the stream.

Ballard, Teena M. and William C. Krueger. 2005. Cattle and Salmon II: Interactions Between Cattle and Spawning Spring Chinook Salmon (*Oncorhynchus tshawytscha*) in a Northeastern Oregon Riparian Ecosystem. *Rangeland Ecology & Management* 58 : 3 : 274–278

The study addressed the interaction between cattle and spawning spring chinook salmon late in the summer, when it is common for cattle to be present in pastures that have streams where spawning occurs. We addressed the occurrence of spawning in the study area and 2 potential impacts of cattle behavior during chinook salmon spawning: 1) disruption of spawning behavior by the presence of cattle near the redd and 2) the frequency of actual cattle contact with redds. Frequency of salmon redds was not significantly different in the stream reaches accessible to cattle compared with excluded reaches. Salmon continued preexisting patterns of behavior while cattle were within visible range of a redd. Cattle were seldom close to a redd and the chance for direct interaction to occur was minimal. When cattle were visibly near the active redd, cattle remained greater than 3.0 m from the active redd 84% of the time. Of the total time redds were

observed, cattle contacted the redds <0.01% of the time. Previous studies have shown salmon that are harassed during spawning can retain eggs and even go completely unspawned. All salmon fully spawned in the study area in both years of the study.

Clary, Warren P. 1999. Stream channel and vegetation responses to late spring cattle grazing. *J. Range Manage.* 52:218-227.

A 10 year study in central Idaho in response to cattle grazing-salmonid fisheries conflicts. No grazing, light grazing, and medium grazing were tested. Stream channels narrowed, stream width-depth ratios were reduced, and channel bottom embeddedness decreased under all 3 grazing treatments. Many improvements were similar under all 3 treatments indicating these riparian habitats are compatible with light to medium late spring use by cattle. Changes in total herbaceous plant cover did not differ among treatments in the grazed years. The no grazed treatment ended in with a lower total plant cover than the initial reading. Litter tended to decrease in the moderately grazed pastures, gain in the no grazing treatment and change minimally in the light grazing treatment. No single management approach is best for all situations, nor perhaps is even required for a given situation. Grazing strategies employed in this study were designed to stay within the annual tolerance of the site for plant or stream bank/channel impacts each year. Potential changes in other riparian meadow situations will vary depending on past grazing management, streambank substrates, weather, and other factors.

Clary, Warren P. and Wayne C. Leininger. 2000. Stubble height as a tool for management of riparian areas. *J. Range Manage.* 53:562-573.

The effects of residual stubble height in riparian functions have received limited direct experimental examination. Consequently, much of the information is derived from studies indirectly related to the questions raised and to some extent from observations of experienced professionals. The authors identified areas of scientific investigation needed to improve understanding of the effects of stubble height on riparian function and grazing management.

Laliberte, Andrea S., Douglas E. Johnson, Norman R. Harris and Grant M. Casady. 2000. Stream Change Analysis using Remote Sensing and Geographic Information Systems (GIS). *Journal of Range Management.* 54(2) (CD-Electronic Section).

Remote sensing and Geographic Information Systems (GIS) are common tools for time change analysis, however, in most cases satellite imagery or small-scale aerial photography is used. The increased resolution of large-scale aerial photos helps in identifying small features on the ground and is highly useful in the assessment of riparian areas. In this project, large-scale aerial photography from 1979 and 1998, GIS, Global Positioning Systems (GPS) and ground truthing were combined in a time change analysis of an eastern Oregon riparian area. The objectives of this study were: 1) to examine changes in stream morphology over 20 years, 2) to assess if changes were associated with management, topography or other factors, 3) to determine the feasibility of using large-scale aerial photography, GIS and GPS techniques as a tool for assessing change over time.

The 2.5 km long study area, consisting of the stream and riparian area was separated into enclosures and grazed areas in 1978. Aerial photos from 1979 and 1998 (scale of 1:4000) were geo-referenced using 102 ground control points for the 41 ha study site. In addition, older aerial photography and previously collected survey data were available for this study. Stream features, such as islands and stream channel, were digitized using a GIS. Stream length, stream width and

areas of change were identified for both years. The width of the stream was extracted automatically every 0.5 m along the 2.5 km long stream section, yielding 5070 width measurements.

Although stream length remained the same over time, stream width decreased in both grazed and exclosed areas. The area of change (3.65 ha) was slightly larger than the area of no change (3.2 ha). Number of islands and island perimeter decreased, while the island area increased. Exclosures and grazed areas responded similarly, and it was concluded that the topography and stream dynamics had a greater impact than the grazing regime in this study. The use of large-scale aerial photography, GIS and GPS proved to be a powerful tool for detecting change and it is expected that these techniques will become more common in rangeland analysis in the future.

Allen-Diaz, Barbara, R.D. Jackson. 2000. Grazing effects on spring ecosystem vegetation of California's hardwood rangelands.

Three watersheds at University of California's Sierra foothill Research and Extension Center were selected to study cattle grazing effects on the vegetation surrounding cold-water springs and their down slope creeks. Three spring-creek systems from each of 3 watersheds were randomly assigned to grazing treatments (9 total). Treatments were ungrazed, lightly grazed (1500 kg per hectare residual dry matter (1600 lbs/ acre)) and moderately grazed (1000 kg per hectare residual dry matter (1120 lbs/ acre)).

Total herbaceous cover varied significantly among the 6 years only once (greater in 1994 than all others) covarying with the previous years rainfall. With few exceptions stable plant communities persisted on sites regardless of grazing intensity or cover changes. Total herbaceous cover was sensitive to inter annual fluctuations, especially under increased grazing intensities. Cover is a more useful gauge of ecosystem health than plant composition as the latter may not provide evidence of potentially deleterious grazing by climate interactions until after soil erosion or water table characteristics are altered.

Porath, M.L., P.A. Momontt, T.De.Curto, N.R. Rimbey, J.A. Tanaka, M. McInnis. 2002. Offstream water and trace mineral salt as management strategies for improved cattle distribution. J. Anim. Sci. 80: 1-11.

Scientists find cattle and salmonid streams compatible at the OSU Union Experimental Station in Northeastern Oregon. Livestock don't degrade riparian areas if they have other sources of water and trace mineral salt. Three treatments were randomly assigned to one pasture in each of three blocks. Sixty cow/calf pairs were allotted to the grazed pastures. The treatments included stream access and access to off stream water and trace mineral salt, stream access and no access to off stream water or trace mineral salt, and ungrazed control.

Properly managed cattle grazing can be compatible with healthy streams. The study found that livestock can be lured away from stream bottoms in the summer to avoid damage to the streams. Cattle and grazing in those streams may be difficult, by and large riparian areas can be grazed, and if managed properly, healthy streams will be present.

Cattle often prefer to graze away from streams in the early morning hours, then search for water in the late morning and seek shade or graze less intensively through the hot afternoon hours. No off stream cattle began the day further from the stream than cattle without offstream water but consistently moved closer to the stream after the morning grazing period. Cattle also tend to spend summer afternoons in the same areas where they last drank and move away from water sources in the evenings.

Grazing activity, fecal deposit distribution, and travel distance of cattle were not affected by the presence of off stream water and trace-mineral salt.

Livestock with a stream as their only water source were on average 150 feet to 200 feet away from the stream between 3 p.m. and 9 p.m., the researchers found. When tanks or other alternative water sources were available, cattle tended to move 350 feet to 400 feet away from the stream during the same hours. This study quantified what the cattle actually do as they graze, how far they go from the stream and how long they stay away." Luring cattle away from Eastern Oregon streams gets more difficult in late summer. In late summer, forage away from stream bottoms often has been cured by the sun and is less attractive to cattle, while some upland water sources are disappearing.

The presence of cattle, or some cloven-hoof animal, may actually benefit low-elevation bunchgrass country and some other types of terrain. Periodic defoliation by cattle or fire eventually could prove healthy for such areas, although that has not yet been scientifically established. The study is indication that careful management of livestock to ensure uniform distribution throughout grazing areas is a better way of protecting streams and fish than fencing streams or excluding grazing altogether.

Parson, C.T., P.A. Momont, T. DelCurto, and J.L. Sharp. 2002. Effects of season of use on beef cattle distribution patterns and subsequent vegetation use in mountain riparian areas Journal of Range Management. (In Press)

To quantify the effects of season of use on cattle distribution relative to riparian areas fifty-two cow/calf pairs were randomly assigned to two years of 3 replications of treatments: 1) early season (ES) grazing (mid-June-mid-July, and 2) late season LS grazing (mid-August to mid-September). Based on previous years DM production estimates pasture were stocked to achieve 50 percent utilization after 28 days of grazing. Livestock observation points, livestock activities and ambient temperatures were recorded hourly during two 4 day periods in each season of use. Locations were transcribed to a geographical information system for the study area on OSU's Hall Ranch in northeastern Oregon. Cow weight and body condition score (BCS), calf weight, ocular vegetation utilization estimates, forage quality, and fecal deposits within 1 meter of the stream were recorded pre- and post-grazing.

During ES, cattle were further from the stream ($p < .01$) than LS grazing averaging 161.41 and 99.4 m for ES and LS, respectively. Grazing distribution also displayed a diurnal response ($P < .01$) with increasing diurnal response resulting in decreased cattle distance from the stream. Fecal deposits within 1 m of the stream tended ($p = 0.13$) to be greater following LS than ES grazing. Forage quality varied between seasons with ES forage having lower DM, greater CP, lower fiber and greater IVDMD compared with LS forage. Livestock activity (grazing, ruminating or drinking) and grazing times, min/day were not affected by season of use. However forage utilization was influenced by season of use with ES grazing vegetation use as compared to LS grazing ($p < .05$). In summary the grazing season affected cattle distribution relative to the riparian area, with LS having more concentrated use of riparian vegetation.

Morrison, J.A., T. DelCurto, C.T. Parsons, G.D. Pulsipher and E.S. Vanzant. 2002. The influence of cow age on grazing distribution and utilization of mountain riparian areas and adjacent uplands. Journal of Range Management. (In Review)

In a 2 year study sixty cow-calf pairs were stratified by age into the treatments of first calf heifers, and mature cows (5, 6 and 7 years). The research was conducted on the Milk Creek drainage at Oregon State University's Hall Ranch in northeast Oregon from late July to early September. The

analysis of 13,000 cattle location observations during the grazing time revealed a three way interaction between cow age, time of day and grazing bout. Mature cows were farther from the stream during the morning than the first-calf heifers. There were no significant differences between the distances of the first calf heifers and cows from the stream or in the percentage occupying the riparian vegetation type from noon until dark. During the later portion of the grazing bout no significant differences were observed between the distribution of the age classes from the stream or in the percentage of each age class in the riparian vegetation type. Forage utilization and utilization pattern were not different when comparing pastures grazed by the different age classes. Fecal deposits within one meter of the stream did not differ between mature cows and first calf heifer treatments during the entire grazing bout. In summary the mature cows distributed farther from water and spent more time outside the riparian vegetation zones early in the grazing period and during the morning hours as compared to first calf heifers.

Lile, David F., Kenneth W. Tate, Donald L. Lancaster, Betsy M. Karle. 2003. Stubble height standards for Sierra Nevada meadows can be difficult to meet. California Agriculture. 57:2:60-64.

Standards for the height of herbaceous vegetation remaining in meadows at the end of the growing season have been, and continue to be, implemented on public grazing lands throughout the Sierra Nevada. Although supporting research is limited, stubble height standards are intended to benefit riparian resources by limiting grazing pressure. This study illustrates how the timing and intensity of defoliation in mountain meadows can affect the stubble height of herbaceous vegetation at the end of the growing season, and compares these findings with current standards. The research also can help livestock operators and public lands managers develop grazing management strategies to meet stubble height standards and conduct local applied research to evaluate the appropriateness of general stubble height standards.

Parsons, Cory T., Patrick A. Momont, Timothy DelCurto, Michael McInnis, and Marni L. Porath. 2003. Cattle distribution patterns and vegetation use in mountain riparian areas. 56:334-34

To quantify the effects of season of use on beef cattle distribution relative to the riparian area, 52 cow/calf pairs were used to evaluate 1) early summer grazing (mid-June to mid-July), and 2) late summer grazing (mid-August to mid-September) during the summers of 1998 and 1999. Within a block, cow/calf pairs used during early summer were also used during late summer grazing periods. Pastures were stocked to achieve 50% utilization of herbaceous vegetation after a 28-day grazing trial. Livestock location and ambient air temperature were recorded hourly during two, 4-day periods in each season of use. Locations were transcribed to a geographical information system for the study area. Ocular vegetation utilization estimates, forage quality, and fecal deposits within 1-m of the stream were recorded post-grazing. During early summer, cattle were further from the stream ($P < 0.01$) than late summer, averaging 161 and 99-m, respectively. Cows were observed closer ($P < 0.01$) to the stream when ambient air temperatures were higher. Fecal deposits within 1-m of the stream were similar ($P = 0.13$) following early and late summer grazing. Forage quality varied ($P < 0.01$) between seasons, with early summer forages having lower dry matter, greater crude protein, lower fiber, and greater in situ dry matter disappearance compared with late summer forages. Utilization of riparian vegetation was lower and use of upland vegetation greater during early summer than late summer ($P < 0.05$). In summary, season of use affected cattle distribution relative to the riparian area, with late summer pastures having more concentrated use of riparian vegetation.

George, Mel, Royce E. Larsen, Neil K. McDougald, Kenneth W. Tate, John D. Gerlach, Jr., Kenneth O. Fulgham. 2004. Cattle grazing has varying impacts on stream-channel erosion in oak woodlands. California Agriculture. 58:3: 138-143.

We conducted a 5-year study on the impact of grazing on stream-channel bare ground and erosion, and a 3-year study of cattle-trail erosion on intermittent stream channels draining grazed oak-woodland watersheds. While the concentration of cattle along stream banks during the dry season resulted in a significant increase in bare ground, we were unable to detect stream-bank erosion resulting from any of the grazing treatments applied. However, we did find that cattle trails are an important mode of sediment transport into stream channels. While cattle trails are common on grazed rangeland, excessive trailing often indicates that stock watering points are too far apart.

Long, Jonathan W. and Alvin L. Medina. 2006. Consequences of Ignoring Geologic Variation in Evaluating Grazing Impacts. *Rangeland Ecol. Manage.* 59:373-382.

The geologic diversity of landforms in the Southwest complicates efforts to evaluate impacts of land uses such as livestock grazing. We examined a research study that evaluated relationships between trout biomass and stream habitat in the White Mountains of east-central Arizona. That study interpreted results of stepwise regressions and a nonparametric test of “grazed and ungrazed meadow reaches” as evidence that livestock grazing was the most important factor to consider in the recovery of the Apache trout (*Oncorhynchus apache* Miller). That study had assumed that geologic variation was insignificant in the study area. However, lithologic and topographic differences between the felsic slopes of Mount Baldy and adjacent mafic plateaus influence many attributes of trout habitat. We tested the robustness of the earlier study by using its dataset and its method of stepwise regression, but with the addition of a variable representing geologic variation. The results suggested that geology was a highly significant predictor of trout biomass ($P < 0.0001$), whereas bank damage by ungulates was not a useful predictor of residual variation in trout biomass after accounting for geology ($r^2 = 0.015$, $P = 0.290$). However, the associations between natural variation and land use impacts in this spatial dataset confound attempts to make inferences concerning effects of livestock grazing upon trout. Despite fundamental problems in the analysis, the results of the earlier study were repeatedly cited in scientific literature and debates about grazing management. To fairly decipher relationships between ecological production and livestock grazing in diverse landscapes requires temporal studies with reliable methodologies and proper controls for landscape variation. Ignoring geologic variation has the potential to mislead conservation policies by inappropriately implicating land use, by undervaluing inherently favorable habitats, and by inflating expectations for inherently less favorable habitats.

Courtois, Danielle R., Barry L. Perryman, and Hussein S. Hussein. 2004. Vegetation Change After 65 Years of Grazing and Grazing Exclusion. *Rangeland Ecology & Management*: 57:6:574–582.

The Nevada Plots enclosure system was constructed in 1937 following passage of the Taylor Grazing Act to assess long-term effects of livestock grazing on Nevada rangelands. A comparison of vegetation characteristics inside and outside enclosures was conducted during 2001 and 2002 at 16 sites. Data analysis was performed with a paired *t-test*. Out of 238 cover and density comparisons between inside and outside enclosures at each site, 34 (14% of total) were different ($P < 0.05$). Generally, where differences occurred, basal and canopy cover were greater inside enclosures and density was greater outside. Shrubs were taller inside enclosures at 3 sites grazed by sheep (*Ovis aries*). Perennial grasses showed no vertical height difference. Aboveground plant biomass production was different at only 1 site. Plant community diversity inside and outside enclosures were equal at 11 of 16 sites. Species richness was similar at all sites and never varied > 4 species at any site. Few changes in

species composition, cover, density, and production inside and outside exclosures have occurred in 65 years, indicating that recovery rates since pre-Taylor Grazing Act conditions were similar under moderate grazing and grazing exclusion on these exclosure sites.

SUMMARY OF NUTRIENTS, SEDIMENTS, AND RIPARIAN PLANT COMMUNITY INTERACTIONS

What is the role of nitrogen in the riparian area and stream water?

How does a riparian area filter sediments out of runoff from non point source erosion?

What do we know about "filter strips" in riparian areas and large woody debris (LWDs)?

An ample amount of literature is available through review of journal publications and can be found on topics that discuss riparian vegetation as being a filter for nutrients, sediments, and a general catchall for harmful elements to fishery habitat.

From a scientific approach a riparian area may or may not play as important a role in directly protecting aquatic habitats for fish as some have implied. Best available science doesn't make links that connect the nitrogen cycle or nitrogen sources to sediment deposits in streams and then to fish survival. Such concepts are foreign in the science disciplines that have the task of studying each process.

Nitrogen forms found in a riparian area such as nitrates are not harmful to the fish itself as far as the health of a fish is concerned. Sediments in a stream are only a concern in streams if they are a particularly small size and somehow able to drop out of the water column due to very low velocities of the water which allows the smallest particles be deposited into a fish egg nest called a redd. These "fines" would be a concern for fish egg survival if there were enough "fines" that the eggs became smothered.

Due to the lack of careful examination of the known facts about riparian area interactions within a watershed, a distorted picture of cause and effect was found in much of the available literature. For studies to determine all of the interactions that many speculate about, the authors Snedecor et al 1963, Hurlbert 1987, and Romsberg 1981 lay out the steps necessary to make the links if it is possible. To date, most nutrient/salmon survival studies have not been conducted in a manner to allow a factual linkage and do not meet the criteria for "best available science".

Listed below are studies reviewed and selected as "best available science" on the topics of sediment and runoff and plant communities. Eight studies were added that specifically studied the nitrogen cycle in near-stream plant communities. These studies did not speculate on how fish survive due to land conditions, because aquatic life survival is a topic unrelated to these processes. Fishery studies were not located that demonstrate fish populations are physically and directly affected by the presence of nitrates, sediments, and runoff from uplands into riparian areas. There are opinions about such cause and effects, but studies to document the links did not show up as "best available science" when using the 6 criteria provided in the Introduction.

Several textbooks have been listed as important in reviewing literature about plant communities if a person is not familiar with the science discipline of plant ecology. Also, in order to understand the process of nutrients and sediments, basics must be established about the interaction of the nutrients, soils, and plants on a site by accounting for specific variables that change with place and

time.

The Fundamentals of Science Theory for Land and Plant Community Management

Schimper, A. F. W. 1903. Plant Geography upon a Physiological Basis. Clarendon Press, Oxford.

Schimper's First Law states: The type of flora (species), insofar as it depends on existing factors, is determined primarily by heat.

Schimper's Second Law states: The local distribution of plants and of plant communities is determined chiefly by the nature of the soil, either directly, or in its relation to other factors.

Schimper's Third Law: The type of vegetation (life-form) in the tropical and temperate zones is determined by the amount and seasonal distribution of the rainfall and by the humidity of the air.

USDA Natural Resource Conservation Service. 1986. Major Land Resource Areas.

USDA Natural Resource Conservation Service. 1989 Soil Survey of (County name) County

USDA Soil Survey, 1989 and 1986 are records of investigations identifying soil series and land resource areas conducted by Soil scientists and compiled over many years. WAC 365-195-905 criteria 1, 2, 3,4, 5, and 6 are the basis for the report and make the report a reliable source of site specific knowledge. The USDA Soil Survey, 1989 creates a clear picture of where soils are present that can support vegetation and are the major function of sediment deposition.

There are soil surveys available for nearly every major county area in the country. They are considered standard reference books for research, land planning, and construction purposes. They are recognized as a valuable resource by the professional soil scientists.

Anderson, E.W., M. M. Borman, and W.C. Krueger. 1998. Ecological provinces of Oregon. SR 990. Oregon Agriculture Experiment Station. Corvallis, OR. (Book)

Zones of Oregon classified by geologic formation and plant communities. The Coastal Zone extends through Oregon into Washington to the North and into California to the South.

Nutrient Cycles & Nitrate Cycles

Burford, J.R. and J.M Bremner. 1975. Relationships between the denitrification capacities of soils and total, water-soluble and readily decomposable soil organic matter. Soil Biol. Biochem. &: 389-394.

The relationships between the denitrification capacities of 17 surface soils and the amounts of total organic carbon, mineralizable carbon, and water-soluble organic carbon in the soils were investigated. The soils used differed markedly in pH, texture, and organic matter content. Denitrification capacity was assessed by determining the N evolved as N₂ and N₂O on anaerobic incubation of nitrate treated soil at 20°C (68 °F) for 7 days. Mineralizable carbon was assessed by determining the C (carbon) evolved as CO₂ on aerobic incubation of soil at the same temperature for the same time period.

The work indicates that denitrification in soils under anaerobic conditions is controlled largely by the supply of readily decomposable organic matter and that analysis of soils for mineralizable carbon or water soluble organic carbon provides a good index of their capacity for denitrification of nitrate.

Overcash, S. C. Bingham, P. W. Westerman. 1981. Predicting Runoff Pollutant Reduction in Buffer Zones Adjacent to Land Treatment Sites. American Society Of Agricultural Engineers. Transactions of the ASAE-1981

Overcash et al provides an example of how to assess the BMP for watersheds regarding the need for riparian buffers. This study presented the hydraulic continuity equation which takes into account runoff discharge per area, time, depth of flow, distance through the buffer and rainfall above the saturation of soil types. It becomes obvious that filter strips are not designed for entire systems as cure all for pollution capture. Factors between soil textures suggest that soil infiltration is an important consideration. Major influences on buffer length (rather than prescribed width) and performance are: dilution, infiltration, and pollution potential of the waste area.

Bormann, B.T. and D.S. DeBell. 1981. Nitrogen content and other soil properties related to age of red alder stands. Soil.Sci.Soc. Am. J. 45: 428-432.

In 1981 Bormann et al found soil characteristics beneath alder stands differed markedly from those beneath adjacent Douglas fir stands. They studied stands with tree ages of 5-41 years growing on the same soil type in the same general area. Soil nitrogen content had accumulated a nearly constant rate of about 35 Kg/ ha/ year in the soil measured beneath alder stands (0- 20 cm depth)

They noted that after an apparently rapid buildup in the first decade, forest floor N (nitrogen) increased from 10 to 40 years old at a rate of 15 Kg/ha/year Other mineral soil characteristics beneath the alder stands differed markedly from those beneath adjacent Douglas-fir stands. organic matter content was 20% higher, pH and bulk density were much lower. The study found mixed stands offered opportunities for Douglas fir growth and that soil nitrogen regressed over stand age indicated an accumulation of N at a nearly constant rate in mineral soil.

Alder can fix appreciable amounts of N on wide range of sites varying from poorly productive to productive soils with high N content sampled in this study. Understanding the effects of alder-derived N and other changes in soil properties on site productivity will help determine the extent of future alder use. Economic feasibility of mixed and rotational cultures of alder in Douglas-fir managed forests needs further work in light of increasing energy costs. Addition of N fertilizers derived from fossil fuels is part of the economic feasibility considerations.

Bormann, B.T and J.C. Gordon. 1984. Stand density effects in young red alder plantations: Productivity, photosynthate partitioning, and nitrogen fixation. Ecology. 65(2) 394-402.

Red alder (*Alnus rubra*) is sometimes considered for use in intensive forest management in the Pacific Northwest primarily because of its rapid growth and ability to fix atmospheric nitrogen.

Red alder has rapid juvenile growth with characteristics which are ideal for maximum fiber yield. Annual biomass production in 8-10 year old, naturally established stands can reach 29 Mg/ha. Growth characteristics had not been fully analyzed, and little is known about alder production in managed natural stands or plantations.

Red alder forms a symbiosis in which N₂ can be fixed. From previous studies it appeared that a

great deal of energy was sacrificed for the process. Much is yet unclear about the processes involved.

Red alder spacing trials were established to estimate aboveground and below ground biomass and aboveground productivity and structural characteristics. Branch and bole measurements were made. Nodules and roots were also sampled.

Bormann et al evaluated the effects of stand density on nitrogen fixation and canopy characteristics in a 5 year old red alder plantation. Stand and average tree dimensions were strongly affected by stand density. Average tree values for dbh, wood volume, branch surface area, and number of growth sites were greatest in trees growing in the open stands. Similar values for crown volume and live crown ratio were also greatest in open stands. Intermediate stands had the highest branch surface area and canopy volume per unit area. Tree height ($p=0.41$), crown shape intercept and slope, and leaf density were little affected by stand density.

The maximum aboveground net production was midrange compared with cool temperate zone estimates. Compared to the natural 8-10 year old alder stands measured in British Columbia the estimate on this study appeared low. The Oregon site may have been medium to poor for alder or from a seedling stock not adapted to the site. Freeze rings, aphids and black leaf mold were abundant during the growing season also stand age or methods may have accounted for some of the lower productivity estimates.

Low density stands had the highest mass, volume, and surface area components as well as nitrogen fixation. High density stands had the highest wood volume and above ground dry mass. The lack of correlation between leaf mass and nitrogen fixation per unit area suggested that high density stands allocated less photosynthate to the nodules for nitrogen fixation. These findings suggest that dense stands comprised of 85% older trees of 24" DBH which cannot mitigate nutrient uptake.

Intermediate to wide spacing on a relative basis, maintained over a complete alder rotation will apparently result in near maximum cumulative fixation of atmospheric nitrogen and the most economic wood production (near maximum bole volume growth on the fewest stems).

Lowrance, R., R. Todd, L.E. Asmussen. 1984. Nutrient cycling in an agricultural watershed: I. Phreatic movement. *J. Environ. Qual.* 13(1): 22-27.

Runoff from agricultural fields in southeastern Coastal Plain is carried to a stream channel system in a shallow phreatic aquifer. The subsurface runoff often passes through a band of riparian forest before becoming streamflow. It is hypothesized that the riparian ecosystem acts as a nutrient sink and reduces the concentrations and loads of nutrients in the shallow aquifer before the nutrients reach the stream channel. The total water volume moving off the watershed at the study site in subsurface flow was less than 1% of the streamflow with corresponding small amounts of nutrients. Nitrate nitrogen, calcium and magnesium had significantly higher concentrations in field wells than in forest or streamside wells.

In 1979 thirty-seven wells were located along nine transects extending from the field/forest or field/pasture interface to the stream. 500 ml samples were taken after rainfall events or at least each 2 weeks between events. Darcy's equation was used to estimate water movement in the phreatic zone.

The soils of the Atlantic and Gulf Coastal Plan are generally sandy and have high infiltration rates. The study area at Tifton Georgia in the Tipton Upland has permeable surface horizon underlain by

a zone less permeable (0.9 to 1.5 meters below) where incident precipitation infiltrates and moves laterally as phreatic flow. The flow then enters the alluvial zones near the stream and eventually moves to the stream channels of the Tifton Upland which generally are bordered by a layer of mixed hardwood riparian forest. Water and nutrients from upland fields must flow through the forest as either subsurface or surface flow.

As shown in schematic representation of the units, Well 1 was located at the top of the unit just below a field with an agriculture crop, Well 2 was below a field, and Well 3 was located below the hardwood riparian at the interface with the stream channel.

Each season of 3 months long beginning with January in season 1 was tested. Streamflow nitrate nitrogen was generally highest in season 1 and lowest in season 3, but streamside wells showed little change between seasons. Decreases in nitrate nitrogen and SO₄-S during the summer months could have been due to increased microbial activity reducing more sulfate and nitrate to gaseous forms.

Nutrient loads and water volumes transported off the watershed in subsurface flow were small compared with volumes and loads transported in streamflow. Total water volume was only 0.07% of the streamflow volume. Total phosphorus, calcium, magnesium, potassium and sulfates as well as chlorine were all less than 0.075 of the streamflow load, indicating that they were relatively less concentrate in subsurface than in the streamflow. Organic nitrogen, nitrate, total nitrogen were all relatively more concentrated in subsurface flow than streamflow. In general, subsurface discharge through the watershed boundary carried negligible quantities of nutrients due to the small volume of water movement.

The riparian forest zone acted as a filter for nitrates, calcium, magnesium, potassium and sulfates. Nitrogen was transformed from inorganic to organic forms in the bottomland forest. Almost all water and nutrient movement from the watershed was in streamflow with subsurface discharge off the watershed accounting for less than 1% of the streamflow.

Lowrance, R., R. Todd, L.E. Asmussen. 1984. Nutrient cycling in an agricultural watershed: II. Streamflow and artificial drainage. J. Environ. Qual. 13(1): 27-32.

Runoff from agricultural fields in southeastern Coastal Plain is carried to a stream channel system in a shallow phreatic aquifer. The objective of this study was to examine seasonal variations of nutrients in streamflow and to quantify the effects of artificial drainage effluent on streamflow nutrients on an agricultural watershed.

Loads per hectare of organic N were lower from the drained fields, but loads of other elements were lower from the mixed cover watershed. In-stream and riparian zone processes apparently converted inorganic N to organic forms and removed N through denitrification. Annual streamflow N load was about 29% of the precipitation input of 12.2 Kg per hectare per year. Sediment associated N and P (phosphorous) loads in streamflow were 0.35 and 0.9 kg per hectare per year, respectively accounting for 9.0 and 8.5% of total N and P, respectively.

The two highest flow events for the year carried 19% of the total annual flow and 19% of the annual sediment load, but had 30 and 27% of the total annual sediment N and P loads. This indicated that part of the sediment load moved directly from upland areas.

Lowrance, Richard, Robert Todd, Joseph Fail, Jr., Ole Hendrickson, JR., Ralph Leonard, Loris Asmussen. 1984 Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience. 34:374-377.

Riparian vegetation may help control transport of sediments and chemicals to stream channels. Studies of a coastal plain agricultural watershed showed that riparian forest ecosystems are excellent nutrient sinks and buffer the nutrient discharge from surrounding agroecosystems. Nutrient uptake and removal by soil and vegetation in the riparian forest ecosystem prevented outputs from agricultural uplands from reaching the stream channel. The riparian ecosystem can apparently serve as both a short - and long-term nutrient filter and sink if trees are harvested periodically to ensure a net uptake of nutrients. Proper streamside forest management requires both periodic harvest of trees to maintain nutrient uptake and minimum disturbance of soil and drainage conditions.

Sexstone, A.I., T.B. Parkin, and J.M. Tiedje. 1985. Temporal response of soil denitrification rates to rainfall and irrigation. *Soil Sci. Soc. Am. J.*, 49:99-103.

The response of soil denitrification to increased soil moisture was compared in a non-aggregated sandy loam soil and an aggregated clay loam soil using a soil core technique and lab procedures. Elevated field denitrification rates were observed on 9 of 11 occasions on three sites following irrigation or rainfall of greater than 1 cm. Sandy loam soil increased immediately after water addition and reached a maximum rate within 3-5 hours and returned to pre-irrigation levels within 12 hours. Clay loam soil required 8-12 hours before a maximum rate was observed and 48 hours before the original background rate was restored.

Nitrogen losses from the clay loam soil were double that of the sandy loam although the sandy loam received almost twice the water input. The difference was apparently due to the longer duration of the enhanced denitrification rate in the clay loam soil following the increase in the soil moisture.

The study confirmed that significant denitrification losses can occur in bursts in response to rainfall, and illustrated that sampling schemes based on integration of denitrification rate measurements must include these episodes to obtain meaningful estimates of N loss. Denitrification response to rainfall was not always the cause suggesting that nitrate or carbon may also limit nitrogen loss.

Groffman, P.M., E.A. Axelrod, J.L. Lemunyon and W.M. Sullivan. 1991. Denitrification in grass and forest vegetated filter strips. *J. Environ. Qual.* 20:671-674.

Denitrification was measured in two grass and two forest vegetated filter strips (VFS) in Rhode Island. Grass plots were established on well drained soil and were planted to tall fescue or reed canarygrass. One forest site was on an excessively well drained soil and was dominated by oak, and the other was a poorly drained soil and was dominated by red maple.

Denitrification was measured using soil cores under aerobic and anaerobic conditions with a range of treatments: no amendment, acetylene, water, nitrate, and nitrate plus carbon.

Unamended rates of denitrification were low in all plots. Nitrates and NO₃ plus C amended rates were consistently higher in the grass plots than in the forest plots. Nitrate plus carbon amended rates were higher than NO₃ amended rates in all plots, but the differences were significant in the forest plots only. Denitrification enzyme activity was measured in 14 addition forest sites of varying natural drainage classes and was related to soil moisture at these sites. The results suggest that the ability of VFS to support denitrification varies strongly with vegetation, soil type and pH, and that denitrification of VFS may be amenable to management.

Groffman, P.M., A.J. Gold and R.C. Simmons. 1992. Nitrate dynamics in riparian forests: microbial studies. *J. Environ Qual.* 21: 666-671.

Measurements were made from groundwater during growing and dormant seasons (reported in a companion study Lowrance et al (1984)) at two sites on stratified glacial drift and a third site on unstratified glacial drift to study nitrate removal from uplands due to uncertainty about the mechanisms of nitrate removal in these areas.

Poorly and very poorly drained soils had higher denitrification enzyme activity (DEA) than upland-wetland transition zones (moderately drained to somewhat poorly drained) surface soils. Microbial biomass C(carbon) and N (nitrogen) content were more variable but showed the same general pattern. Levels of denitrification enzyme activity were consistently low or undetectable at the band below the seasonal high water table. Surface soil DEA and microbial biomass were correlated with nitrate removal from groundwater reducing the growing season. Low levels of DEA and microbial biomass in the subsurface suggested that plant uptake was the dominant groundwater nitrate sink during the growing season. In the dormant seasons the water table levels were higher and groundwater nitrate was able to interact with the near surface soil and be removed by denitrification and/or microbial immobilization. The potential net denitrification was very low at most sites. The transition zone soils with a densely developed upland, which had high rates of nitrate production, suggested that the long term buffering potential of the site was limited.

The study took place on 3 sites using 4 soil types based on drainage classes of being moderately well drained, somewhat poorly drained, poorly drained and very poorly drained soil. The denitrification was higher in wetland portions of the riparian zone than in upland-wetland portions of the zone likely due to the presence of anaerobic conditions and higher levels of organic carbon in the wetland. Denitrification enzyme activity has been shown to be highly correlated with annual rates of denitrification in north temperate forest soils and is useful for site comparison studies. Microbial biomass and activity were also high in wetland areas relative to the transition zone due to favorable moisture conditions and high levels of organic C in the wetlands. The denitrification enzyme activity and microbial biomass and activity data measured suggests that wetlands have a greater potential for microbial nitrate attenuation than transition zones of uplands.

The high correlation during the growing season though does not prove that denitrification or microbial immobilization were responsible for the removal. The low level of the parameters in the subsurface may reflect interactions with the dominant nitrate sink, plant uptake. Soil DEA does not provide information on the actual rate of denitrification occurring at any point in time. A lack of detectable DEA is a strong indicator that denitrification is NOT occurring. The data indicates that there is significant spatial and temporal variations.

A major question when evaluating the water quality maintenance value of riparian zones relates to long term effectiveness. If a site receives high levels of subsurface nitrate inputs for many years, the ability of the site to attenuate nitrate may increase or decrease over time. It is possible that plant and microbial sinks can become saturated with nitrogen. Groundwater nutrient inputs have been shown to stimulate both plant and microbial populations increasing their potential to act as sink.

One site in the study may have been an N-rich site susceptible to nitrate losses. The symptom of N enrichment was marked in the transition zone soils at the out wash site with a developed upland. The high nitrification rates may be indicative that a long-term buffering potential if the site is limited.

Lowrance, R. 1992. Groundwater nitrate and denitrification in a Coastal Plain riparian forest. *J. Environ. Qual.* 21:401-405.

Mechanisms of nitrate (NO₃) removal from groundwater in riparian forests are poorly understood. This study was conducted in the Georgia coastal plain to : (i) determine changes in NO₃ and CL concentrations within shallow groundwater moving from a row-crop field to a stream; (ii) determine the spatial and temporal distribution of denitrification potential relative to changes in NO₃ concentrations; and (iii) determine whether NO₃ or C supply was limiting denitrification potential. Nitrate and CL concentrations in groundwater were measured biweekly or monthly for October 1988 through May 1990. Denitrification potentials, indicated by the denitrification enzyme assay, were measured bimonthly from October 1988 through October 1989.

Denitrification potential was more than two orders of magnitude higher in the top 10 cm of soil than in the top 19 cm of the shallow aquifer. Denitrification potential was consistently highest in surface soil nearest the field and nearest the stream and was limited by NO₃ availability in all surface soil samples. Denitrification potential was highest in October and August. Although NO₃ is definitely being removed from shallow groundwater, it is apparently not due to direct denitrification from the saturated zone. High denitrification potential in surface soils, especially near the field/forest interface, may contribute to NO₃ disappearance from shallow groundwater. Processes associated with intact riparian vegetation appear to play the primary role in N removal.

Lowrance, R., G. Vellidis, and R.K. Hubbard. 1995. Denitrification in a restored riparian forest wetland. *J. Environ. Qual.* 24:808-815.

Groundwater nitrate moving from upland areas toward streams can be removed by denitrification in mature riparian forests, but denitrification in restored riparian forests has not been quantified. We determined denitrification rates in a restored riparian wetland below a liquid mature application site. A riparian forest buffer consisting of hardwoods along the stream and pines above the hardwoods was established according to USDA specification. Denitrification was measured monthly using the acetylene inhibition technique on intact soil cores for 2 mo before mature application began and for 24 mo after mature application. Groundwater movement of nitrate nitrogen and total Kjeldahl N were estimated biweekly. Average annual denitrification rate was 68 kg N₂O-N ha/yr. Denitrification was significantly higher in a grassed area than in either of the forest areas. Denitrification did not differ significantly between the hardwood and pine areas. Denitrification was greater than a conservative estimate of groundwater input of total N. Denitrification rates were higher in April and May 1992 and 1993, after manure application to the upland began, compared with April and May 1991, before manure application began. These results indicate that riparian wetland, which has not undergone hydrologic modifications can have denitrification rates comparable to mature riparian forests. High denitrification rates in and adjacent grassed wetland and lack of difference in denitrification in hardwood and pine zones indicates that the high denitrification rates were due to factors other than the reforestation itself. Compared with groundwater inputs of N, denitrification was an important sink for N moving from the upland management system.

Lowrance R., G. Vellidis, R.D. Wauchope, P. Gay, and D.D. Bosch. 1997. Herbicide transport in a managed riparian forest buffer system. *Trans. ASAE* 40:1047-1057.

The effect of a riparian forest buffer system (RFBS) on transport of two herbicides, atrazine and alachlor, was studied during 1992-94. Herbicides were applied to an upland corn crop in March of each year. The buffer system was managed based on USDA recommendations and averaged 50m in width. The system included a grass buffer strip immediately adjacent to the field (Zone 3); a managed pin forest downslope from the grass buffer (Zone 2); and a narrow hardwood forest

containing the stream channel system (Zone1). After the first year of the study, the managed forest was clear cut to 1/3 and thinned in 1/2 of Zone 2. The other 1/3 of Zone 2 was left as a mature forest. Most of the herbicide transport in surface runoff occurred before 30 June with about 25 cm of cumulative rainfall after herbicide application. During this period of higher herbicide transport, atrazine and alachlor concentrations averaging 34.1 ug/Liter and 9.1 ug per liter at the field edge, respectively were reduced to 1 ug per liter or less as runoff neared the stream. There were generally no differences among the mature forest and the two treatment areas (clear cut and thinned) for either concentration or load in surface runoff. Using precipitation data collected on site, the effects of dilution versus other concentration reduction factors (infiltration, adsorption) was estimated for surface runoff. Concentration reduction was greatest per meter of flow length in grass buffer adjacent to the field. There was only minor transport of herbicides through the buffer system in shallow groundwater and little difference between the Zone 2 treatment areas. IN 1992 and 1993, herbicide concentrations in shallow groundwater in the RFBS and at the edge of field were generally at or below detection limits. IN 1994 well concentrations of both herbicides increased, probably in response to infiltration of surface runoff containing high herbicide concentrations. Average herbicide concentrations were at or below detection limits in groundwater near the stream for most of 1994.

Bosch, D.D., R.K. Hubbard, L.T. West, and R.R. Lowrance. 1994. Subsurface flow patterns in a riparian buffer system. Trans. ASAE 37:1783-1790.

Matric potential was measured in a grass and forest riparian buffer system adjacent to a cropped field in the Georgia Coastal Plain. The soil in the adjacent cropped field is a Tifton loamy sand, containing an argillic subsurface horizon with plinthite at approximately 1 m which has been shown to restrict vertical infiltration and induce lateral flow. Two years of matric potential data and measurements of soil hydraulic characteristics were examined to evaluate and quantify unsaturated water flow in the riparian buffer. The lowest soil matric potential occurred at the grass/forest interface and the greatest surface infiltration occurred within 10 m downslope of the same interface. The area of low matric potential was likely due to water uptake by trees. Water flowed laterally through the unsaturated soil into the riparian area from the upland field, apparently induced by low vertical conductivity in the subsurface and driven by the high water demand of the forest.

Bosch, D.D., J.M. Sheridan, and R.R. Lowrance. 1996. Hydraulic gradients and flow rates of a shallow coastal plain aquifer in a forested riparian buffer. Trans. ASAE 39:865-871.

Three years of water table measurements and estimates of saturated hydraulic conductivity were used to evaluate and quantify saturated water flow gradients, directions and rates for a hillslope consisting of a tilled upland field and a downslope riparian forest buffer system located in the Gulf-Atlantic coastal Plain Uplands. The gradient of the water table from the top of the landscape to the bottom varied from 0.9 to 9.2% less than the 1.5% land slope. The direction generally followed the land slope. During summer months the hydraulic gradient within the forested buffer reversed direction. Water table data indicate that riparian area was saturated from January through March. During this time, flow direction the shallow aquifer is from the top of the field to the stream bottom. During summer months high rates of forest evapotranspiration created large water sinks in the shallow subsurface and large local hydraulic gradients. Examination of water table elevations indicates that seasonal water demand of the forest shifts the direction of shallow subsurface aquifer flow. During these periods flow direction within the riparian buffer was from the lowest landscape position to the riparian forest, reversed from winter months. Total subsurface flow within the hillslope was calculated as 35 mm per year, 3% of annual precipitation. Average groundwater linear velocity was calculated as 1.4 mm per hour. Evapotranspiration loss was estimated as 67% of average annual precipitation

Groffman, Peter M., G. Howard, A.J. Gold, and W.M. Nelson. 1996. Microbial nitrate processing in shallow groundwater in a riparian forest. *J. Environ. Qual.* 25:1309-1316.

Denitrification, immobilization, and respiration in microcosms that simulated groundwater conditions in a riparian forest were measured in Rhode Island. Rates were compared with rates of nitrate removal measured in a companion study using a groundwater monitoring well network. While there were significant variations in water table levels, dissolved oxygen, dissolved organic carbon and total carbon within the aquifer in the riparian forest, there was little spatial variation in denitrification or respiration rates.

Rates were higher in summer than in winter and were nearly always limited by a lack of organic C (carbon). Measured denitrification rates were much lower than rates of groundwater nitrate removal directly measured in a companion hydrologic study at the same time, suggesting that there is still considerable uncertainty about the mechanism of nitrate removal from groundwater in riparian forests.

Addy, K.L., A.J. Gold, P.M. Groffman and P.A. Jacinthe. 1999. Groundwater nitrate removal in subsoil of forested and mowed riparian buffer zones. *J. Environ. Qual.* 28:962-970.

Two similar riparian sites in Southern New England were examined for ground water nitrate removal in the subsurface of mowed vs forested vegetation. Soil cores were extracted from the study area. Substantial ground water removal and denitrification occurred at all locations. Ground water removal rates were significantly correlated with carbon enriched patches of organic matter.

The correlation of the data supports previous work that patches function as hotspots of microbial activity in the subsoil. Our ability to manage the export of nitrates from coastal watersheds is limited by a lack of understanding of the various processes that retain or remove nitrate in terrestrial landscapes. There is considerable uncertainty regarding the site characteristics that promote substantial ground water nitrate removal in riparian zones and the influence of different types of vegetation cover on groundwater nitrate removal.

Similar patterns of soil morphology and hydrology existed at both sites. The depth to C horizon was greater at Site A than Site B. Both sites had low ambient nitrate concentrations. There was no significant differences in the percent of organic patch material between forested and mowed areas within each site. The percent of organic patch material was different between sites. Patch material ranged from 0.6 to 3.5% carbon where the matrix material ranged from 0.2 to 0.6% carbon. At site A there was no significant difference in the patch carbon between forested and mowed areas. Patch carbon was significantly correlated with ground water nitrate removal rates and denitrification gas production rates. Ground water nitrate removal rates and denitrification gas production rates were not significantly correlated with matrix carbon.

Roots in all soil samples were present. There was no significant difference in root biomass within or between sites. Root biomass was not significantly correlated with patch carbon, ground water nitrate removal rates or denitrification gas production rates.

The study found no significant difference in ground water nitrate removal rates within the subsoil of forested and mowed riparian areas. Second, they found significant differences in ground water nitrate removal rates between the two riparian sites with similar soil texture, drainage class, and morphology. Implications from management of riparian buffer zones for ground water nitrate removal are that lack of vegetation effect may be related to similarities in the subsoil root

composition and biomass throughout each sampling site. Composition and distribution of roots may not directly reflect the above ground vegetation.

The authors caution against ascribing specific ground water nitrate removal rates to different aboveground riparian vegetation types without recognizing the importance of other site differences such as water table dynamics, land use legacy, and adjacent vegetation.

Denitrification was the primary mechanism for ground water nitrate removal in this study. The study supports previous work demonstrating that patches of organic matter function as hotspots of microbial activity in the subsoil. Riparian zones composed of a mix of forested and mowed vegetation, common in agroforestry and suburban land uses, may remove substantial amounts of ground water nitrates. Reconciling this function with the other less robust functions such as sediment trapping and stream habitat maintenance is an ongoing challenge in riparian buffer zone management.

Borman, Michael. 2005. Forest stand dynamics and livestock grazing in historical context. Conservation Biology.

Livestock grazing has been implicated as a cause of unhealthy condition of ponderosa pine forest stands in the western United States. An evaluation of livestock grazing impacts on natural resources requires an understanding of the context in which grazing occurred. Context should include timing of grazing, duration of grazing, intensity of grazing, and species of grazing animal. Historical context, when and under what circumstances grazing occurred is also an important consideration. Many of the dense ponderosa pine forest and less-than-desirable forest health conditions of today originated in the early 1900s. Contributing to that condition was a convergence of fire, climate, and grazing factors that were unique to that time. During that time period, substantially fewer low-intensity ground fires (those that thinned dense stands of younger trees) were the result of reduced fine fuels (grazing), a substantial reduction in fires initiated by Native Americans, and effective fire suppression programs. Today, livestock numbers on public lands are substantially lower than they were during this time and grazing is generally managed. Grazing then and grazing now are not the same.

SEDIMENTS AND RUNOFF

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North Am. J. of Fisheries Management. 4:371-374.

Some state water quality standards established by the states permit minor increases in suspended sediment when background turbidity is low, allow greater absolute increases as background levels rise, and do not consider acclimation of stream biota to high turbidity. Juvenile coho salmon were subjected to experimentally elevated concentrations of suspended sediments and did not avoid moderate turbidity increases when background levels were low but exhibited significant avoidance when turbidity exceeded a threshold that was relatively high (>70 NTU) and was varied according to previous suspended sediment exposure.

Behavior of coho salmon fell into two categories - normal swimming behavior described as rapid darting movements, huddling, and attempting to hide in corners. The behavior response has been termed "fright huddle" by Mason and Chapman (1965). The authors did not know what elicited the fright response when acclimated to turbid water except to speculate that it was related to the sudden transfer into an environment where cover was lacking (the lab test containers). The study found no evidence of a significant preference for slightly turbid water (10-20 NTU) in any of the

experiments, including fish acclimated to 2-15 NTU. In certain stances water having higher turbidity was sought for cover when the fish behavior response was the "fright huddle" position.

The study suggests that release of coho fry during stream stocking activities should not take place when streams are carrying a high load of suspended sediment. Clear or slightly turbid water will allow fish time to adjust and raise their tolerance to periodic turbidity increases during storms.

The authors also concluded that further testing of controlled, sediment-addition studies in natural streams are needed. Suspended sediment levels described in the state standards have been designed to protect both spawning and rearing periods and are intended to minimize impacts on periphyton and invertebrates. This study indicated that moderate turbidity increases over low background levels may not cause avoidance by juvenile coho salmon.

Alonso, Carlos V., Cesar Mendoza. 1992. Near-bed sediment concentration in gravel-bedded streams. Am. Geophysical Union. Paper 92WR00915. 0043-1397/92/92WR-00915. p 2459-2461.

This paper describes an analytical model for the concentration of suspended sediments in the proximity of the bed of gravel rivers. The model is applicable to high-gradient streams carrying sands and finer sediment particles in suspension over poorly sorted gravel beds. The equations were verified using available flume and river data and evaluated their responses for various combinations of bed roughness and suspended load characteristics.

The results indicate the characterization for the near-bed concentration can be formulated in terms of a velocity defect representation for the mean turbulent velocity profile and sediment eddy diffusivity distribution developed for sand bed rivers.

Dabney, S.M., L.D. Meyer, W.C. Harmon, C.V. Alonso, G.R. Foster. 1995. Depositional patterns of sediment trapped by grass hedges. Trans. ASAE. 38(6):1719-1729.

Stiff grass hedges can resist, retard, and disperse concentrated flows of runoff; trap suspended sediment; and reduce ephemeral gully development. Flume experiments were conducted at a 5% grade using four grass species, four types of sediment and eight flow rates ranging from 0.33 to 2.66 m³ / minute - meter. Sediment trapped was initially deposited 1 to 2 meters downslope from a hydraulic jump transition that formed at the upper edge of the backwater. A delta of sediment then grew back toward the hydraulic jump until flow depth became shallow enough that bedload transport was initiated and the delta began to advance toward the grass. A steady state model was developed that under predicted trapping of fine sediment and over predicted trapping of coarse sediment in situations where the delta neared the grass.

The mechanisms of settling and filtration cause sediment to be trapped by grass hedges. although filtration is important in the removal of fine sediment grass hedges have relatively large flow spaces and thus filter only large particles such as fibrous plant residues. Settling is the primary mechanism for trapping sediment by grass hedges and most models of sediment trapping by grass strips consider only settling.

Sheridan, J.M., R. Lowrance, D.B. Bosch. 1999. Management effects on runoff and sediment transport in riparian forest buffers. ASAE. 42(1):53-64.

The project examined the effect of forest management within a Coastal Plain riparian forest buffer system (RFBS) on runoff and sediment transport over a four year period. The buffer conformed with the USDA Forest Service and USDA natural Resource Conservation Service best management

recommendations, included a narrow strip of undisturbed forest located adjacent to the stream drainage system (Zone 1), a wide managed pine forest downslope from the grass filter (Zone 2), and a narrow grass filter strip immediately downslope from an agricultural field (Zone 3).

To evaluate the effects of forest management within the RFBS, 3 management treatments were imposed within the Zone 2 pine forest. Forest treatments were clear-cutting, selective-thinning, and the mature forest as a reference. All merchantable timber was removed in the clear cut. Thinning treatments were conducted leaving a standing biomass removed from all size classes to target basal area of about 25 square meters per hectare. All woody debris greater than 60 mm diameter was removed during the timber harvest and remaining debris was distributed uniformly by hand. Little or no exposed soil remained in either the clear-cut or thinned plots. Zone 1 was not disturbed during the harvest and the mature forest was left uncut as a reference area.

Rainfall tipping buckets and flow samplers were installed. A total of 24 samplers were installed with two devices located at each zonal interface and at the Zone 2 midpoints for each of the management treatment plots.

Reductions in runoff across the RFBS were significant for all three treatment plots (99% level of confidence). There was less runoff measured on the clear-cut and selectively thinned plots than from the mature forest plot. This was consistent with a previous study that observed that rapid regrowth of herbaceous vegetation occurred within the harvested zones (Lowrance et al 1997).

There was no evidence of concentrated flow or scour occurring within the grass filter portion of the RFBS over the four year record even for the highest rainfall year which included a 100 year, 24 hour storm event. Routine maintenance of mowing was performed on the site but no other was required over the study time. Even after harvest of Zone 2 forests, no period of recovery for this buffer system function was evident.

In the forest management treatments, sediment concentrations showed significant differences between years for the two upper landscape sampling positions. There were no differences in sediment at the two lower positions between years. When a cropped field was planted in peanuts during 1996 sediment concentrations entering and leaving the grass filter strip were significantly different than for other years. Despite higher field edge sediment loadings through the lower sites sediment concentrations were not significantly different than the other years. Seasonal trends were seen with reductions in sediment concentrations between wet and dry period. These trends were noted across the landscape for all seasons, and when tested by sampling position the loads were not significantly different between seasons.

Overall the study indicates that implementation of recommended forest harvest practices had little impact on the runoff and sediment load reduction function of the RFBS for the Coastal Plain Zone 2 forests.

Pearce, Robert A., Gary W. Frasier, M.J. Trlica, Wayne C. Leininger, John D. Stednick, and James L. Smith. 1998. Sediment filtration in a montane riparian zone under simulated rainfall. *Journal Range Management*. 51:309-304.

Sediment yields, measured at the outlet of small and large plots, did not decrease, or increase, as vegetation heights increased. Accurate prediction of sediment filtration from shallow flow in riparian zones required consideration of a combination of vegetation and soil surface characteristics.

Frasier, Gary W., M.J. Trlica, W.C. Leininger, R.A. Pearce, and A. Fernald. 1998. Runoff

from simulated rainfall in 2 montane riparian communities. *Journal Range Management*. 51:315-322.

Riparian ecosystems are the final terrestrial zone before runoff water enters a stream. They provide the last opportunity to decrease nonpoint source pollution delivery to streams by removing sediments from overland water flow from uplands and roads. The study found there were lower equilibrium runoff percentages from dry runs in sedge communities compared to the grass community. The differences were less during wet runs. The organic layer on the soil surface exhibited signs of water repellence that reduced the water infiltration rate during the initial stages of rainfall simulation. These results indicated that runoff and infiltration processes in the surface organic horizon of riparian zones may not respond in the classical manner.

Corley, Carin L., Gary W. Frasier, M.J. Trlica, Freeman M. Smith, and E.M. Taylor, Jr. 1998. Technical Note: Nitrogen and phosphorus in runoff from 2 montane riparian communities. *Journal Range Management*. 52:600-605.

A rainfall simulator was used to evaluate 2 montane riparian communities as filters for removing N and P nutrients from sediment laden overland flow water. Communities were composed of Kentucky bluegrass, tufted hairgrass, water sedge, beaked sedge. There were no consistent differences among specific vegetation height treatments or communities in the removal of N and P nutrients.

Weltz, Laura, Gary Frasier, and Mark Weltz. 2000 Hydrologic responses of shortgrass prairie ecosystems. *Journal Range Management*. 53:403-409.

Different prairie sites were evaluated to determine the hydrologic similarity within a single ecosystem at widely separated sites. There were no consistent patterns. Soil types showed differences in time-to-peak of the runoff event. Overall the study indicated that easily estimated factors such as biomass, cover and litter were not good indicators of hydrologic function. It is necessary to identify which portion of the runoff event is most important in the assessment. To estimate infiltration rates as a function of cover, biomass, soil properties and to stratify soils into the functional units are needed to accurately estimate runoff rates.

Mergen, D.E., M.J. Trlica, J.L. Smith, and W.H. Blackburn. 2001. Stratification of variability in runoff and sediment yield based on vegetation characteristics. *Journal of Am. Water Res. Assoc.* 37:3:617-628.

Runoff and sediment yield were collected from 100 plots during simulated rainfalls (100mm/hr for 15 minutes). A clustering technique was used to stratify the variability of a single data set within a sagebrush-grass community into four groups based on vegetation life form and amount of cover. The four groups were grass, grass/shrub, shrub, and forb/grass and were found to significantly differ in plant height, surface roughness, soil bulk density and soil organic matter.

Runoff was found to be significantly less in forb/grass groups compared with the other vegetation cluster groups, but this was influenced by four plots that produced little or no runoff. Sediment yield was not found to be significantly different among any cluster groups. Discriminant analysis identified important variables and developed a model to classify plots into one of four cluster groups

The study was conducted at Sheep Creek in a temperate mountain zone with summer rainfall events recorded at the study site in 1993 and 1994. Two thunderstorms that produced more than 25 mm of precipitation occurred and events that produce more than 25 mm of rainfall are infrequent event

in the study area, they produce runoff and sediment that can enter the creek.

Soil variables such as soil moisture content, soil organic matter, and silt content were found to be somewhat important. Surface cover variables explained 5 to 28% of the variability in sediment yield, whereas soil characteristics explained from 18 to 34% of the variation in sediment yield.

Fuchs, E., M. Wood, T. Jones and B. Racher. 2003. Impact of tracked vehicles on sediment from a desert soil. *J. Range manage.* 56:342-352.

Off-road military vehicle traffic is a major consideration in the management of military lands. The objective of this study was to determine the impacts of military tracked M1A1 heavy combat tank vehicles on sediment loss from runoff, surface plant cover, and surface microtopography in a desert military training environment. A randomized block design was used which had 10 blocks with 4 plots (0.5 m²) in each block. Each block had randomly selected treatments that included an untreated control, 1 pass by a M1A1 tank under wet seasonal conditions, 3 passes by a M1A1 tank under wet seasonal conditions, 1 pass by a M1A1 tank under dry seasonal conditions, and 3 passes by a M1A1 tank under dry seasonal conditions. Data were analyzed using mean separation and stepwise regression techniques. Most sample periods showed that sediment losses from M1A1 tank treatments, single or triple passes under wet or dry seasonal conditions, did not differ statistically from natural sediment losses under nominal rainfall events. However, comparatively intense rainfall events often generated significantly ($P < 0.05$) greater sediment losses from the M1A1 tank triple pass treatments. Triple pass M1A1 tank impacts had detrimental effects that could last many years, particularly when disturbances were imposed under dry seasonal conditions. Seasonal drought for the area, occurring 2 out of 3 years during the study period, may have exacerbated the effects of triple pass M1A1 tank impacts. Analysis showed that grass cover, litter cover, and microtopographic variance were highly and negatively correlated ($R = -0.62$) with cumulative sediment loss. Depending on precipitation availability, a minimum of 3 years for most triple pass M1A1 tank impacts is suggested for suitable vegetation recovery and soil stability. It is recommended that site repetitious M1A1 tank training maneuvers should be conducted with particular attention to site recovery. Furthermore, the influence of climate, drought in particular, should be among the topics addressed by future military training land use models.

Riparian Communities and Large Woody Debris

Williams, Philip B. and Mitchell L. Swanson. 1989. A new approach to flood protection design and riparian management. USDA Forest Service Gen. Tech. Rep. PSW-110.

Maintenance programs to improve flood conveyance and enhance levee stability such as clearing riparian vegetation in channels and on levees undergo little if any technical scrutiny. Such programs are prescriptive rather than based on actual performance standards. A multi objective hydrologic geomorphic and biologic approach is presented to consider factors that influence stream hydraulics. A failure to account for debris indicated that floods can carry large amounts of debris such as uprooted vegetation and trees, fences, and parts of structures. Such items on smaller streams combined with sediment impedes and blocks hydraulic efficiency of small to medium size culverts. Bridges can also be obstructed causing increases in flood elevations upstream. The rise in water surface elevation due to backwater from an obstructed bridge can greatly exceed the reduction in water surface elevation due to stream channelization which can direct the main flood flow out of the channel.

Buer, Koll, Dave Forwalter, Mike Kissel, and Bill Stohler. 1989. The middle Sacramento River: human impacts on physical and ecological processes along a meandering river. USDA

Forest Service Gen. Tech. Rep PSW-110.

The Dept. of Water Resources, monitored changes in the river using old survey maps, aerial photographs and field surveys. Studies indicate that bank protection had significantly reduced a source of salmon spawning gravel from freshly eroded banks and over time decreased the number of preferred spawning areas such as point bar riffles, chute, cutoffs, multiple channel areas, and areas near islands. Bank protection also increases the tendency of the confined river to deepen and narrow, further reducing spawning habitat. Flood control has interrupted the natural equilibrium between erosion and deposition, resulting in reduction in bank erosion rates and in over bank sediment deposition. Solutions to these problems will require a comprehensive river management program that incorporates the natural processes of meandering and bank erosion. The study makes the conclusion that floodplain deposition replaces silt lost by bank erosion. The study helps determine if the system is in balance. Bank erosion is necessary to maintain riparian succession, anadromous fish and wildlife habitat in the reach. Bank protection will have several negative effects since over 85 percent of the gravel provided to a river comes from bank erosion, it will prevent the recruitment of gravel to salmon spawning areas if banks are protected. Although the study was made regarding flood control structures, it has implications about discerning the contribution of natural bank erosion in a healthy, functioning stream system.

Beechie, T. E. Beamer, and L. Wassermann. 1994. Estimating coho salmon rearing Habitat and Smolt Production Losses in a Large River Basin, and Implications for Habitat Restoration. N.Am. J. of Fisheries Management 14:797-811.

Habitat types were identified based on 6 types found during field surveys, topographic maps, and the national Wetlands Inventory maps. The study assumed that a historical perspective was deemed crucial to the identification of attainable and feasible goals in habitat restoration and they assessed loss and degradation of summer and winter rearing habitats for coho salmon throughout the Skagit River basin. The investigators focused specifically on losses of physical rearing habitats and did not address spawning or other issues. They estimated the magnitude of loss habitat areas and coho salmon smolt production from each habitat type and related the magnitude of the habitat loss to broad categories of land ownership and types of impacts. They attempted to also quantify the amounts of summer and rearing habitat available in the basin and to identify critical elements and assumptions of limiting factors analysis for the salmon in the basin.

The Skagit basin has an area of 8,270 sq. km. Small tributaries were defined as streams with average summer wetted widths less than 6m and were classified based on topographic gradients of less than 2% or 2-4%. Side channels were described as branching from the mainstem typically abandoned river channels or overflow channels and further described them based on 90% having pools (sloughs). Channels with greater than 6m were classified as large tributaries. Lakes and ponds were arbitrarily distinguished according to size. Ponds have a surface area less than 5 ha and lakes had a surface area of 5 ha or more.

Quantification of the area of habitat in each of the units as well as rearing density and survival to smoltification was generated based on mapping techniques and appear to have been lifted out of articles published as Reeves et al (1989) as well as personal communication and unpublished data by Beechie and T. Sibley.

While no water temperature data was collected nor was the investigation focused on water temperature issues as stated in the introduction, a discussion of winter water temperatures in the Skagit basin was provided. Speculation was given as to the importance of the winter temperature influences used in the Reeves et al (1989) smolt production model, and presented but offered no identification of where the water temperature numbers were found nor how they were used in the

overall final conclusions.

The authors suggested that their assessment used pool areas above 50 % for the basin as a whole, but that it would be more appropriate to evaluate the entire basin as a set of the interconnected sub basins. The statements were made in the discussion of the assumptions used regarding temperature and pools. It is unclear where this fits into the topic of estimating rearing habitat.

Smolt production estimate was made at a scoop trap nearby in 1990 and 1992. The data were compared to that in Reeves et al (1989) which estimated that slough areas should produce 0.4 smolts/m² to 0.8 during summer and winter respectively. The trap numbers were higher than Reeves et al (1989) (0.4 - 1.31m⁻²) and the authors state they accepted the Reeves et al (1989) estimates. The authors could not fully estimate the losses in habitat or smolt production from the mainstem river areas because coho salmon use of large rivers is not known reliably. However, through citations of various materials the authors selected to use 600 smolts / km to be appropriate for the river basin.

In conclusions the authors stated that the estimated reductions in coho salmon smolt production provide a clear indication of where efforts should be expended for habitat restoration and the largest benefits can be gained by restoring side channel and slough habitats. They suggest that their analysis provides a basis for pursuing restoration of habitats through culvert improvements.

Beechie, T.J., T.H. Sibley. 1997. Relationships between channels characteristics, woody debris, and fish habitat of Northwestern Washington streams. *Trans. Am. Fish. Soc.* 126:217-229.

Regression analysis showed correlation between pool spacing and percent pools in the study area and by a surrogate term suggested that LWD abundance and channel slope influence pool formation changes with channel slope. They also suggest that low slope channels are less sensitive to LWD abundance because pools are formed by mechanisms other than LWD when LWD abundance is low. Streambed particles sizes were also addressed.

Twenty eight sites were located in four major watersheds of the North Cascades and Puget sound. The surveys focused on low gradient (<.04%) stream reaches as the common habitat for anadromous salmonids and were on channel widths less than 20m.

The authors state that the regression equations are only good on the study streams under the study conditions. There is no relationship between the interaction slope, LWD and pool area. The studied opted to use the slope-LWD interaction term as appropriate of the relationship between channel slope and width, LWD abundance and pool area. No relationship was found between gravel and LWD abundance. Problems in data collection using ocular measurements in identifying LWD pieces caused few actual samples to be collected than needed for the study. Also, ocular estimations contain an error for sampling bias. This likely caused the discussions to revolve around "probable" occurrences.

Management implications are discussed as possibilities. The authors state that studies of logging scenarios with decreased LWD abundance and reductions in number and area of pools "may affect" juvenile Salmonid abundance or species age-class distribution. The authors speculate on what they expect and provide an example of a riparian forest thinning "may benefit" larger streams and may take 75 years or more to begin recruiting LWD of pool forming size.

Wallerstein, N.P., C. Alonso, S.J. Bennett, C.R. Throne. 2001. Froude-scaled flume analysis of large woody debris. *Earth Surf Process. Landforms* 26: 1265-1283

This paper presents the results of a movable-boundary, distorted, Froude scaled hydraulic model. The model was used to examine the geomorphic and hydraulic impact of simplified large woody debris (LWD) elements. The channel model had bed and banks molded from 0.8mm sand and flow conditions were just below the threshold of motion so that any sediment transport and channel adjustments were the result of the debris element.

Field investigation in northern Mississippi has shown that streams are actively eroding their channel banks, introducing into the channel large numbers of fallen trees. These trees have been observed to accumulate at specific locations within the streams, thus causing an accumulation of large woody debris (LWD) and LWD jams. Jams generally form around a triggering element such as a large tree and they either grow over time as smaller debris piles up against the jam or become smaller as the jam breaks down through decay and dislodgment of its elements. It is difficult to separate cause and effect when assessing the actual geomorphic impacts of LWD. A flume model offers an excellent opportunity to determine more accurately the hydraulic forces exerted upon LWD elements and the geomorphic effects of LWD.

LWD can affect the direction and magnitude of the stream flow, and it can significantly increase river stage and channel geometry. Yet in an evolving stream system, it is difficult to separate a river's response to LWD from other possible causes such as channel straightening, bank stabilization, and anthropogenic effects. Thus a flume model study was constructed to examine the effects LWD can have on river flow processes. Using Abiaca Creek, Mississippi as the field case, an experimental model was constructed, and simple cylinders were used to simulate trees that have fallen into the creek.

As the debris elements neared the water surface, the drag forces acting on the elements increased dramatically due to the effects of wave formation. The velocity around an element decreased with time as the channel widened and deepened due to flow constriction and diversion, and channel erosion also caused the formation of new sediment accumulations downstream. Alluvial channel response within each experiment was relatively short, and these experimental results agreed well with observations within Abiaca creek. This new knowledge will enable action agencies to develop better tools to assess the impact of LWD accumulations on river flow conveyance and flood risk potential.

The results show that LWD has a distinct geomorphic impact upon highly erodible channels, causing both bed scour and bank erosion and the formation of mid-channel, lateral, alternate bars and pool-riffle formations. This finding highlights the need to differentiate the local impact of LWD formations from geomorphic processes acting at the river-basin scale, such as degradation. It should be noted, however, that extremely large debris rafts can have geomorphological impacts at larger scale than was represented in the model.

Hydraulic modeling can aid in determining cause and effect in the geomorphic evaluation of stream corridors impacted by LWD. The geomorphic results demonstrate that, while debris may be trapped by high points in the channel bed topography, it will also create a distinctive set of geomorphic features regardless of preexisting channel forms if the channel boundary can be eroded. The channel became progressively less disturbed with distance downstream from each element.

George, Mel, Royce E. Larsen, Neil K. McDougald, Kenneth W. Tate, John D. Gerlach, Jr. Kenneth O. Fulgham. 2004. Cattle grazing has varying impacts on stream-channel erosion in oak woodlands. *California Agriculture*. 58:3: 138-143.

We conducted a 5-year study on the impact of grazing on stream-channel bare ground and erosion, and a 3-year study of cattle-trail erosion on intermittent stream channels draining grazed oak-woodland watersheds. While the concentration of cattle along stream banks during the dry season resulted in a significant increase in bare ground, we were unable to detect stream-bank erosion resulting from any of the grazing treatments applied. However, we did find that cattle trails are an important mode of sediment transport into stream channels. While cattle trails are common on grazed rangeland, excessive trailing often indicates that stock watering points are too far apart.

SUMMARY OF FISH BIOLOGY STUDIES

Literature reviews are useful to develop a foundation on specific topics of interest, but do not meet the criteria for "best available science". Reviews often do not include discussion about whether papers include methods, data collections, and the quantitative analysis required for BAS. The reviews present narratives across many topics to support what the authors intend to point out. If follow up isn't made to track and read the cited paper, literature reviews are of little value.

As an example, some of the cited and popular papers of today including literature reviews, regarding fisheries and stream temperature, do not use any criteria for "best available science". Many articles address buffers, how wide they should be, what their composition should be, and what plant species are important in river basins to prevent harm to the fish, using citations and appeals that are merely narratives themselves. The papers are topical or are studies addressing unrelated topics with insertions of a vast array of speculative statements in an attempt to link cause and effect. As an example there are no experimentally designed papers that give recommendations for 50 foot of trees and 25' of grass as a fenced buffer to improve water temperatures for aquatic life. These dimensions as well as most others are meaningless. To design an experiment that would link buffers to fish survival would be costly, time consuming, and possibly fruitless in the end. Prescriptions for plant communities are usually made on a site specific basis for specific purposes.

Distinct science disciplines are needed to address the question: **What water temperatures are important to salmon, and when are water temperatures critical for their survival?**

The disciplines would include: fish physiology, water science, and plant physiology as well as silviculture practices, and livestock grazing impacts (if the area is to be fenced from all uses).

Brett in 1952 addressed a question about water temperatures needed for salmon before death when they were 2 months old. The ultimate upper lethal temperatures for each species were: spring 25.1 °C, coho - 25.0, sockeye - 24.4 C, pink - 23.9C, chum - 23.8C. These upper lethal temperatures were established by running the experiment in a tank in a lab while holding the fish for many hours without fluctuating the water temperatures.

The test examined in essence, how long does it take for the 5 different species to die when held at a constant temperature under lab conditions. The test does not establish a threshold temperature expected in natural streams for all life stages. The experiment was established to address conditions for hatcheries rather than natural events in a watershed and addressed on 2-4 month old fish that had emerged from the eggs (January - March time period when referencing a natural stream system and life stage).

Combs conducted similar investigations using the newly emerged salmon. It is important to note that newly emerged salmon at 2-4 months old are in a stream during the January-April months. They are not instream during July and August when stream temperatures in the Pacific Northwest are above the generally repeated numerical threshold of 64°F.

The significance of Combs (1965) can not be overlooked. Mortality patterns and time of mortality were related to temperature increases as evidenced by high egg mortality occurring at the warmest temperatures. Mortality occurred primarily during a critical transition period at commencement of the active feeding stage. Once feeding, the fry mortalities decreased and remained low. The "warmest temperatures" were not summer temperatures but were expected winter to spring temperatures. Also, the temperatures were only relevant at a specific point in the embryonic development and not mortality of the salmon at all other ages.

Juvenile salmon of most species are 6 months and older during July and August. At this age, there are other questions about how the fish survives. The important questions for July and August periods center more on rearing temperatures, feeding opportunities, and predation. Brett in 1971 stated: both the prey of sockeye and the predators of sockeye are in a dynamic state of balance with their total environment while a major force in the evolving diurnal patterns are attributed to the energetic.

In 1977 trout were tested to determine if they preferred certain temperatures at 15 months old that differed from their body temperature after being acclimated to a specific temperature. The tested temperature range was 41°F to 77°F. Preferred temperature of the fish did not change more than 3-4 °C (5.4-7.2 °F) over a range of acclimation temperature. No significant differences were found in preferred temperature over the acclimation range studied.

The study by McCauley et al builds on the information provided by Bret and Combs for a different stage of life. At 15 months fish are migrating out of streams and they experience a variety of temperature regimes as they move from natal streams to the ocean.

Cherry et al (1977) studied avoidance temperatures of 15 fish species. They found that upper avoidance of fish tested at high acclimation temperatures between 30° and 36°C (86°F to 96.8 °F), either equaled or exceeded a 7 day upper lethal temperature limit of the species when tested at acclimation. Fish tended to avoid temperatures that increased when they were held in a higher acclimation environment where these temperature increased.

In this project avoidance only occurred above a 3°C (5.4 °F) increment increase which did not confirm Cherry's earlier 1975 study where the significant increment avoidance were 1°C (1.8 °F).

Hicks et al (1991) wrote about evidence in studies which showed that stream side management zones minimize damage to habitat. The consistency was variable over time and places. A study by Bilby and Bisson (1987) also indicated conflicting evidence of the benefits of stream side areas that are vegetated versus those that are not. Bilby and Bisson is further discussed in another section.

Anyone attempting to justify habitat requirements through published literature using studies that are not properly designed to address the specific question without using the criteria for "best available science" (provided in the Introduction) will likely make costly decisions that could be expensive for society and harmful to the aquatic life intended to be helped. Wildlife studies and experiments often lack a proper approach to data collection and then analysis. Many popular articles cited in reports and documents either speculate about links between salmon and habitat or do not fully analyze data in order to be able draw the conclusions that are made. Ultimately the published articles state an outcome that has not been examined and when the outcomes are restated in an appeal to authority by others, the errors become compounded and distorted.

In Poe et al (1991) and Tabor et al (1993) a study was conducted to examine predation of salmon by other species of fish that occupy the same streams as the salmon. Authors often fail to discuss

salmon and population declines in terms of the mortality due to predation by other fish species. Fish populations would be expected to have a natural population cycle that changes from high to low. Northern squawfish and smallmouth bass live in streams with salmon and take advantage of a plentiful food supply when the salmon smolts traverse their territories headed to the ocean.

Salmon losses due to predation by other fish species and other wildlife is rarely discussed when papers speculate on the causes of salmon declines. There are many predators within the salmon's water habitat as well as predators near the habitat edges. Habitat should be studied in the overall picture based on how many fish are in fact dead, injured, or harmed by the habitat itself or by predators associated with the habitat. The physical and chemical parameters of the salmon habitats must be separated from death, injury, or harm from natural predation.

Scriener et al (1994) studied salmon densities in a tributary of the Fraser River in Canada. This publication is of interest simply because the authors were able to observe fish moving into and out of the tributary. The fish took advantage of the stream for feeding and the water conditions while the larger Fraser River was experiencing the seasonal adjustments between the seasons of winter-spring and spring-summer.

In 1995 (40 years after the Brett (1952) study) Konecki et al posed the hypothesis, that a salmon group from a stream with lower and less variable temperatures would have a lower and less variable preferred temperature than a group from a stream with warmer and more variable temperatures. Bockman Creek which has flows derived from snowpack and were identified as being strongly influenced by local air temperatures. Bingham Ck. a tributary of the Chehalis river was described as a thermally buffered stream by groundwater inputs. Stock from these streams were used in the study.

Konecki et al (1995) also reported a study that investigated the critical thermal maximum (CTMs) for salmon. Tolerances varied among the populations and exceeded published data from some laboratory tests. After the salmon had been in the lab for 3 months under constant, common temperature regimes, the CTMs no longer differed, indicating that the population specific differences resulted from different acclimation regimes rather from genetic adaptations. This is an important concept as the literature often discusses the salmon species in terms of their genetic requirements for a specific water temperature threshold.

Dockray et al (1999) tested juvenile rainbow trout under conditions of a limited ration, low pH water and temperature increases. The study measured the metabolic and physiological response of the trout to changes in the control conditions. The study results describe the rainbow trout physiologic changes in terms of being able to compensate for low pH levels and increasing water temperatures if the fish is limited by food intake versus a trout response when the fish has a normal diet. This study makes no claim that humans therefore must control water temperatures and relies on the information of the study to report how the trout make metabolic changes to a changing environment.

Ingraham (1998) and Kaczynski (1998) both address the influences of the ocean conditions on the survival of salmon. Considering that salmon spend the majority of the life in the ocean and that the ocean climate influences the land climate, it is appropriate if not critical to examine these papers.

The ocean influences on our lives can often be a challenge to our personal habitats when flooding and blizzard events take place. We are influenced a great deal by the interaction of the ocean and land mass as climate develops across the topography. The salmon species spends most of its life in the ocean environment and these papers are important contributions to the literature and knowledge about the salmon populations.

Each of the articles reviewed are studies that meet the criteria for "best available science" using criteria 1-6. The limited number of reviewed articles presented in no way indicates that they are the only articles read. These were selected from over 75 reviewed papers written and used as appeals to authority often used as references to facts regarding salmon requirements.

These selected few are important "best available science" to the fundamentals of salmon tolerances of warm water. None of the studies published after Brett 1952 contradicted his work. The work stands. Salmon emerging from the egg state are sensitive to temperatures more at a developmental stage than after emerging and feeding starts. Temperature variations likely do occur in natural settings, but an estimate of what ranges the fish responded to in 1952 are acceptable today.

There is no connection though between the life stage described by Brett and the requirements of salmon during the summer months. The fish were not at summertime rearing sizes nor were they present in streams ready for spawning. The test was investigating hatching temperatures for hatcheries and to add to the knowledge base about fish at that time. In 1995 Konecki increased our understanding of the difference between a genetic and an adaptive response to the temperatures.

Science (best science) is progressed when a study is published and someone at a later time demonstrates through a second experiment whether the first was confirmed or found to contain an error. The studies presented have not been repeated with new results to establish a theory on fish mortality due to temperatures preferred by salmon up to approximately 4 months old. Salmon during summertime months are not sensitive to these same stream conditions identified as lethal to eggs and newly hatched juveniles, because the salmon in July and August are beyond the age limit when these temperatures are critical.

Fish Literature

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish Res. Bp. Can. 9(6), 1952.

In 1952 a laboratory study was conducted to assess the lethal limits of high and low temperatures for 5 species of Pacific salmon, the spring (*Onchorhynchus tshawytscha*), pink (*O. gowuscha*), the sockeye (*O. nerka*), the chum (*O. keta*) and the coho (*O. kisutch*). Brett cited a study reported in Fry, 1947 that concluded the existence of a known upper and lower limit of temperature tolerance in fish that is extended through adaptation as well as resistance either separately or collectively to distinguish the fish species.

Brett reports that five species of Pacific salmon common the west coast were obtained as eyed eggs from three hatcheries in Washington and British Columbia, Canada. A transition from alevin to free-swimming, feeding fry included feeding which had to be encouraged by frequent presentation of small particles of food. The feeding was made of finely ground beef or hog liver, four times daily over periods of 15-20 minutes. The diet was a modification of a 1948 study which used 50 percent beef or hog liver together with 48 per cent ground "fish pack" (haddock and cod fillet waste) and 2 percent yeast through the second month.

The mortality in the stock tanks holding the fish had a constant temperature of 8.8 ± 0.2 °C (48.8 °F). At temperatures above 20°C Brett observed mortality rates of up to 5% mortality, and in two cases disease became significant with one group experiencing an apparent inability to derive nutrition from their diet at temperatures increased by increments up to 24°C.

The pH of the well water used to supply the lab tanks was 7.3 with total solids amounting to 254.3

parts per million. The study was conducted on fish 3 months after hatching and was continued for an additional two to three months. When tanks were loaded with the maximum number of fish (4) the oxygen concentrations were never reduced below 93% saturation. The tanks were 36 inches high, 36 inches in length, and 20 inches wide.

200 young spring chinook were held in troughs kept at a constant temperature. There were no significant losses in troughs of 24°C at which temperature they proved to be very active and to be good feeders, but had reduced growth rates when compared to groups in lower temperature. As a result, the constant 24°C was used as a standard to test the tolerance of the other species. Most species in 40% of the cases curtailed feeding and activity was reduced.

Mortality was tested on fish held at the constant high temperatures over 3.5 days or 5000 minutes. Brett discusses "lethal" temperature as the temperature at which 50% of the population is dead after indefinite exposure. His study observed that the duration can be as long as a 7 day period used for Pacific salmon and that it varies for different species and different acclimation. He distinguishes between a zone of resistance and a zone of tolerance.

Brett states that at each lethal level of temperature there is a characteristic rate of dying which may be influenced within limits by acclimation. He notes that in this study that the results apply to the stocks of salmon from which the eggs were collected which may be traced back to a comparatively few females. The possibility of variation both within and between local stocks cannot be disregarded.

Summary of findings:

1. No significant difference in response to upper lethal levels of temperature exists between spring and coho salmon.
2. Spring and coho salmon show a highly significant difference ($p > 0.01$) from that of sockeye, pink or chum there is a very highly significant linear fit of the logarithmic relation for data (log of the median time to death in relation to the temperature causing that death).
3. The slope of the lines relating log resistance time to temperature for the five species are not significantly different.
4. The ultimate upper lethal temperatures for each species were: spring 25.1 °C (77.2 °F), coho - 25.0 (77 °F), sockeye - 24.4 C (75.9 °F), pink - 23.9 C (75 °F), chum - 23.8 C (74.8 °F).
5. An initial period of rapidly increasing resistance to low temperature was followed by relatively little change in resistance for 2 or 3 degrees (3.6 - 5.4 °F) increase in temperature (15-23°C) (59-73.4 °F) acclimation.
6. Mixed responses were noted in the lethal baths from acclimation temperature of 20°C (68 °F).

A rapid death of all fish occurred at the lowest temperatures.

Temperatures slightly above 20°C (68 °F) caused rapid death in part of the sample followed by a long delay and then death of the remainder.

Temperatures somewhat higher, yet still low enough to cause death, did so only after prolonged exposure.

The zones of thermal tolerance were determined and indicated that the high degree of sensitivity to low temperatures resulted in a comparatively low thermal tolerance rating. The spring and coho

were almost identical, next sockeye, followed by the chum.

An intolerance to low temperatures particularly restricts Pacific salmon in their biokinetic range. For prolonged exposure up to one week to high temperatures, the spring and coho salmon were most resistant, the sockeye intermediate and the pink and chum salmon least resistant. These differences are in keeping with taxonomic conclusions and certain ecological distinctions.

Combs, Bobby D., R.E. Burrows. 1957. Threshold temperatures for the normal development of chinook salmon eggs. *The Progressive Fish-culturist*. 19:1:3-6. Combs and Burrows studied spring chinook salmon eggs during 1952-1956. The study related three but separate experiments were included in the study. The first tested high temperatures ranges, the second low range temperatures, and the third was designed to duplicate the middle range of temperatures tested in the two previous trials. The experiments were designed to test the effect of constant incubating temperatures on the development of chinook salmon eggs.

Eggs from the Entiat River salmon stock were incubated at constant temperatures of 35°F, 50, 55, 57.5, and 60°F. Complete mortality occurred in the 35°F lot which set 35 °F as the lower limit for future experiments. In 1953-54 two races of chinook salmon eggs (Skagit and Entiat River) were subjected to constant temperatures of 35, 37.5, 40, 42.5 and 45 °F. Again complete mortality occurred in the 35°F lot. Mortality was significantly higher in the 37.5 and 40°F than in the 42.5 and 45°F lots. The lower threshold temperature of normal development was established at a level of 40 to 42.5. The threshold temperature was the same for both reaches of chinook salmon. The Skagit eggs showed less mortality as a group when compared to the Entiat eggs, the significant difference between losses within both groups occurred between those incubated at 40 and those at 42.5°F.

During the 1955-1956 experiment which duplicated the middle range of temperatures tested in previous experiments confirmed that there was a significant difference between the lots incubated at 40°F and 42.5°F reaffirming the range as the lower threshold.

The established ranges in these experiments are for normal development and applies only to constant temperatures. The study found that the stage in development of the eggs when subjected to temperatures outside the range is more important than temperature alone.

Other results were that the pink and chinook salmon eggs could tolerate long periods of very low temperatures if the initial incubation temperature was above 42°F for a month. The cause of death due to adverse temperatures may be lack of coordination between growth and organic differentiation within the embryo or dislocations in the order of differentiation.

Combs, Bobby D. 1965. Effect of temperature on the development of salmon eggs. *Progressive Fish Culturist*. 134-137.

Combs conducted a study on the development of salmon eggs which concluded that sockeye eggs would tolerate water at a temperature of 35°F if they had developed beyond the 128-cell stage. He emphasized that the results of the threshold temperature experiments were derived from constant incubating temperatures. The conditions imposed on the salmon eggs would rarely be duplicated either in nature or in artificial propagation procedures at hatcheries. Combs referenced a study on the Fraser River of sockeye salmon indicating that if spawning conditions included abnormally high water temperatures due to the temporary and local conditions mortality of the unspawned adult sockeye was extensive. Fish that did survive to spawn at temperatures above 55°F incurred higher than normal losses.

Also noted was a study by Burrows (1960) on late spawning chinook salmon at the Entiat station study a race of chinook which normally spawned in the main Columbia River or lower reaches of large tributaries in October and November while in water above 40°F. At the Entiat holding pond, the water temperature abruptly dropped below 40°F early in November causing the female chinook salmon to lose inclination to spawn naturally. Using spring water at a favorable temperature excellent spawning and egg mortality were observed.

1. Combs results indicated that the lower temperature threshold for the normal development of sockeye salmon eggs was established as between 40 and 42.5°F.
2. The upper threshold temperature for sockeye salmon eggs occurred between 55°F and 57.5°F.
3. Chinook salmon eggs which had developed to the 128-cell stage in 42.5°F water could tolerate water at 35°F for the remainder of the incubation period. The 128-cell stage was attained in 144 hours of incubation. Sockeye salmon eggs reached the 128-cell stage in 72 hours, at 42.5°F but required an additional 24 hours of development at that temperature before they could withstand 35°F water.

Olson, P.A., R.E. Nakatani, and T. Meekin. 1970 Effects of thermal increments on eggs and young of Columbia River Fall Chinook. Battelle memorial Institute. USACE. Seattle, WA.

The Fisheries research Institute, University of Washington in Seattle and the Washington State Department of Fisheries in Olympia contracted with the Battelle Memorial Institute to study and determine more precisely the temperature response of eggs and young derived from local chinook salmon to different heat increments. The thermal effects were defined in terms of mortality and growth of developmental stages. The results provided biological data required for comprehensive guidelines to determine permissible standards for the addition of heat to the Columbia River water during fall, winter, and spring without significant damage to reproductive success of adult chinook. The population of salmon tested were *Onchorhynchus tshawytscha* which spawns each fall in the Priest rapids- Hanford section of the Columbia river, south-central Washington.

The study was conducted over 177 days using four series of spawn. Seven temperature increments differing by intervals of about 2°F were used which encompassed a test range of 12°F. Rearing temperatures paralleled the Columbia's normal seasonal pattern where the coldest test temperatures approximated the mean river temperature.

Due to falling river temperatures after the start of the experiment, successively later series tolerated greater thermal increments. Temperature of 7.0°F in excess of the base river temperatures resulted in large mortalities in the spawned salmon of Oct. 30 and 12.0°F resulted in a total mortality. However, a 12.5°F increment above the base river temperatures in salmon spawned at the December 8 date, had a mortality of only 12.4%. This was within the normal hatchery production.

Mortality patterns and time of mortality were related to temperature increases as evidenced by high egg mortality occurring at the warmest temperatures but when there was considerable embryonic development and deaths just prior to hatching. The increased losses occurred primarily during the critical transition period at commencement of active feeding. Once feeding the fry mortalities decreased and remained low.

Increased temperatures increased growth with fish in the warmest lots 8 times heavier than those in the coldest lot when exposed to similar thermal units at the conclusion of rearing. The study concluded that the developmental stages of fall chinook can safely withstand greater thermal additions during winter when temperatures are low. It also suggested that elevated temperatures

would favor egg and fry survival of late spawners over those of earlier spawners when spawning temperatures were higher.

Brett, J.R. 1971. Energetic Responses of Salmon to Temperature. A Study of Some thermal Relations in the Physiology and freshwater Ecology of Sockeye Salmon (*Oncorhynchus nerka*). *Am. Zoologist*, 11:99-113.

Brett published a review of literature in 1971 on the relation of temperature tolerance, preference, metabolic rate performance, circulation, and growth of sockeye salmon. The author stated that most studies pointed to a physiological optimum in the region of 15°C (59 °F) for the young sockeye salmon during lake residence. Their natural occurrence is limited in time and space at temperatures above 18°C (64.4 °F) despite being able to tolerate 24°C (75.2 °F). Forms of physiological inadequacy can be demonstrated which account for restrictions in distribution.

In concluding comments Brett states that 15°C (59 °F) derived from physiological studies remains a very meaningful parameter for performance, metabolic rate, and cardiac function of sockeye. Sustained performance can confidently be expected to be maximum in the vicinity of 15°C (59 °F) no matter where the animal is. The field condition that dictated much of the energetic physiology of young sockeye was restricted rations. Few experiments had been performed where the biotic factor of ration had been coupled with the abiotic variable such as temperature (or light or salinity). The work concluded that it is the retention of a high food conversion efficiency over the full range of daily temperatures experienced which becomes most meaningful. He also observed that both the prey of sockeye and the predators of sockeye are in a dynamic state of balance with their total environment while a major force in the evolving diurnal patterns are attributed to the energetics.

Pacific Northwest salmon rely on many interwoven factors to maintain their health, well being, population, and distribution. Abnormal conditions in a fish's environment may elicit a stress response. If a fish is already responding to one stressor, it is less likely to withstand another. Temperature can be a biological, physical, or chemical stressor. Biologically, temperature affects the metabolism of fish and their ability to resist disease. Physically, temperature affects properties of water and fishes' tolerance to suspended sediment. Chemically, temperature can change the concentration of substances in water and reduce a fish's ability to withstand chemical exposure. Not all these relationships are well understood.

A wide range of biological, chemical, and physical factors can challenge the physiological systems of fish. Thus, the success of fish and fish populations in acclimating to environmental changes depends on the compensatory abilities of individual organisms. To persist and ultimately reproduce, fish need to perform such necessary activities as obtaining oxygen, swimming, metabolizing, and resisting pathogens.

Cherry, D.S., K.L. Dickson, J.Cairns JR. 1977. Preferred, avoided, and lethal temperatures of fish during rising temperature conditions. *J. Fish Res. Board Can.* 34:239-246.

Fifteen fish species were tested in a laboratory acclimated to 3°C increments between 12 and 27°C and showed preferences that exceeded their acclimation temperatures except for the telescope shiner, yellow perch, rainbow trout, brown trout, and brook trout. At 30,33, or 36°C acclimation, preferred temperatures were less than the acclimation temperature. The highest temperature preferences were at acclamations of 27, 30 and 33°C (80.6°F, 86.0°F, and 91.4 °F). Bluegill, spotted bass, rockbass, and spotfin shiner consistently selected the highest temperatures while the lowest temperatures were preferred by the Salmonids. Final temperature preferences were less than 19°C (66.2 °F) for the trout species tested.

Preferred temperatures changed with the changes in season from winter to summer. The upper limit for temperatures that the fish avoided increased as their acclimation temperatures increased. Fish temperature responses are dependent upon their thermal history and some of the species tested have adapted to the thermal regimes resulting from the operation of power plants such as one located in South Carolina that had been in existence for 56 years.

Avoidance temperatures increased as acclimation temperature increased.

Upper avoidance's tested at high acclimation temperatures between 30° and 36°C either equaled or exceeded a 7 day upper lethal temperature limit of the species when tested at acclimation.

In this project avoidance's only occurred above a 3°C (5.4°F) increment increase which did not confirm Cherry's earlier 1975 study where the significant increment avoidance's were 1°C (1.8°F). Mortality did occur and absolute avoidance's were slightly lower than the statistical avoidance ranges.

McCauley RW, Elliot JR, L.A.A. Read. 1977. Influence of acclimation temperature on preferred temperature of rainbow trout, *Salmo gairdneri*. *Trans Am Fish Soc* 106:362-365.

The relation of preferred temperature to acclimation temperature of 29 rainbow trout 15 months old was examined during summer. Fish were acclimated to 5, 10, 15, 20, and 25°C (41°F, 50, 59, 68, and 77 °F), respectively and tested individually in an electrically controlled shuttle box device. Body temperatures monitored by a radio thermometer ingested by the fish closely approximated occupied temperatures to within 0.2 °C.

No significant differences were found in preferred temperature over the acclimation range studied. Fish regulated environmental and body temperature with precision as they selected temperature in a spatial gradient. The authors indicated that acclimation temperature exerts little or no effect on temperature preference of adult rainbow trout. Preferred temperature of the fish did not change more than 3-4 °C (5.4-7.2 °F) over a range of acclimation temperature. This study acclimated fish over a long 16 hour period compared to other studies and provided a progressive series of changing water temperatures until the final preferendum was attained. The results indicate that mean body temperature as determined by telemetry can provide a close approximation of preferred temperature. Salmon, trout, and bass have been studied in similar experiments which had similar results.

Meisner, J.D., J.S. Rosenfeld, and H.A. Regier. 1988. The role of groundwater in the impact of climate warming on stream salmonines (*Fisheries* 13:3:2-8)

Meisner, J.D. et al. adds further understanding of the complexities of energy transfers from the atmosphere to groundwater and to stream water. This paper provides many studies that have documented that groundwater temperature is strongly linked to air temperature. Mean surface soil temperature generally exceeds mean annual air temperature: a common rule of thumb holds that 1 °C be added to the mean annual air temperature to derive the mean surface temperature of the ground. Surface soil temperatures follow seasonal air temperature fluctuations with a time lag related to depth. This paper references known theories and understanding Earth's thermal systems. Solar radiation is the energy that affects all components throughout all the planet and the task in the study is to experiment and apply the thermal theories to the measurements within the project.

Data is provided that acknowledges the influence of adiabatic lapse rates with changes in topographic elevations. These components are part of the fundamental considerations given to all experiments conducted on-the-ground in natural resource science. They are components of the physical laws established in Physics. Elevated groundwater temperatures may depress dissolved

oxygen concentrations in groundwater discharge due to decreased oxygen solubility and increased rates of microbial oxidation of dissolved organic matter. Suboptimal oxygen concentrations of groundwater may affect where trout build redds in streams. Current research involves the use of quantitative relationships such as the ratio of groundwater baseflow to average volume of stream flow over a given reach during critical warm periods.

Hicks, B.J., I.D. Hall, P.A. Bisson, and I. R. Sedell. 1991. Responses of salmonids to habitat changes. IN: Influences of forest and rangeland management on salmonid 96-506.

Role of Streamside management zones section of Chapter 14 (IN Influences of forest and rangeland management on salmonid) discusses streamside management as a tool to protect fishery values. The evidence in the studies considered, indicated that streamside management zones minimize damage to habitat but the consistency was variable over time and places. The Alsea study was one cited in Oregon, but the study relied on speculation about the causes of observations between logged and unlogged stream reaches. Variability between treatments in studies conducted on Carnation Creek in Canada also occurred. On Carnation Creek it was observed that smolts of age 1 were fewer in logged areas, but adult salmonids grew faster in higher water temperatures on some reaches. Winter survival from age 0-1 should have been reduced by the decrease in the amount and stability of large woody debris in the logged area compared to old growth, forested riparian area but instead survival was better. Changes in abundance of fish populations in Carnation Creek have been difficult to attribute to specific streamside treatments due to flaw in the research design. As a result many of the data summaries indicate that a hypothesis of the direct influence of woody debris presence in a stream due to the old growth stands versus a logged riparian area could not be answered.

A study by Bilby and Bisson (1987) also indicated conflicting evidence of the benefits of streamside areas that are vegetated versus those that are not. Both clear-cut and vegetated streambanks offer benefits to fish at different stages of growth which indicates that variety in habitat and woody debris presence and/or absence each have a role in salmonid management.

Climatic variation was discussed to indicate the difficulty in tracking logging-related habitat disturbances over time. Large floods have a significant influence on channel morphology. In evaluation of logging and vegetation removal as they relate to habitat, disturbance regimes imposed by management should be compared to natural disturbances in both frequency and amplitude. Salmonids have evolved in a landscape where they experience many environmental stresses: forest fires, floods, mass soil and ice movements, debris torrents, glaciation and volcanism. Their life history strategies enable them to withstand considerable environmental variations and unpredictability.

Focus on individual stream reaches has limited the accuracy of many studies. Study designs used have underestimated sampling error and have not addressed the comparative importance of different parts of a basin (Hankin, 1984). Reach analysis does not effectively assess cumulative effects and this is especially evident in short-term post harvest evaluations.

The authors caution that there is much to learn before we can predict with confidence the effects of activities that will provide habitat protection.

Vigg, Steven, T.P. Poe, L.A. Prendergast, H.C. Hansel. 1991. Rates of Consumption of Juvenile salmonids and alternative prey fish by northern squaw fish, walleyes, smallmouth bass, and channel catfish in the John Day Reservoir, Columbia River. Trans Am Fish Soc 120:421-438.

The study took place in four regions of the John Day reservoir from April to August 1983-1986 to quantify the consumption of 13 species of prey fish, particularly seaward-migrating juvenile Pacific salmon and steelhead. For each predator consumption rates varied by reservoir area, month, time of day and predator size or age. The technique used to establish prey/predator relationships reconstructed an average diel feeding pattern from pooled stomach contents of samples of predators collected from the natural environment. Several regressions were performed

The greatest daily consumption of Salmonids by northern squaw fish and channel catfish occurred in the upper end of the reservoir below McNary Dam (0.7 to 0.5 prey/predator). Greatest daily predation by walleyes and smallmouth bass occurred in the middle and lower reservoir. Consumption rates of all predators were highest in July, concurrent with maximum temperature and abundance of juvenile Salmonids. Consumption rates varied with time of day; diel patterns were generally consistent throughout the season.

Poe T.P., H.C. Hansel, S. Vigg, D.E. Palmer, L.A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. *Trans Am Fish Soc* 120(4):405-419.

The study took place in four regions of the John Day reservoir from April to August 1983-1986 to study the diets of northern squaw fish, smallmouth bass, walleye and channel catfish to determine the extent of predation on juvenile salmonids during seaward migrations of the salmonids. Juvenile Pacific salmon and steelhead were the most important food group by weight of the northern squaw fish – about 67% - but made up smaller proportions of the food of the other predators: channel catfish, 33%; walleyes, 14%; smallmouth bass, 4%.

Squaw fish preferred juvenile salmonids in May and August (generally the peak of the salmonid out-migration), and switched to prickly sculpin when numbers of salmon declined. Walleyes and smallmouth bass showed a preference only for prickly sculpin among the prey fishes analyzed. Walleyes and smallmouth bass were much less important predators on salmonids and appeared to select subyearling chinook salmon only in August when the distribution of the prey overlapped with that of the predators.

Size-selective predation by northern squaw fish may also play an important role in reducing survival of the smaller individuals within each run of the out-migrating juvenile salmonids.

Fraser, N.H.C., N.B. Metcalfe, J.E. Thorpe. 1993. Temperature-dependent switch between diurnal and nocturnal foraging in salmon. *Proc. R. soc. Lond. B* 252: 135-139.

The activity patterns of animals whether diurnal crepuscular or nocturnal are usually fixed. This study demonstrates that juvenile Atlantic salmon switch between diurnal and nocturnal foraging solely in response to environmental temperature and independently of photoperiod and season. At temperatures above 10°C juvenile fed predominantly during daylight, spending the night exposed in the water column but relatively quiescent. As temperatures dropped below 10° C they became increasingly nocturnal taking refuge by day but emergent to feed at night.

It has previously been shown that parallel physiological changes take place in the retinae of several species of Salmonids: the quantity and composition of the visual pigments change so as to make the fish more dark adapted at low temperatures. As the fish were found to be far less aggressive by night than by day all temperatures the switch to nocturnal activity was also accompanied by a change in social structure. The authors suggest that this temperature-dependent strategy maximizes feeding efficiency in summer but reduces predation risk in winter.

Tabor, R.A., R.S. Shively, T.P. Pie. 1993. Predation on juvenile salmonids by smallmouth bass, and northern squawfish in the Columbia river near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

The importance of juvenile Salmonids in the diet of smallmouth bass and northern squawfish was examined at a 6 km stretch of the Columbia River.

The importance of juvenile Salmonids in the diet of smallmouth bass and northern squawfish was examined during 1990 during emigration of juvenile anadromous Salmonids. 62 smallmouth bass and 69 northern squawfish were sampled. Juvenile Salmonids made up 59% of the smallmouth bass diet, by weight and were present in 655 of the stomachs of the bass and were estimated to consume from 1.4 to 1 salmonids per predator daily. Crayfish were dominant prey consumed (41.4% by weight) of northern sawfish, but juvenile Salmonids were 28.8%. The squawfish consumed 0.55 to 0.34 salmonids per predator daily during two sampling periods of May 2-3 and June 20-21 respectively. Smallmouth bass and northern squawfish consumed mostly subyearling chinook salmon which may have been wild chinook salmon that emigrated downstream from the Hanford reach. The predation rates by smallmouth bass were estimated as high during spring and early summer because subyearling chinook salmon are abundant and of suitable forage size and their habitat overlaps with that of smallmouth bass.

24 transects along the shore, 500 m long, were established. 12 transects were located on each shore. Six random transects were sampled first each day, then additional transects were sampled to maximize catch of northern squawfish.

Stomach contents were sampled from bass of 200 mm fork length size. Samples were taken to a lab, magnified and identification of the contents took place.

92 bass with a mean length of 234 mm (range was 109-389 mm) fork length were used for stomach analysis. 8 had empty stomachs and 2 contained large prey that couldn't not be removed. All 69 squawfish collected were examined with 11 empty stomachs. Fork length of the squawfish averaged 385 mm and ranged from 261 to 495 mm.

Juvenile salmonids were the major prey items for all size classes of bass representing 59% of the diet by weight. Crayfish and other fish represented 19 and 18% of the diet respectively. Little other food was found except for various orders of insects. Overall for all size classes of the bass, juvenile salmonids were in 65% of the stomachs and constituted 84.2% of all consumed fishes. The mean number of salmonids per smallmouth bass stomach was 1.87. In May when 1.4 salmon per predator was consumed each day the average fork length of the ingested salmonid was 43.8 mm and in June they averaged 67.6 mm.

Squawfish consumed a variety of crayfish (dominant by weight of 41.4%) fish 28.8% plants 11.6%, insects 10.4% and mollusks. 29% of the squawfish digestive tracts contained salmon. The authors suggest their estimates of consumption rates of Salmonids by smallmouth bass are evidence that the bass may be a major predator on juvenile Salmonids in some situations especially in rearing areas of subyearling Salmonids. They also suggest that predator-prey relationships in other areas of the Columbia River system should be examined.

Scriener, J.C., T.G. Brown, and B.C. Andersen. 1994. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) utilization of Hawks Creek, a small and nonnatal tributary of the Upper Fraser River. Can. J. Fish. Aquat. Sci. 51:1139-1145.

Scriener et al (1994) examined Hawks Ck. a small tributary of the upper Fraser River where there are no records of spawning salmonids during 1990 for the presence of juvenile salmonids. Chinook salmon have a variable life history strategy in freshwater. Some reside in or near their natal streams for a year after emerging from the streambed. Others reside for only a few days or months before migrating to the ocean. Both strategies are observed among most populations for chinook salmon from the Fraser River British Columbia. The ocean-type behavior is more prevalent in the lower tributaries described in other studies.

Hawks Ck. has a fish barrier 300 m (984 feet) upstream from the confluence with the Fraser River. The study area was within the 300 m long reach which has a $< 2\%$ gradient and is shaded by poplar, birch and willow layers of trees 1-3 m in height and pine 15-25 m (49-82 feet) in height. Riffle/pool sequences were at 10 m (32.8 feet) intervals along the length. Irrigation use occurs above the fish migration barrier.

During the study period, winter flows were low and snow and ice built to a height of 3 m at the confluence of Hawks Ck. and the Fraser River. In April, peak stream flows and sediment loads breached the ice when the snow melted in Hawks Ck. watershed (water level = 1.2 m (3.9 feet) and sediment concentration = 689 mg/liter (0.04 lbs/ cu. ft.) in mid April). Hawks Ck. was clear by May while flows and sediment loads in the Fraser River were still increasing. Hawks Ck. increased a few days during rains storms and then cleared again.

Number and distribution of fish in the study reach were determined on 12 occasions between May 18 and November 1, 1990. Species were identified, counted, and released. All fishable areas were seined so that fish distribution in the study reach was determined. Fish were captured and marked at each sampling date, using a different mark each time. When loss of marks was not significant population size was estimated. Stream temperature and water level were determined for 14 occasions between May 18, 1990 and April 23, 1991. Sediment samples were collected from both the Fraser River margin near Hawks Creek and the study reach at Hawks Creek.

Abundance and area occupied by juvenile chinook salmon increased during the spring and decreased during the autumn in the Hawks Creek study reach. Abundance of age 0+ juveniles increased during May and June, declined in July after a storm, increased again in August and declined again during September and October. The area occupied increased, while total catch showed little variation between May 27 and July 6. The salmon use of Hawks Creek was limited almost exclusively to age 0+ fish from wild stocks. Hatchery chinook salmon did not appear to use the study area as marked adipose fins were never observed in a capture.

Average residence in Hawks Creek was 9 days for individual fish. Recapture was rare after 55 days. The maximum population size in the study reach was estimated with mark-recapture data from August 22 and 25. The chinook population peaked between 346 and 325 fish which averaged a peak density at 0.76 fish per meter for 443 square meters of stream.

Suspended sediment in Hawks Creek were lower than those of the Fraser River. A peak of 689 mg/L occurred during snow melt in April and < 25 mg/L from May to November. The Fraser river concentrations were > 150 mg/L during May and June and exceeded 60 mg/L throughout the summer.

Water temperature and water levels in Hawks Creek were also different from those of the Fraser River. Hawks Creek was $> 2^{\circ}\text{C}$ warmer during May, June and July and $> 5^{\circ}\text{C}$ cooler during August and September than the Fraser River. By late August Hawks Ck. consisted of a series of pools that were connected by narrow (0.5m) and shallow (~10 cm) riffles. Water level in the Fraser River

declined continuously after July 15.

Discussion of the results include descriptions of the overall patterns of use. The authors suggest that during May through August salmonids were attracted to the clearer and warmer waters of Hawks Creek. The high densities and changes in the habitat preferences might have caused them to remain only a short time. The change in densities during September and October were thought to be due to declining water levels, velocities, and temperatures in Hawks Creek and also declining sediment in the Fraser River which made it more attractive for that time period.

Other speculative remarks are made unrelated to the data testing. Finally, the use of small nonnatal tributaries of the upper Fraser River by juvenile chinook salmon appeared to be a rearing and growing habitat during times of high sediment concentrations in the Fraser River during periods of downstream fish migration. The authors felt feeding was probably less inhibited in the clear smaller stream but they observed it was a short-term and seasonal residency with high fish densities they felt supported the refuge concept.

Konecki, J.T., C.A. Woody, T.P.Quinn. 1995. Temperature preference in two populations of juvenile coho salmon, *Oncorhynchus kisutch*. *Environ. Biology of Fishes* 44: 417-421.

Konecki et al (1995) studied two groups of coho salmon raised under identical regimes to test the hypothesis that the group from a stream with low and less variable temperature would have a lower and less variable preferred temperature than a group from a stream with warmer and more variable temperatures.

The study was conducted using stock from two coastal Washington streams. Bingham Ck. a tributary of the Chehalis river is a thermally buffered stream by groundwater inputs. Hour temperature averages in 1993 were 11.3°C and varied by + or - 5°C. Bockman Creek flows are derived from snowpack and were identified as being strongly influenced by local air temperatures. The average hourly temperatures were 12.5°C with a range of 10°C.

Eggs were collected, inseminated, and progeny incubated in trays maintained at around 6°C, juveniles were reared at 10°C well water and were fed a semi moist diet daily. At 4-5 months fish were tested for thermal preference.

The tests were conducted in a shuttle box with a boundary temperature of 2°C and 28°C. Results were reported as the temperature at which 70% of the observations were made. The range of temperatures where the fish spent 70% of their time were between 6-20 °C and 7-22°C for the Bingham and Bockman Ck. respectively. The average temperatures during 70% of the observations were 8.4-12.5 °C and 9.2-13.7°C for each group. There were no significant differences between the two groups.

In conclusions Konecki et al (1995) observed that in the literature salmon in general may prefer temperatures near those where their realized optimum growth occurs, even though they can more efficiently utilize food at higher temperatures and they can tolerate much higher temperatures.

Konecki, J.T., C.A. Woody, T.P.Quinn. 1995. Critical thermal maxima of coho salmon fry under field and laboratory acclimation regimes. *Can J. Zool.* 73:993-996.

Juvenile coho salmon from three populations in Washington State were captured and tested for critical thermal maximum (CTM). Tolerances varied among the populations and exceeded published data from some laboratory tests. The population from one of the streams were from

streams that are relatively cool and they had a lower CTM than the two populations from warmer streams. After the salmon had been in the lab for 3 months under constant, common temperature regimes, the CTMs no longer differed, indicating that the population specific differences resulted from different acclimation regimes rather from genetic adaptations.

Ingraham Jr. W.J., C.C. Ebbesmeyer, R.A. Hinrichsen. 1998. Imminent climate and circulation shift in northeast Pacific Ocean could have major impact on marine resources. EOS, Trans. Am. Geophys. Union. 79:16 197-199.

Ingraham et al (1998) describes an imminent climate shift. Based on ocean drift and tree ring records the most recent decadal phase appears to be one of the longest during the last five centuries. Tree ring intervals studied averaged 30, 30, and 31 years between growth troughs. The trajectories provide insight on the impacts ocean conditions have on salmon populations.

Kaczynski, V.W., J.F. Palmisano, J.E. Levin. 1998. Marine survival of opia hatchery Coho salmon related to marine temperatures. Proce. 49th Annual Pacific Northwest Fish Culture Conference. Boise, ID. P. 131-147.

Sea surface temperature information for the northeast Pacific Ocean were examined for annual trends (49,029 monthly records). The trends reveal that distinct temperature latitude differences are apparent for locations. Decade scale temperature trends are the same for all 4 locations between California and Alaska. The trend data shows how the warm ocean problem has progressively marched northward over the years first affecting California, then Oregon and Washington and then British Columbia.

Dockray, J.J., I.J. Morgan, S.D. Reid, C.M. Wood. 1998. Responses of juvenile rainbow trout, under food limitations to chronic low pH and elevated summer temperatures, alone and in combination. J Fish Biol 52:62-82.

Rainbow trout were exposed (90 days) in synthetic soft water to sub lethal low pH (5.2) and simulated climate warming scenario (2°C above the control summer temperature range of 16.5-21 °C) alone and in combination of limited food (~4% dry body weight).

The gradual increase in temperature over the 90 day exposure period, in combination with daily fluctuations and the fact that fish are able to acclimate more rapidly to increases than to decreases in temperature resulted in metabolic compensation. This effect was evident in an experiment Dockray et al, 1996. The continuous +2° C elevation was sufficient to reduce growth rates in the limited ration fish in these treatments. Similar effects of temperature on growth were obtained in 1996, although the effects were most obvious in the period during which temperatures increased rapidly towards incipient lethal levels. The similar metabolic rates, both over time and among treatments, throughout the 90 period indicated that there was no substantially increased cost of living in a warmer environment.

Chronic exposure of juvenile rainbow trout to warmer environmental temperatures and sublethal low pH under limited ration conditions did not result in more clear cut treatment effects on their physiology and energetics than previously seen under unlimited ration. The combination of warmer temperatures and sublethal low pH appeared to be slightly more costly than either stressor alone, in trout that have an unlimited or limited ration.

The trout exposed to 5.2 pH exhibited no evidence of ionregulatory disturbance. High summer temperatures above the optimum temperature for growth, reduce conversion efficiency. These effects were more evident in limited ration fish because they were unable to increase their food

intake to combat the subsequent high metabolic rates (relative to energy intake), resulting in low conversion efficiencies.

It appears that feeding trout would withstand low pH conditions and to some degree warmer environmental temperatures more effectively than starved trout. A further reduction in ration to the maintenance level, may uncover treatment effects. Trout in the wild would have such limitations on their diet, particularly under winter conditions. Further studies relevant to the wild should be aimed at determining the seasonal effects of these environmental stressors on fish.

Dickerson BR, Vineyard GL. 1999. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. *Trans Am Fish Soc* 128:516-521.

Tests of chronic temperature tolerance indicated that the upper limit for survival and growth of Lahontan cutthroat trout was between 22°C and 24°C. Lahontan cutthroat trout experienced complete mortality within 2 days at 28°C and approximately 60% mortality over 7 days at 26°C (78.8 °F).

Fish suffered no significant mortality at temperatures of 24°C (75.2 °F) and below. No significant differences in growth of fish held at 22°C (68°F) relative to fish held at cooler temperatures were found. Significant reductions in growth were observed at 24°C. When fish were subjected to fluctuating temperatures similar to field conditions which cycled daily from 20°C (68°F) to 26°C (78.8 °F), they still grew.

The upper temperature limit for growth and survival of Lahontan cutthroat trout under chronic elevated thermal stress appears to be between 22°C (71.6 °F) and 23 °C (73.4 °F), however responses were modified by exposure to fluctuating temperature conditions. The authors acknowledge that the study was site specific to the Truckee River and they used fish stock from a lacustrine environment. Additional studies of stream-derived fish from other areas would help elucidate whether there may be stock-related differences in thermal tolerances.

BOOKS

The following book list contains standard texts that can provide the basic fundamentals to many of the natural resource sciences.

Bedunah, Donald J., and Ronald E. Sosebee. 1995. *Wildland plants: physiological ecology and developmental morphology*. SRM. Denver, Colorado Pages 23-59.

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APPENDIX A

Hydrosphere and the hydrologic cycle

Hydrosphere - all water in all forms present at or near the earth's surface (including water in lithosphere, atmosphere and biosphere). Hydrosphere covers 71% of the surface of the planet.

Composition of hydrosphere

Water in hydrosphere is contained in the following reservoirs (by volume):

World oceans	97.2%
Fresh water	2.8%
Ice sheets and glaciers	2.15%
Ground water	0.63%
Water at or near surface and in the atmosphere	0.02%
Freshwater lakes	0.009%
Saline lakes and inland seas	0.008%
Soil water	0.005%
Water in streams and rivers	0.0001%
Water in atmosphere	0.001%

A few terms

- * Subsurface water = Soil water + Ground water.
- * Soil water - water contained in soils (within 1-5 meters from the surface), can be reached by plants
- * Ground water - water below soil, cannot be reached by plants
- * Surface water = Lakes + Stream channels

Hydrologic cycle and global water balance
Global water cycle

Global water cycle - processes involved in moving water around the globe.
 Cycle implies that water circulates between the global water reservoirs.

Inflows		Outflows
Continents Precipitation	=	Evapotranspiration + Runoff
Oceans Precipitation + Runoff	=	Evaporation

- * **Precipitation** - all processes by which water descends through the atmosphere reaching the surface.
- * **Evapotranspiration** = evaporation + transpiration. Water is evaporated from land by two processes:
 - o from open water, soil and other inanimate surfaces - evaporation
 - o by plants - transpiration (by far the more important of the two processes)
- * **Runoff** - rivers transporting water into oceans or closed inland basins.

Global water balance - more specific notion than cycle - incoming and outgoing flows have to be balanced for globe as a whole and any part of it.

Average annual water balance

1. For continents and oceans:

Inflows		Outflows
Continents 110 km ³	=	70 km ³ + 40 km ³
Oceans 380 km ³ + 40 km ³	=	420 km ³

2. For the whole Earth:

Total annual precipitation:
 110 km³ (land) + 380 km³ (ocean) = 490 km³

Total annual evaporation:
 70 km³ (land) + 420 km³ (ocean) = 490 km³

Humidity

Humidity - amount of water vapor present in the air.

Air typically contains less water vapor than it can carry (except for very humid conditions => high humidity). Maximum humidity - maximum quantity of moisture that can be held in the air.

Two ways to measure humidity:

- * Specific humidity - actual mass of water contained in a given mass of air, g/kg (absolute measure)
- * Relative humidity - amount of water vapor present relative to maximum specific humidity, % (relative measure)

Specific humidity:

- * Maximum specific humidity increases sharply with air temperature;

This is the maximum possible quantity of water vapor, in reality air typically contains less water. It can't, however, contain more.

- * Since specific humidity is an absolute measure, it can be applied to compare air masses anywhere (polar, tropical, etc.)
- * Specific humidity can vary 100-200 times: cold & dry polar air mass vs warm & humid equatorial oceanic mass
- * If air is slowly cooled, it will reach saturation (maximum amount of air moisture possible for a given temperature); saturation temperature is known as dew point temperature. Moist air has higher dew point temperature than drier air.

Relative humidity:

- * Relative humidity is simply a ratio:

Specific humidity / Maximum specific humidity for this temperature

- * A change in relative humidity can happen in 2 ways:

1. By direct gain or loss of water vapor (for example, air mass gains moisture from open water surface) - slow process because it involves diffusion of molecules)
2. Through a change of temperature.

- * The effect of temperature on a daily relative humidity cycle
 - If temperature rises THEN relative humidity falls, and vice versa
 - Specific humidity typically remains almost the same; It changes when a different air mass arrives

Lapse Rate

Essentially, the lapse rate is a measure of how much air decreases in temperature as it rises through the atmosphere.

Environmental Lapse Rate : (ELR)

This is the actual measured decrease in temperature with height above the ground (i.e. the rate which is actually occurring, not a theoretical rate).

Generally this is about 6.5 C per 1000 m. This rate does vary and depends on local air conditions. There are several influencing factors:

- * Height: Lapse rates depend on ground temperature (and are normally less near the ground)
- * Time of Year: Lapse rates are lower in winter or during a rainy season.
- * Surface: Lapse rates are lower over land than sea.
- * Air masses: Different properties of air masses mean different lapse rates.

Adiabatic Lapse Rate :

This is a theoretical rate and can be calculated.

Looking at Dry Adiabatic Lapse Rate : (DALR)

A dry parcel of air which does not mix at all with the surrounding air is considered. As this parcel does not mix it can be considered to be adiabatic (i.e. it does not lose any heat outside of the parcel in the process). As the parcel of air rises through the atmosphere the surrounding pressure is less and so the parcel expands. Expanding takes energy and so the parcel cools (i.e. heat energy used in expansion). The rate at which the parcel cools, the DALR (dry adiabatic lapse rate), stays constant at 9.8 c per 1000m.

The dry adiabatic lapse rate only applies when the relative humidity is less than 100%. When the air cools to dew point (the temperature at which the air can hold no more water without condensing) water vapor condenses out leading to complications due to the energy introduced from the latent heat. This then means that the saturated lapse rate is used below this temperature.

Looking at Saturated Adiabatic Lapse Rate (SALR)

The saturated lapse rate has to take into account the fact the energy is released when water condenses (called the latent heat). This means that once the air has cooled to the dew point and water has started condensing the air parcel cools more slowly.. The SALR (saturated adiabatic lapse rate) range from 4 C per 1000m to as high as 9 C per 1000m. The average SALR is about 5.4 C per 1000m.

History of the Theory of Heat

In our everyday experience of heat our intuitive sense about hot tea and cold showers mirrors the Greek science theory of heat. In 300 BC Aristotle believed that heat is what produces the sensation of hotness. He believed observation was essential to science and derived the heat theory from personal observations. Aristotle's theory of heat stated : heat is what produces the sensation of hotness. The Greeks and others held to the theory for hundreds of years, that heat flows into our bodies creating a sense of hotness and flows out of our bodies and we sense coldness.

The Greeks were clever in their speculations and discovered many facts about nature, but they had no principles to guide them so science could grow (Motz and Weaver, 1991). Personal observation combined with a logical thought process was the common scientific methodology employed to make new discoveries. The idea that a sense of how hot or cold an object felt could determine how much "heat" it contained gave way when Galileo invented a thermoscope to

investigate degrees of heat and cold. He used a glass bulb having a long tube extending downward into a container of colored water, although Galileo in 1610 is reported to have used wine (Quinn 1982). In 1714 Fahrenheit unveiled an instrument that used mercury sealed inside a bulb with a scale that measured the freezing point and boiling points of water. This development established that heat caused the column in the thermoscope to change height. In the late 1750s Joseph Black baked equal quantities of mercury and water in an oven and checked their temperatures. Black's results showed that mercury was hotter than the water after being heated by the same oven for the same amount of time which created a theory: that heat consists of a caloric fluid that is invisible, weightless, and indestructible (Gullen, 1995).

J. P. Joule published a paper in 1847 that described heat as a form of energy. Joule discovered the law of conservation of energy through relentless, painstaking experimentation for whom scientific research was a matter of measurement, not speculation (von Baeyer, 1999). Work of other scientists confirmed the paper's theory and the ideas of heat were again changed. Joule's experimentation was concerned with the heating of water, but once the gaseous state of air was appreciated the students of heat turned the this less familiar form of matter (von Baeyer, 1999). In the mid 1800s Rudolph Clausius described the heat theory using a mathematical foundation and established of the Laws of Thermodynamics.

We no longer base heating laws on the Aristotelean "thought experiments" that the human can feel temperature as heat and our personal sensations can be transferred to everything around us. We now know that heat and temperature are not the same. Heat is energy that flows between a system and its environment by virtue of a temperature difference that exists between them. The Laws of Thermodynamics, established in the 1600s allow us to explain that when two different materials are brought into thermal contact with each other, they reach thermal equilibrium, but do not experience the same changes in temperature because of their different specific heats and masses. The heat lost by the hotter object is equal to the heat gained by the colder object. The goal of fundamental science is to discover the laws of Nature, which means we are interested in finding that few set of rules that apply to all objects and systems in the Universe. The Laws of Thermodynamics describe how the water heats in a watershed, as well as air and soil.

Thermodynamics states that If three or more systems are in thermal contact with each other and all in equilibrium together, then any two taken separately are in equilibrium with one another (Quinn 1982). Thermometers are based in the laws of Thermodynamics and humans are not reliable thermometers (Bohren 1998). The laws establish the principles of using a thermometer to indicate the quantity of accumulated energy in a substance and imply the irreversibility of certain processes. These concepts of temperature explain how heat (thermal energy) flows from one body to another. When two different materials are brought into thermal contact with each other, they reach thermal equilibrium, but do not experience the same changes in temperature because of their different specific heats and masses. The heat lost by the hotter object is equal to the heat gained by the colder object (Kirkpatrick, and Wheeler, 1995). Heat and temperature are not the same. Heat is energy that flows between a system and its environment by virtue of a temperature difference that exists between them (Halliday and Resnick 1988).

Classification of Pathogens including Fecal coliforms:

1. PATHOGENS ARE ORGANISMS THAT ALWAYS CAUSE SPECIFIC DISEASE OR CONDITION

2. THE ABILITY OF PATHOGENS TO CAUSE A SPECIFIC DISEASE DEPENDS ON THEIR BEHAVIOR IN THE BODY:

- a. ABILITY TO ENTER THE BODY
- b. GROW AND INFECT
- c. PRODUCE TOXINS

3. REQUIREMENTS OF FECAL INDICATORS:

- a. APPLICABLE TO ALL TYPES OF WATER
- b. ALWAYS PRESENT IN WATER WHEN THERE IS CONTAMINATION FROM FECAL SOURCES

4. QUANTITATIVE TEST METHOD AVAILABLE

Simplified classification of the coliform bacteria group ENTEROBACTERIACEAE including the species *Escherichia coli*

TOTAL COLIFORM GROUP

FECAL COLIFORM GROUP

- Citrobacter* sp.
- Enterobacter* sp.
- Klebsiella* sp.

INCLUDING THE SPECIES:

Escherichia coli

Simplified classification of the Streptococcus groups

STREPTOCOCCUS

GROUP D

- S. equinus*
- S. bovis*
- S. gallinarum*

ENTEROCOCCUS GROUP

- E. faecium*
- E. faecalis*

GROUP Q

S. avium

Includes species of the genus *Enterococcus*

COLIFORM BACTERIA

Looking at total coliforms, some are intestinal and indicate the quality of finished water

Looking at fecal coliforms, most are intestinal—indicate the quality of recreational and finished water and the possible presence of fecal contamination

ESCHERICHIA COLI

Strictly intestinal -- indicates the quality of finished water and fresh recreational water and is direct evidence of fecal contamination.

STREPTOCOCCUS AND ENTEROCOCCUS Groups

STREPTOCOCCUS SP., Most are intestinal and indicate the possible presence of fecal contamination.

ENTEROCOCCUS SP., Most are intestinal and indicates the quality of fresh and marine recreational waters and the probable presence of fecal contamination.

OTHER FECAL INDICATORS: SOMATIC AND F-SPECIFIC COLIPHAGES (viruses that infect coliforms)

These indicate the presence of sewage, and are present in only 5 percent of humans (unlike E. coli which is present in all humans and warm blooded animals), and are more persistent in the environment than E. coli

OTHER FECAL INDICATORS

CLOSTRIDIUM PERFRINGENS (a spore-forming bacterium)

Indicates the presence of human and animal waste, like protozoan parasites, and sewage and is very resistant to disinfection and environmental stressors

PATHOGENS

BACTERIAL:

Salmonella sp.

Shigella sp.

Campylobacter sp.

VIRAL

Polio virus

Norwalk virus

Rotavirus

PROTOZOAN

Cryptosporidium parvum

Giardia lamblia

SUMMARY

Concentrations of fecal bacteria are highly variable characterized many source inputs which are difficult to model

Nitrogen

Forms:

N_2 = Dinitrogen

N_2O = Nitrous oxide

NO = Nitric oxide

NO_2^- = Nitrite

NO_3^- = Nitrate

NH_3 = Ammonia

NH_4^+ = Ammonium

Sources and Transformation: Most nitrogen on earth occurs in the atmosphere and in the rock mantle of the earth. Nitrogen used by plants, represents a small amount of the total nitrogen on earth and is found primarily in the soil. The amount of soil nitrogen available to plants is dependent on the amount of dead plant and animal tissue found in the soil, soil microorganisms, temperature, and moisture. Nitrogen can be found in the soil in all of the forms listed above. Plants use nitrate as their primary source of nitrogen.

Plant and animal protein contains nitrogen in the form of amino acids. When plant or animal tissue is decomposed and/or digested (animals, insects or microbes) a waste product of ammonia or ammonium results. Ammonia and ammonium serve as a food source for a group of soil bacteria (ie nitrosomonas) that convert it to nitrite. The nitrite is then quickly converted by a second group of bacteria (ie nitrobacter) into nitrate. The oxidation process of transforming nitrogen found in organic matter into nitrate is called mineralization or nitrification.

Denitrification occurs when nitrate is reduced by anaerobic bacteria (bacteria living in an environment lacking oxygen). In this case the nitrate is reduced in sequence to nitrite, nitric oxide, nitrous oxide and dinitrogen. Denitrification requires an organic source for anaerobic bacterial activity to occur and the reduced form of nitrogen escapes from the soil into the atmosphere.

Leaching and Erosion: Nitrogen can be transported from the soil into groundwater and surface water by leaching or runoff. The principle form of nitrogen that is lost in this manner is nitrate. Nitrate has a negative electrical charge. This is the same charge as that found on clay and organic colloids found in the soil. As a result there is no electrical attraction to hold nitrate to these particles and excessive amounts of nitrate can migrate in the soil via soil water movement. Nitrate leaching is not a universal problem and is most likely to occur on sandy, well-drained soils with a shallow water table, in areas that receive high rainfall or intensive irrigation and frequent use of fertilizers, manures, or other nitrogen sources.

Runoff occurs when water accumulates on the surface of a soil at a faster rate than soil infiltration. Soil infiltration is influenced by soil texture, soil surface characteristics, soil moisture, and slope. In this case, nitrogen can be lost as soluble nitrate at the soil surface or organic sources moving in the runoff. Once again as in leaching, nitrogen loss by runoff is site specific and can be managed by managing the timing and rate of nitrogen application, avoiding situations when soil infiltration is reduced (ie frozen soil), and providing grassed buffers that filter sediment from runoff.

Nitrates & Phosphates and Turbidity from Ag Land via Non Point Sources

A turbidity test indicates presence or absence of small, nearly microscopic particles in a water

column without identification of the causes. Turbidity data are somewhat meaningless for agriculture land management if identification of suspended particles is not made.

When water temperatures are warm, sunlight is present, and soluble nitrogen and phosphorus is available in the water, an environment for algae growth is created. If the growth is excessive (algae bloom) the algae population will contribute excessive amounts of dead algae to the water. Microbes in the water digest the dead algae consuming oxygen through respiration. This can lower the oxygen level in the water to the point that fish are deprived of oxygen. This is one linkage between nitrogen, phosphorus, and fish that water quality regulators want to avoid. Sloughs and ponds are often found to have poor oxygen levels for fish because the waters are still, are not regularly receiving aerated fresh water, and are a good place for algae to grow thus starting the process and keeping it in a perpetual state of depleted oxygen supply for fish requiring a higher availability. There are documented slough areas that have elevated N and P present.

When monogastric digestive systems (man, pigs, etc.) digest organic material they breakdown and either absorb or excrete the nitrogen and phosphorus contained in the food. However, this digestive system is not particularly efficient and considerable amounts of the nutrients are lost in urine and feces (all mammal feces will contain fecal coliform).

Since monogastric mammals are the most likely source of excess nitrogen and phosphorus and concentrated fecal coliform, people conduct tests for N and P in the water. If there is a strong concentration of the two elements, then it is worthwhile to check for fecal coliform. The presence of all three suggests a concentrated sewage source (man or animal) is contributing in the area. City sewage treatment plants are regulated on how clean the treated water must be to reenter a stream or be placed on land for further filtering.

Ruminants have microbes in the stomach that digest organic materials and the microbe waste products and dead bodies are also digested and absorbed by the ruminant digestive system. This is done in a much more efficient manner than monogastric digestion and only small amounts of N and P are lost in the form of urine and feces by the ruminant group of animals.

When urine, feces, and vegetation are present in water, microbes and insects use them as nitrogen and phosphorus sources for their bodies and excrete excess as waste. In general none of the above processes is a problem for fish except under certain conditions.

A final way that nitrogen can enter the water is from an excessive source of nitrate in the soil. Most forms of Nitrogen are tied up by clay particles in the soil and cannot become soluble. Nitrate is a water soluble form of nitrogen important to agriculture. We test for it in the water. If nitrates are present in the soil, they are soluble, and if runoff is excessive the nitrates can be picked up in the runoff and eventually reach a stream in sufficient quantities and concentration to be detected. This is not likely though under normal land management. Areas that use large amounts of fertilization with nitrogen (farm crop areas) have been known to contaminate water with nitrates due to irrigation return flows as well as having it reach ground water sources. These areas and management techniques have been documented and different methods and rates commonly used to prevent the problem are well known.

Phosphorus like nitrogen is easily tied up in soils. It is extremely difficult to pick up out of the soil. P applications are made to land in many areas because crops cannot use it from one season to the next because it is unavailable and so little can be retrieved from the soil. When the form of phosphorus is soluble, phosphate, it is nearly always due to a natural background source or it is a sewer or septic system that is the source. Ag lands are the least likely to be contributing to a phosphate contamination. It's just not likely under normal land management.

In many areas of Oregon, the types and amounts of fertilization described above for Nitrogen and Phosphorus are not applied. Concern about nitrates and phosphates is minimal from agriculture land. It is a concern below Fish Hatcheries and sewer discharge areas, or other point source discharge permit sites, if they are discharging animal wastes. That's usually where the sources are and those sites are considered a part of the point source discharge regulations and must be under a permit to operate. Non point agriculture contributions to those levels have not been documented, and are usually lumped by EPA and the authorized state agency (authorized to handle water pollution under the Clean Water Act) with natural background conditions.

APPENDIX B

Management Practices for Agriculture

Adaptive management practices are practices that are the product of best available science which have come about through research and studies that meet the criteria described in WAC -365-195 900 through 925, Guidelines for Identifying best science available.

In many of the land grant university systems a Cooperative Extension System has been incorporated as an educational outreach program. The Extension Services provide a mechanism for University research programs to reach the general public for whom the research is being conducted. The Extension personnel act as the intermediary and a "translator" of research results so that those who will benefit from the new knowledge can apply tested theories to their operations.

Extension publications are valuable tools for people when assessing land management practices. The publications are guides for local activities based on a regional area. These guides are intended to be a tool so that a land manager can assess the value of the information for different sites. A management practice may be useful in one area, but not useful in another only a few miles away. A single practice is rarely suggested as being one that will work everywhere all the time. Instead "practices" are described as useful in a number of situations depending on the goals of the land manager. There are many practices that can be used in an area, which allows choices for a practice based on the objectives the manager wants to meet, as well as consideration of the site specific characteristics.

Extension Service information can be put into categories of practices recommended as being "sound" for the different kinds of management activities. The term "best management practices" is sometimes used to describe the information and sometimes it is published as a summary of the "state-of-the-art" knowledge on a specific topic. Following are some examples of practices published by Extension offices across the United States. While some refer to a specific situation in a state, the practices can be applied elsewhere.

GRASS AND PASTURE MANAGEMENT

M. J. Trlica. Grass growth and response to grazing. Colorado State University Extension. Ft. Collins, CO. #6.108.

Grazing strategies

Develop flexible grazing management strategies that allow plants a rest or deferment after grazing.

This is necessary for regrowth and to maintain sufficient leaf area for growth and maintenance. Heavy grazing throughout the growing season usually is the least desirable grazing strategy. A management strategy that incorporates rest periods and movement of animals through different pastures usually is more desirable for grass growth than season-long grazing. If you know the amounts, kinds, and locations of available plants (cool- and warm-season grasses), and what grasses grazing animals prefer, you can develop a strategy that meets the needs of plants and animals.

Management plans should utilize the forage resource and maintain it through time. Grazing plans, however, must be flexible. Consider differences in growing conditions among years as a result of drought or wet cycles, depletion of forage supply by wildlife or insects, and other rapidly changing environmental conditions. Consider these along with the impacts of grazing livestock, to determine what effects the combined impacts will have on plants.

Try to avoid rigid plans that require moving animals from one pasture to another on given dates. Other environmental factors certainly will influence grass growth and utilization at any point in time. Base your decision to move stock on how much the grasses are used and how much green leaf material remains; not a predetermined date.

University of Maine Extension Service. This old hayfiled: a fact sheet on hayfield renovation. #2491. <http://www.umext.maine.edu/onlinepubs>.

The hayfield renovation process depends on many factors: site characteristics, goals for the site and resource available. To better understand what needs to be done to renovate a hayfield, a review of what happens to neglected land is provided.

Eck, Kenneth J. Vegetated Filter Strips for Improved Water Quality. Vegetated filter strips for improved water quality. AY-285.

Filter strips are areas of vegetation bordering a body of surface water. Seeded with close-growing plants, such as grasses or legumes, filter strips protect surface water from eroded soil, nutrients, chemicals, and organic materials. Plants in the filter strip slow water runoff, which reduces the water's ability to carry pollutants. Potential pollutants, especially those associated with sediment, are deposited before they reach surface water. Filter strips also preserve highly erodible ground often found near moving surface water.

Filter strips are a "best management practice" (BMP) near field boundaries or within fields near water sources or inlets. They are often used along with practices such as conservation tillage, pest scouting, crop rotations, strip cropping, soil testing, contour tillage, riparian zones, and proper nutrient and pest management to improve water quality. Many state and federal agencies recommend filter strips as an agricultural and urban best management practice because of their potential environmental benefits.

Benefits

Filter strips often provide unrealized economic benefits; possibly returning more than traditional field crop production. Filter strips planted to marketable hay or forest species, or used for very limited grazing, can easily recover much of the construction and maintenance expenses. Where good markets exist for alternative products, such as timber or hay, filter strips may prove more profitable than a corn/soybean rotation. Property taxes may be waived for filter strips located along legal drainage ways, although the filter strip can not be used for profit and must fall within a county's legal right-of-way (consult your local assessor's office for full details). Federal and state programs, such as the USDA Conservation Reserve Program, may increase the economic feasibility

of filter strips in more environmentally sensitive locations.

Additional benefits of filter strips:

- year-round access to land for farming operations
- improved drainage through access to ditches and tile outlets
- increased safety through more stable stream banks and ditches
- wildlife and hunting areas
- natural beauty

Franti, Thomas G. Bioengineering for hillslope, streambank and lakeshore erosion control. Nebraska Cooperative Extension, Institute of Agriculture and Natural Resources, U. Nebraska. Lincoln, Nebraska. #G96-1307-A.

The NebGuide describes bioengineering techniques for hillslope, streambank, and lakeshore erosion control. Tips for a successful bioengineering installation and demonstration project are described.

Borman, Michael. July 2001. INTERACTIONS BETWEEN WEEDS, NATIVE PLANT COMMUNITIES, AND GRAZING. Oregon State University Rangeland Resources. Grazier. OSU Extension. No. 309

Livestock exclusion does not stop weed encroachment. Appropriate, light to moderate, cattle grazing should not accelerate weed encroachment. Small ruminants, sheep and goats, can be used as tools to selectively graze and suppress weeds. Livestock provide a direct economic return. Other weed control measures do not. Any grazing program must be part of an overall integrated weed management program.

An excellent reference is: "Biology and Management of Noxious Rangeland Weeds" edited by Roger Sheley and Janet Petroff, available through Oregon State University Press, Corvallis, Oregon.

Borman, Michael, and Larry Larson. November, 2001. Cottonwood Establishment, Survival, and Stand Characteristics. Oregon State University Rangeland Resources. Grazier. OSU Extension. No. 310.

Cottonwood establishment is largely determined by reach type and stream flow. Thus, high flow along one reach of a stream may promote cottonwood establishment while an equivalent flow along a second reach may scour away established cottonwood (Everitt 1968, Bradley and Smith 1986). Differences in geology, elevation, climate, and tributary influences can exist between two reaches of the same stream (Frissell 1986). Because of the difference in dominant fluvial processes, cottonwood distribution will also be different along different reaches of the same stream.

The riparian corridor is a complex mosaic of moisture and disturbance patterns. Plants that form communities within those corridors survive on sites where their basic requirements for establishment, growth, and reproduction are being satisfied. It is obvious that restoration efforts in riparian areas require an understanding of both the environmental mosaic and the life history/adaptations of riparian species.

Cottonwood establishment is largely determined by reach type and stream flow. Differences in

geology, elevation, climate, and tributary influence can exist between two reaches of the same stream. Because of the difference in dominant fluvial processes, cottonwood distribution will also be different along different reaches of the same stream.

Cottonwood can tolerate substantial flooding, but not to the same extent as many herbaceous riparian species. Cottonwood trees are often associated with soils that contain a layer of coarse substrate, which drains more quickly than fine-textured soils, providing a quick return to aerobic conditions. Cottonwood trees survive flooded environments through anaerobic respiration, the production of shallow adventitious roots, and the presence of lenticels along the stem and root crown.

SOILS AND NUTRIENTS

Karen Mancl. Nitrate in Drinking Water. University Outreach and Extension, University of Missouri.

Nitrate (NO_3) is the primary source of nitrogen (N) for plants; it is a nutrient they cannot live without. Nitrates are naturally occurring in soil and water. Extensive farming can rob the soil of its natural nitrogen source, so farmers often add nitrate fertilizers. Properly managed, nitrogen does not endanger health and can increase crop production. However, when more nitrogen is added to the soil than the plants can use, excess nitrate can leach into groundwater supplies and contaminate wells. On-site sewage systems (such as septic tanks and lagoons) also can be a source of nitrate pollution. Because nitrate is converted to a very toxic substance (nitrite) in the digestive systems of human infants and some livestock, nitrate-contaminated water is a serious problem.

Ruminant animals (such as cows and sheep) and infant monogastrics (such as baby pigs and chickens) also have nitrate-converting bacteria in their digestive systems. For this reason, nitrate poisoning affects them the same way it affects human babies. Because adult monogastrics generally do not have nitrate-converting bacteria, they are not affected by methemoglobinemia. Horses, however, are an exception. They are monogastric, but they also have a cecum, which is similar to a rumen. The nitrate-converting bacteria living in the cecum increase the risk of nitrate poisoning.

Barbarick, K.A. Soil: Nitrogen sources and transformations. Colorado State University Extension. Ft. Collins, CO. no. 0.550

Nitrogen in the air is the ultimate source of all soil nitrogen. Nitrogen may enter the soil through rainfall, plant residues, nitrogen fixation by soil organisms, animal manures and commercial fertilizers. There is no difference between the nitrogen that enters the plant from commercial fertilizers and that from organic products. Nitrogen may be lost from the soil by plant removal, volatilization, leaching or erosion. leaching of nitrate is a pollution hazard; control losses of nitrogen with proper management practices.

Nitrogen Loss

Nitrogen may be lost from the soil by plant removal, denitrification, leaching, volatilization and erosion.

The first alternative, absorption by crops, is the desired goal. Erosion losses of N can be significant. The loss of 10 tons of soil/acre/ year with 2 percent organic matter can result in a loss of 20 pounds of N. Leaching can contribute to ground and surface water pollution problems.

Loss of nitrates by leaching is undesirable from all standpoints. The loss is minimized and crop utilization maximized by proper management practices:

- Split the applications of nitrogen on sandy or shallow soils where leaching or erosion hazards are greatest and when heavy rates of nitrogen are required.
- Apply nitrogen during the growing season (not in the fall) on soil subject to leaching and erosion.
- Apply the proper amount of nitrogen and other plant nutrients for vigorous crop growth. Base this on a soil test.
- Use good soil conservation techniques to minimize erosion losses of topsoil.

Johnson, Gordon. Nitrates in Soil and water. Oklahoma Cooperative Extension Service. Division of Agricultural Sciences and Natural Resources. Oklahoma State University. #F-2242.

It should be clear that fertilizer use and nitrate levels in groundwater are not associated by a direct cause and effect relationship. Present nitrate in groundwater may be a result of ancient, natural excesses of nitrate in soil as a result of disturbances of the biological nitrogen recycling. Modern technology has provided agriculture with the tools to safely manage nitrogen to minimize risk of polluting domestic water supplies. Nevertheless, efforts will continue to identify sources of pollution and management strategies to eliminate them.

Waskom, Reagan M. 1994. Best Management Practices For Phosphorus Fertilization. Colorado State University Cooperative Extension. Ft. Collins, CO. #XCM-175.

Water quality problems associated with phosphorus are generally confined to surface water. Phosphorus in most Colorado soils is tightly held to soil particles and does not leach. However, the P held in organic phases from residues such as manure can dissolve in water and be lost if improperly managed. Adsorbed P on soil particles can cause surface water contamination as P containing sediments move off the land in agricultural runoff. When large amounts of nutrients enter lakes and streams, they accelerate the natural aging process, or eutrophication, by enhancing the growth of algae and other aquatic weeds. As these plants flourish, depleted oxygen and light reduce the survival of more desirable species and the natural food chain declines. Eventually, impounded waters such as lakes, ponds, and reservoirs become overgrown with aquatic vegetation and, in a sense, die.

BMPs are recommended methods, structures, or practices designed to prevent or reduce water pollution. Implicit within the BMPs concept is a voluntary, site-specific approach to water quality problems. Development of BMPs in Colorado is being accomplished largely at the local level, with significant input from chemical applicators and other local experts. Many of these methods are already standard practices, known to be both environmentally and economically beneficial.

Lilley W.D. and R. Merchant. The Forest nutrient cycle: Forestry notes. University of Maine Cooperative Extension. #7029.

There are major factors required for plant growth---sunlight, water and nutrients. Each factor is also renewed: sunlight, daily; water, usually every week or two; and nutrients anywhere from several to hundreds of years. The key to an adequate supply of nutrients is the nutrient cycle, which store nitrogen, phosphorus, potassium (N,P,K) and other elements.

Schmidt, J.L. B.F. Wolfley. Protecting groundwater: managing livestock on small acreage.

WSU Cooperative Extension. Pullman, WA. pp 11. eb1713.
<http://cru.cahe.wsu.edu/CEPublications>.

Management practices can reduce water pollution from farms and contribute to the overall improvement of water quality. Sound livestock management keeps contaminants such as sediments, fertilizers, animal waste, and pesticides out of water sources. Best Management Practices can improve or protect surface and groundwater quality. Farm owners can carry out BMPs on a long term basis to maintain the productive life of the farm.

LIVESTOCK & PASTURE MANAGEMENT

Adams, Edward B. Riparian Grazing. Clean Water for Washington. WA State Cooperative Extension. Pullman, WA. p 9. EB1775.

A discussion of Riparian areas, the use of the areas for grazing, practices and management tools,

Undersander, D., Beth Albert, Pamela Porter, Alan Crossley, N. Martin. 1997. A3529 Pastures for Profit. Univ. of Minnesota and Wisconsin-Extension. Madison, WI. pp 35.

Under rotational grazing, only one section of pasture is grazed at a time while the remainder of the pasture "rests." To accomplish this, pastures are subdivided into smaller areas and livestock are moved from one pasture to another. rotational grazing allows forage to renew energy reserves, to rebuild plant vigor, and to give long-term maximum production.

Faries, Jr. F.C., J.M. Seeten, and J.C. Reagor. 1998. Water quality: Its relationship to livestock. Texas Agricultural Extension Service. Texas A&M University System. L2374.

To evaluate water quality in relation to livestock health problems it is imperative to obtain a thorough history, make accurate observations, ask intelligent questions and submit suspected water and properly prepared tissue specimens without delay to a qualified laboratory. Obtain assistance from a local veterinarian, county Extension agent or a Veterinary Medical Diagnostic Lab.

Baker, T.T., J.C. Boren, C.D. Allison. Strategies for Livestock management in riparian areas in New Mexico. Cooperative Extension Service, New Mexico State University. Guide B-119.

The impact of cattle grazing on riparian ecosystems depends largely on the grazing management practices. It is important to remember that there is not one, single, grazing system because each situation is unique and requires its own management system. The only way to know if a management system is meeting the goals for a particular site is to monitor the effect of management activities. Therefore, riparian grazing plans should be site-specific and based upon available research and current monitoring.

Larry A. Redmon. Grazing Systems for Pastures. Oklahoma Cooperative Extension Service • Division of Agricultural Sciences and Natural Resources. F-2567

Thoughts on Grazing Systems

The key to proper grazing management is to obtain a balance between animal diet selectivity and harvest efficiency; the "right" system will vary between locations and producers. Close attention should also be paid to matching livestock nutrient requirements with forage availability. Using either a continuous or rotational grazing system can result in the optimum use of available forage, acceptable animal performance, and thus, a profitable livestock operation depending on the producer's managerial expertise.

Producers considering changing the type of grazing system of their operation, or producers who may just be getting into livestock production should:

- 1) Think through the process with respect to their expectations and inputs required for each system and,
- 2) Seek an optimum balance among harvest efficiency, resource conservation, individual animal performance, and, most importantly, the economic returns from the enterprise.

The most significant aspect of a grazing system, however, is to provide grazing livestock with an adequate amount of forage of high nutritive value. This requires choosing the proper forage species for grazing, a sound soil fertility program, and the proper stocking rate. If you require further information about which of the grazing systems offers the most potential for your livestock production operation, contact your local county agricultural agent.

Rayburn, Edward B. 1992. Forage management. Principles of grazing management. West Virginia University Extension Service. 5710-5711.

When managing a pasture, a producer needs to stem reserves for regrowth. In some grasses where reserves are stored in the lower leaf stem, close grazing will physically remove energy reserves and slow regrowth. On the other hand, in some plants the lower leaves at the base are older and inefficient in photosynthetic activity.

If these leaves are removed through close grazing, new more efficient leaves are allowed to grow. With some forage species low stubble or root reserves are maintained and leaves must be left to provide the energy for regrowth.

Larson, Larry and Michael Borman. July 2001. AN EXAMPLE OF A RIPARIAN VEGETATION MOSAIC. Oregon State University Rangeland Resources. Grazier. OSU Extentsion. No. 309

In the May 2000 and October 2000 issues of the Grazier we discussed factors that influence the establishment and survival of plants within riparian corridors. We observed that the periodic occurrence of flooding, erosion, deposition, and drought directly influence plant composition and that knowledge of plant adaptations will help interpret the site potential of a riparian corridor. The purpose of this article is to illustrate the geomorphic, soil, and vegetation patterns that occur along the Burnt River between Unity reservoir and Bridgeport, Oregon as an example.

McInnis, Michael L. March 1997. PRINCIPLES OF SUCCESSFUL LIVESTOCK GRAZING IN RIPARIAN ECOSYSTEMS. Oregon State University Rangeland Resources. Grazier. OSU Extentsion. Number 291.

Livestock production can be compatible with riparian ecosystem management. The key is to design and implement thoughtful management strategies that incorporate the following components: (1) clearly defined objectives; (2) implementation of management activities based on scientific principles to meet these objectives; (3) site-specific monitoring to appraise whether the objectives are being met; and (4) alteration of management activities if they are not meeting objectives.

The four key components of a successful livestock grazing plan are: (1) clear, specific and measurable objectives; (2) practical and science-based management activities to meet these objectives; (3) a monitoring program to evaluate effectiveness of management activities; and (4) willingness and ability to alter management strategies that do not result in desired outcomes.

Livestock grazing can be compatible with riparian ecosystem management. Successful livestock grazing in riparian areas means implementing science-based management strategies to meet specific objectives; monitoring effectiveness of management activities; and changing management activities when they fail to yield desired results. Goals of successful livestock grazing should include maintenance or improvement of riparian ecosystem functions and meet production goals of commodity users. Management activities should be based on the principles of grazing management as they relate to plant ecology, plant growth, riparian geomorphology and hydrology, and animal behavior. As Krueger (1996) observed: "when this is done with full involvement of all the people affected by the management program, successful grazing programs can be developed, because people will support what they create themselves.

George, Mel, Royce E. Larsen, vNeil K. McDougald, Kenneth W. Tate, John D. Gerlach, Jr. Kenneth O. Fulgham. 2004. Cattle grazing has varying impacts on stream-channel erosion in oak woodlands. *California Agriculture*. 58:3: 138-143.

We conducted a 5-year study on the impact of grazing on stream-channel bare ground and erosion, and a 3-year study of cattle-trail erosion on intermittent stream channels draining grazed oak-woodland watersheds. While the concentration of cattle along stream banks during the dry season resulted in a significant increase in bare ground, we were unable to detect stream-bank erosion resulting from any of the grazing treatments applied. However, we did find that cattle trails are an important mode of sediment transport into stream channels. While cattle trails are common on grazed rangeland, excessive trailing often indicates that stock watering points are too far apart.

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4.

REPORT 2001-2002 DATA
Skagit County Cattlemen Stream Study

Prepared for the Skagit County Cattlemen

by

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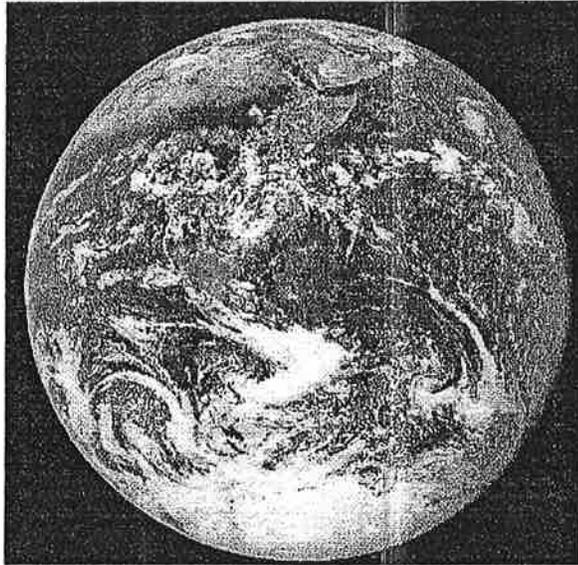
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*** Version: March 2003 will be revised through requested edits.



Welcome to Planet Earth
Credit: Apollo 17 Crew, NASA

Introduction

Earth, third planet from the Sun is sphere shaped and composed mostly of rock. The Earth's surface (land and water) is 196,938,800 square miles and can roughly be divided into 1/3 land mass and 2/3 water. The planet receives energy from the Sun which is distributed through an atmosphere that maintains an energy balance that sustains all living systems.

The atmosphere has more than a minor influence on the surface temperature; it has a profound one. In the absence of an atmosphere the earth would average about 50 °F lower than it does at present. Life (as we now know it) could not exist. About 30% of the solar energy reaching Earth is reflected,; it never helps heat the Earth. Another 20 % is absorbed at various heights in the atmosphere and about 50% of the incoming solar radiation reaches the ground and oceans where it is absorbed as heat. The energy transfer down into the ground occurs through a slow process of heat conduction. During the day the ground absorbs solar radiation, is heated, and in turn heats the air in contact with it and at night as the ground cools the air closest to the surface cools also (Sellers, 1965).

The surface of the Earth receives it's energy from two sources: the sun and the atmosphere. The atmosphere emits radiation for the same reason the sun does: each has a finite temperature. Earth receives nearly twice as much energy from the atmosphere as it does from the sun. Even though the sun is much hotter, it does not cover nearly as much of the sky as does the atmosphere. A great deal of radiation coming from the direction of the sun does not add up to as much energy as the smaller amount of radiation coming from all over the sky (Bohren, 1988) .

Water is fundamental to life and Earth is the only planet in the Solar System where the present surface temperature and pressure allow the three forms of water, solid (ice), liquid (ocean), and gas (water vapor condensing in clouds) to exist simultaneously. Due to the abundance of water it has been used as a standard for a variety of units of measure. The Celsius temperature scale was developed using the triple point of water where all 3 phases of water (liquid, solid, and gas) exist. The calorie (a unit of heat) is based on the amount of energy it takes to heat 1 gram of water 1 °C which determines the specific heat of other elements such as air and soil. The specific heat of a material doesn't depend on the size or shape of the objects made from the material.

For example, the specific heat of water is 1 and air is 0.24; meaning it takes 0.24 the amount of energy to increase air temperatures 1 °C than it takes to increase 1 gram of water 1 °C which allows for consideration about the amount of time needed to heat and cool the two materials (Kirkpatrick and Wheeler, 1995). Water requires 4 times as much energy to increase temperatures 1° than is needed to increase the same volume of air 1 °. Water temperature increases do not occur instantaneously nor do temperature decreases.

Knowing these facts about the energy cycle and solar radiation (based on facts that meet the “best available science” criteria WAC-365-195-900 through 925) , energy exchanges between the atmosphere, land and water can be examined. Energy exchange is described by The First and Second Law of Thermodynamics. These laws tell us that we can transform but not create nor destroy energy and that energy exchange occurs from areas of high temperature toward areas of lower temperature. The laws also state: if $a = b$ and $b = c$, then $a = c$. This equation is important for describing equilibrium in systems, which is basic in using thermometers as instruments that record the increase and decrease in energy of the substances being measured (Haliday and Resnick, 1988).

It is easy to demonstrate that when two objects are put in thermal contact, the object with the higher temperature cools while the cooler object becomes warmer until a point is reached after which no more change occurs. When the thermal changes have stopped, we say that the two systems are in thermal equilibrium. “If three or more systems are in thermal contact with each other and all in equilibrium together, then any two taken separately are in equilibrium with one another”(quote from T. J. Quinn's monograph Temperature).

A thermometer is an instrument that measures the temperature of a system when it is in thermal equilibrium with the system.

Over the years a lot of interest has developed about the temperatures of streams in watersheds due to the Endangered Species Act listing of salmon. Thermometers have been widely used to record daily temperature cycles to assess if the waters are thermally polluted and harmful to Salmonid life stages. Stream water exceeding a 7 day average of the maximum temperatures of 64 F has been used as an indicator for regulatory concerns and is often categorized as being thermally polluted.

Skagit County contracted to have a literature review written (NRC 2000) to identify the “best available science” regarding protection for salmon in the Skagit and Samish River basins. The NRC report cited a number of studies from which the County has concluded “ambient stream temperatures in a given stream reach primarily reflect the combined temperatures of the upstream waters as affected by solar radiation (seasonal and diurnal), ambient surface temperatures (runoff) and subsurface (groundwater) flows. The net rate of gain or loss of heat (thus temperature) as it moves through a landscape is determined by net solar radiation, evaporation, convection, conduction and advection (horizontal movement of a mass of fluid). The relative importance of each of these factors is determined by environmental factors such as cloud cover, ambient air temperature, the geometry of the stream (shallow/wide versus narrow/deep) and flow magnitudes” (Skagit County, 2003).

Of particular interest in these statements is “the net rate of gain or loss of heat (thus temperature) as it moves through a landscape is determined by net solar radiation, evaporation, convection, conduction and advection”. The statement is in reference to a well known “energy balance” or “heat flux” equation: $\text{Energy} = \text{solar radiation} + \text{evaporation} + \text{convection} + \text{conduction} + \text{advection}$.

The “energy balance” equation could be applied to water studies conducted in a laboratory, but has not been used in field studies. To apply the equation on a flowing stream a number of instruments

would be needed to quantify the immediate area solar radiation, evaporation, convection etc. and more than one site would be needed to account for variations between places. The equation has most often been used as a component of numerous stream temperature modeling exercises. These computer models attempt to predict stream temperatures by simplifying the system and "fiddling" and manipulating the equation parts. Use of a "heat budget" equation for this type of work is appropriate because the models are intended to derive the final temperature of water at a specific time. To ensure that the model is "close" or reasonable to what is taking place in the stream being modeled, thermometer data is used for comparisons. At no time are instruments that measure solar radiation, convection, advection, conduction etc. ever taken to the stream to determine if the quantities inserted into the model are accurate.

The Skagit County Cattleman's study used thermometers on streams to record the amount of energy present in streams, and relied on a different equation to assess the data. The equation is: change in temperature = temperature A (recorded at time 1) - temperature B (recorded at time 2). The equation result does not address how the energy arrived in the stream but quantifies whether the temperature increased or decreased and by how much. No part of the data describes the components of the heat budget equation.

The rise of average surface-air temperatures typically lag 4-8 weeks behind the period of maximum solar radiation (summer solstice), shifting the period of maximum summer heating from June into July and August (Trewartha, 1968). In the Pacific Northwest, an example of the redistribution of summer heat can be observed when pressure systems, originating in southern California, migrate northward, generating daytime high temperatures of 100°F as far north as British Columbia. Similarly, an "arctic express" during the winter can produce below 0°F temperatures as far south as New Mexico and Texas.

If all of Earth's water was represented in a quart jar, the oceans would take up 97% of the water in the jar. Freshwater would be 2 tablespoons of water remaining. Some of this water is in the form of ice and some is underground. The amount of water in the lakes and rivers out of the 2 tablespoons of freshwater would amount to 2 big drops of the water. 1 drop of the water would represent the amount of water in both the soil and air. Ocean water, covering 2/3 of the Earth affects the global air masses which bring a variety of weather changes as they move across land masses.

A river running through a watershed is very small compared to the area that a local climate event can cover. On a watershed scale, both air and soil serve as thermal reservoirs that are directly influenced by global patterns of heating and cooling. These reservoirs are large in comparison to flowing streams and one would anticipate that the temperature of the layer of water would be dependent upon, not independent of the air mass over the stream and the soil mass beneath it.

During late spring and summer, air typically warms during the day to temperatures that are greater than the temperature maintained beneath the soil surface. The water and soil, having a lower temperature receive energy mostly from atmospheric radiation as a day progresses. Air temperature can be used as an indicator of the thermal environment of the watershed and when water temperatures are compared to the air data, a number of tests can be conducted to determine if the water temperature increases are skewed due factors outside of the expected natural thermal profile.

The Laws of Thermodynamics explain that the flow of energy in a watershed is from the warmest reservoir of energy to coolest reservoir (Kirkpatrick and Wheeler, 1995). The laws describe the rate of energy transfer through determination of the "thermal gradient" that sets up between the warmest and coolest reservoir. This can be demonstrated using air temperature and water temperatures recorded on thermometers each hour of the day. In Figure 1 the "thermal gradient"

can be determined for each hour by subtracting the water temperature from the air temperature. When the difference between the air temperature and the water temperature is large the rate of water heating is more rapid than when the difference is small. When thermal gradients are averaged over 12 hour periods throughout the spring and summer seasons, streams located in different places will have similar average gradients and similar rates of heating (Larson and Larson , 2001).

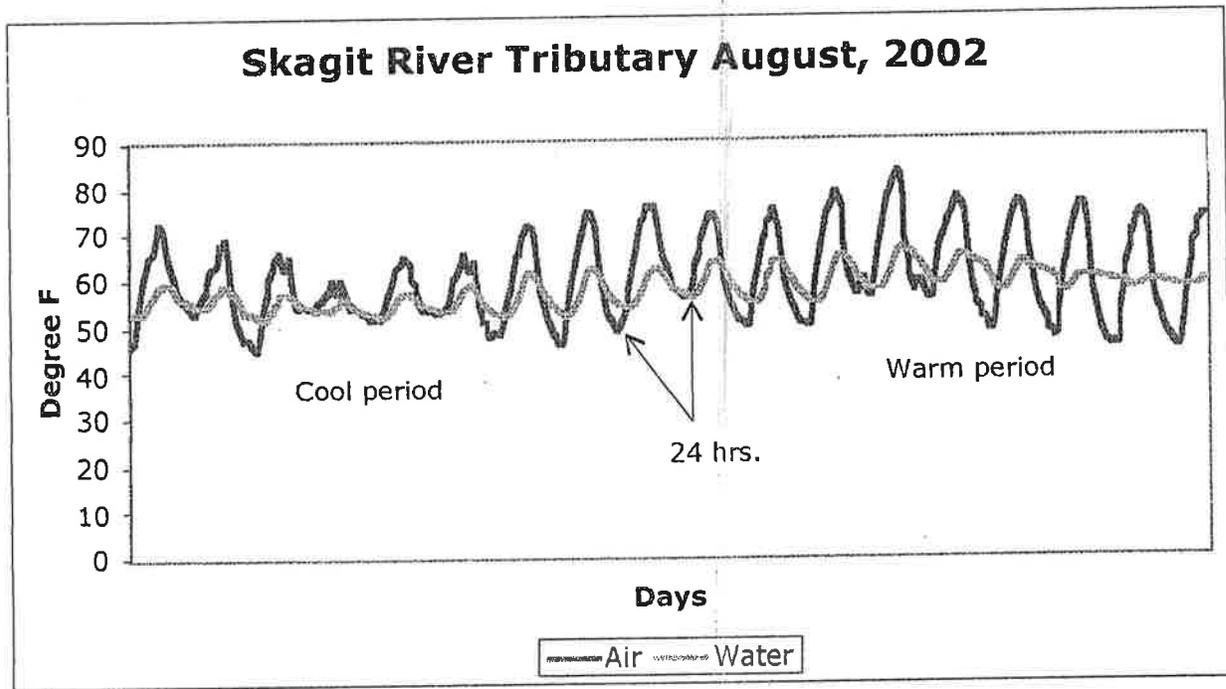


Figure 1. The Skagit River tributary thermal cycle is typical of other streams in the Skagit and Samish River basins. During a cool period water temperatures have less variation compared to warm periods. Water temperature patterns follow the heating and cooling patterns that reflect the natural background conditions for the area.

Temperature increases during the summer period have been used as an indicator of poor water conditions for fish and there have been accusations that agriculture practices contribute to high water temperatures: crops remove shade from streams during field preparations, livestock browse and trample vegetation thus limiting tree recruitment and tree growth. Studies have established the "natural" heating cycle for streams in the Pacific Northwest through statistical analyses of data collected using thermometers. Some published articles about stream heating and shade have concluded that shade is needed to prevent streams from heating, but the studies rarely collected data at a number of sites using air, water, and soil temperatures. Others failed to collect data and instead relied on computer simulations to express an outcome.

The Washington state standards are compared with stream temperatures using a 7 day average of the daily maximum temperature. The rest of the data is ignored resulting in a very limited view of the actual conditions in a watershed. The 7 day average is an exploratory statistical test performed on the data sets that lack a rigorous comparisons against the standard using statistical tests.

It is important to analyze stream temperatures throughout the day and during each month of the spring and summer season. If a stream is heating and cooling within the background conditions of a watershed a foundation of understanding about the system can be established. The data then becomes valuable in understanding many other parameters that are measured to determine water

Summary and Conclusions

1. The Samish River and tributaries above the fish hatchery are not on the Washington 303(d) list for water quality impaired streams. In the Skagit River system some streams are listed for temperature, but none are listed as being impaired due to excessive nutrients, pH, dissolved oxygen, or sediments. The results of the data analysis for water and air temperatures collected during this study period conflict with the 303(d) list designation. Through statistical comparisons of data we found no differences between streams on days with similar thermal gradients. The stream temperature patterns followed very closely the patterns of air temperature which were influenced by the local climate over the area during the testing. Water temperatures were determined to be within the range expected under natural thermal cycles as described by Halliday and Resnick (1988) and applied in Larson and Larson, 2001. The observations were similar to those identified by Stoneman, C.L. and Michael L. Jones.(1996) and Zwieniecki, M.A. and M. Newton (1999).

Air temperatures are lower than water temperatures during the overnight periods. A negative thermal gradient exists between the air temperature and water temperature at 5 am. The Chi Square tests provide a means to assess if water temperatures are influenced by solar radiation between dawn and 9 am when heating of the environment begins. If solar radiation was a significant influence on water temperature we would expect to see water temperature increase at rate nearly equal to air temperatures. We did not detect this trend. On many segments water temperatures remained constant until after 9 am each day. Overall water temperatures during 12 hour periods increased 2-5 °F on a daily basis.

We found that no water temperature increases were measured until the air temperatures exceeded an average of 12-15°F. Once the air temperatures had increased this amount, the thermal gradient was large enough to affect the water temperatures which is consistent with the Thermodynamic Laws.

- Application of thermodynamic principles produced results that were consistent at each site during all years. Rates of heating at each site were similar and consistent with thermal gradients. A summary of the expected rates and gradients for the Skagit and Samish River basins were calculated using a mathematical analysis of the physical attributes and illustrates a pattern of thermal cycles due to natural background conditions. The method provides a way to examine stream temperatures in a consistent way regardless of the location. The chart in Figure 3 has been replicated in many other watersheds in Oregon and Washington and demonstrates the ubiquity of the Thermodynamic Laws. (Larson and Larson, 2002, 2001). Other factors affecting water temperatures were not detected.

2. Screened material from the stream beds sorted by size gave no indication that sediment was entering the stream due to land activities. Generally the smallest grain sizes found in substrate samples in both the Skagit and Samish basin streams were in the sand size category. Erosion due to runoff from agriculture lands was not detected at any of the sample sites during 2001 or 2002.

Soil types were identified using the Skagit County Soil Survey published by the USDA Natural Resource Conservation Service. Major soil series were identified as Cokedale, Larush, Pilchuck, Samish, and Wickersham within the study area that are located near the basin streams. Runoff from these soils due to erosion above the expected background erosion rates would likely be found in the streambed containing silt and clay particles in amounts exceeding that found in the soil types.

Skagit County Cattlemen are familiar with the many references that suggest erosion from agriculture land is a problem on most streams in the Pacific Northwest. However, these reports do not address actual measurements of the stream bottom material. Either the authors speculated that the erosion and runoff are occurring or they based their statements on ocular survey summaries that

failed to make any site specific measurements. Agriculture lands in the study area are being managed with best management practices suitable for the local areas and production goals. Statements that agriculture activities in the study area do not protect fish and/or habitat are in error. The lack of sediment in the streams is evidence that full protection is taking place.

3. Nitrogen can enter the water is from an excessive source of nitrate in the soil. Most forms of Nitrogen are tied up by clay particles in the soil and cannot become soluble. Nitrate is a water soluble form of nitrogen. If nitrates are present in the soil and runoff is excessive the nitrates can be picked up in the runoff and eventually reach a stream in sufficient quantities and concentration to be detected.

4. Crops cannot use phosphorus from one season to the next because it is unavailable and so little can be retrieved from the soil. Phosphorus applications are made to land in many areas each year and if applied in excessive amounts that can't be used by the plants on site, it can become soluble. When the form of phosphorus is soluble, phosphate, it is nearly always due to a natural background source or it is a sewer or septic system that is the source. Ag lands are the least likely to be contributing to a phosphate contamination because fertilization with phosphorus is usually done at a rate that meets the needs of the plants on the site which use it for growth. Phosphorus is easily tied up by soil particles so the time period between application and plant use is short.

5. When urine, feces, and vegetation are present in water, microbes and insects use them as nitrogen and phosphorus sources for their bodies and excrete excess as waste. In general none of the above processes is a problem for fish except under certain conditions. Fish protection from nitrate or phosphate contributions from agriculture lands in the Skagit and Samish River basins is taking place because there are no concerns about "pollution" from these sources.

The 2001-2002 data collection and analyses did not find N or P at levels that indicated runoff is taking place in frequency or volume that would be needed to be considered a non point source contribution. The levels found in this study indicate that stream water is not polluted due to the agriculture activities in the study area. There were no differences found in the water samples when examined between years. Levels of nitrate and phosphate present in the streams appear from all information gathered for the study to be at a natural background level. Protection of salmon habitat is taking place regarding this type of pollution. None of the testing sites were noted as having an algae problem which would be another indicator of nutrient input concerns.

6. Tree species covered a broad range and were typical of vegetation noted as occurring on the different soil types for the area. Alder and maple were dominant with abundant leaf litter, ferns, horsetail and various small forbs. Western red cedar dominated some sites which produced little ground cover in the way of grasses, forbs, or litter other than needle drop. Cottonwood and alder sites were included which produced an open canopy allowing small alder clumps to become established with horsetails, juncus spp. and reed grasses. Blackberry shrubs were a common barricade between pastures and the stream banks.

Tree diameters throughout the basins ranged from 3 inches to 44 inches and had heights of 40-80 feet. Sites on soil types that support trees and shrubs were generally fully stocked with a variety of size and species of plants. Sites without a tree component were fully stocked with grass species and shrubs.

A properly functioning landscape should contain the full range of plant species composition and structure. The existing vegetation management is yielding a desired mosaic of vegetation with the expected composition and structure for each soil type. These conditions are present in the Skagit and Samish basins.

7. Focus on individual stream reaches has limited the accuracy of many studies. Study designs have underestimated sampling error and have not addressed the comparative importance of different parts of a basin. This study examined two basins in Skagit County and did not find pollution to be a concern in the mainstem Skagit or Samish Rivers or the tributaries. The study incorporated the standard methods of sampling and statistical analyses of the data sets collected over 2 years. There were no differences between years when temperature, streambed substrates, nitrates and phosphates, and riparian vegetation areas were examined.

8. Assertions that an addition of riparian vegetation to facilitate shading on the Samish River in order to prevent stream water warming is not supported by the testing results and is not supported by the Laws of Thermodynamics. From all observations and analyses during the 2 year study, the Skagit and Samish River mainstems and tributaries have excellent water temperature profiles and there is no evidence that thermal pollution is occurring. Water temperature increases are not equal to the air temperature increases, but are proportional. Thermal gradients established between air temperature and water temperatures throughout the day determine how fast stream water heats. Calculation of the rates of heating indicate that over the 2 years study period, the streams are heating and cooling within the natural background thermal cycles found in the Skagit and Samish basins.

9. Protection for the fish and other aquatic life is excellent and is consistent with the natural background conditions for the watershed. Best management practices (BMPs) used by the agriculture landowners are preventing water quality problems. BMPs are varied throughout the area and have been put in place to meet the production needs while observing the site conditions.

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Mapping Riparian Land Use Agricultural Zones

Skagit County GIS
study shows 80%
forested natural buffer
canopy at 75 feet
for streams in all Ag-
NRL and RRc-NRL zones

Abstract

In 2008, as part of Skagit County's Salmon Policy Resolution (R20070499), Skagit County tasked its GIS Department with performing a land use analysis within Agricultural-Natural Resource Land (Ag-NRL) and Rural Resource-Natural Resource Land (RRc-NRL) zones. Using heads-up digitizing from high-resolution aerial photos, the GIS Department digitized and analyzed 15,000 acres, 9,031 acres of which were within standard buffer distances. We evaluated our compiled information to answer the most commonly-posed questions from past discussions regarding the imposition of riparian buffers on agricultural land uses:

- How much riparian area in Ag-NRL or RRc-NRL zones is already in a forested, grass, or wetland state that would be expected under a regulatory buffer system?
- Of that land, how much is protected from development by conservation easements, public agencies, or conservation organization ownership?
- How much riparian land would be eligible for protection under a habitat acquisition program such as Skagit County's proposed Salmon Heritage Program?

Our analysis reveals that within standard buffer distances, 73% of the area is forest, wetland, or grass. The remaining land uses includes 22% agriculture and 5% developed land or road cover. The amount of vegetated area decreases as buffer widths increase, but the amount of vegetated area that covers significant distances from streams is contrary to conventional wisdom; at 50 feet, nearly 84% of studied stream reaches are vegetated and more than 80% of that vegetation is forest. Even at 100 feet, 76% of studied stream reaches are vegetated and nearly 85% of that vegetation is forest.

Only 22% of the study area within standard buffer distances is agricultural land. Of that 22%, there are 75 acres of publicly-owned land, 42 acres protected by conservation organizations, and 64 acres with no ecosystem functions or values. Together, these three categories, which would not qualify for habitat acquisition programs, constitute 10% of the total agricultural land studied within the standard buffer area. Of the remaining agricultural area, 90% is potentially restorable. The amount of agricultural land in different regions of the County varied greatly from 13% in the Sauk region to 35% in the Nookachamps.

We compared the results of this study with other satellite land use analysis studies of the area and found that courser studies overestimated agricultural land use by as much as 289%. The information compiled from this study is useful for policy discussions and future planning of riparian protection programs.

Skagit County GIS/Mapping
700 S. 2nd Street, Room 202
Mount Vernon, WA 98273
360-336-9368

Variation by Buffer Width

Land use varied with different buffer widths. Within 25 feet of a stream, less than 10 percent of the buffer area was in agricultural use; agriculture was almost 23 percent of the area, however, within 150 feet of a stream. Conversely, within 25 feet of a stream, forest cover accounted for almost 70 percent; however, forest only made up 60 percent of the buffer area within 150 feet of a stream.

Table 5. Percent of buffer in each land use classification for varying buffer widths

Land Use Classification	Buffer area for varying buffer widths				
	25 feet	50 feet	75 feet	100 feet	150 feet
Agriculture	9.49%	12.90%	16.11%	18.84%	22.94%
Natural	87.82%	83.56%	79.6%	76.39%	71.51%
Forest	69.59%	68.20%	65.80%	63.58%	60.03%
Grass	5.67%	5.05%	4.88%	4.78%	4.55%
Wetland	12.56%	10.31%	8.92%	8.03%	6.93%
Development	2.69%	3.58%	4.28%	4.77%	5.56%
Developed	1.24%	1.68%	2.17%	2.60%	3.28%
Road	1.06%	1.51%	1.74%	1.74%	1.68%
Other	0.39%	0.35%	0.37%	0.43%	0.60%

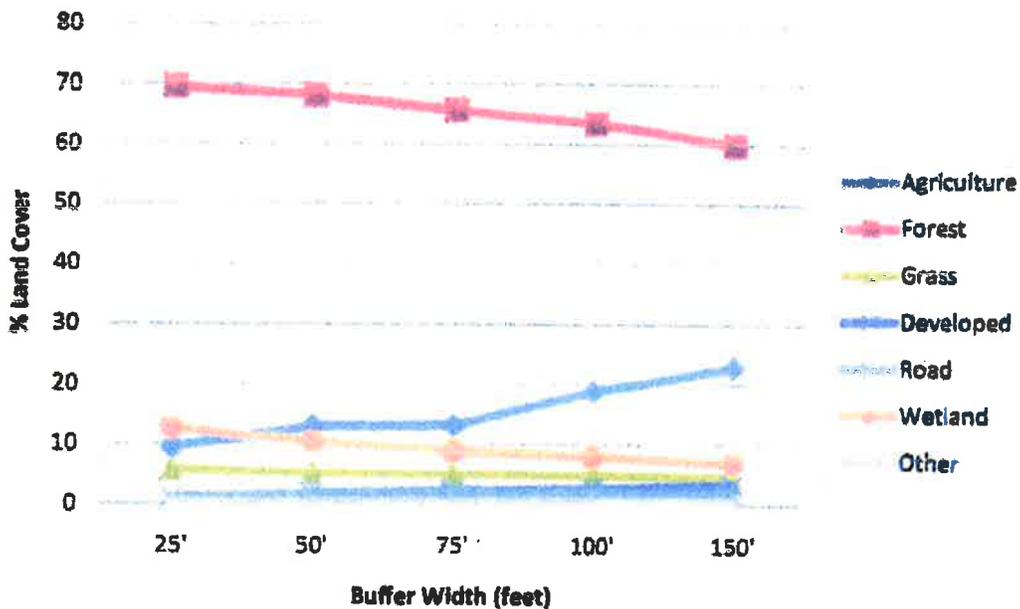


Figure 10. Percent of buffer in each land use classification for varying buffer widths

6. Who's really polluting?

Fecal output loading rate: 1 skunk is equal to 2.3 cows

DNA testing is needed before enforcement.

tration, fecal output dialing loading rate and relative λ in several domestic and wildlife species.

	Fecal output Kg/day		Daily Coordinate oocysts/day	Ratio to Beef
Stein, <i>Bos taurus</i>				
Cows	67	60	4,000	0.7
Calves 5,000	3,000,000,000	1	3,000,000,000	
California Beef Cattle (mixed breeds, <i>Bos taurus</i>)				
Cows	150	40	6,000	1
Calves	150,000	4	600,000	1,000
California Horses (various breeds <i>Equis caballies</i>)				
Adults				
Striped Skunk (<i>mephitis mephitis</i>)				
Adults	2,800,000	0.05	140,000	23.3
Juveniles	4,000,000	0.02	88,000	14.7
California ground squirrel (<i>Spermophilus beechyi</i>)				
Adults	6,500,000	0.012	78,000	13.0
Juveniles	10,300,000	0.004	41,200	6.9
Coyotes (<i>Canis latrana</i>)				
Adults	205,000	0.2	41,000	6.8
Juveniles	505,000	0.7	35,000	5.8
Yellow-bellied marmot (<i>marmota flaviventis</i>)				
Adults	10,400,00	0.02	208,000	34.7
Juvenile				

^a The values are the number of beef cows it takes to equal one of a given species for example. Adult coyotes $41,000/6,000 = 6.8$ beef cows to equal one adult coyote.

ESTIMATING ENVIRONMENTAL LOADING RATES OF THE WATERBORNE PATHOGENIC PROTOZOA, *CRYPTOSPORIDIUM PARVUM*, IN CERTAIN DOMESTIC AND WILDLIFE SPECIES IN CALIFORNIA

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ABSTRACT

Waterborne transmission of the pathogenic protozoa, *Cryptosporidium parvum*, has emerged as an important public health concern. To develop focused strategies to minimize the risk of waterborne transmission of this parasite to humans or animals, a standardized methodology is needed for comparing environmental loading rates for different populations of vertebrate hosts for *C. parvum*. A reasonable approximation for an estimate of the environmental loading rate is to measure the prevalence of infection and the intensity of shedding using cross-sectional surveys of the mammalian population, and then multiplying by an estimate of fecal production. We applied this concept to a variety of livestock and wildlife species found throughout California.

In general we found that regardless of age, striped skunks, coyotes, California ground squirrels, and yellow-bellied marmots were substantial sources of *C. parvum* oocysts. In contrast, only the young stock of beef and dairy cattle were substantial sources of oocysts; adult cattle appear to excrete only limited numbers oocysts relative to either calves or wildlife. Watershed management plans that endeavor to minimize contamination of drinking water with *C. parvum* need to focus on appropriate management of wildlife reservoirs of *C. parvum* in addition to the traditional concern of animal agriculture.

KEYWORDS: *Cryptosporidium parvum*, waterborne, protozoa, zoonoses, cattle, stock, skunks, ground squirrels, rats, marmots, coyotes.

INTRODUCTION

Waterborne transmission of the pathogenic protozoa, *Cryptosporidium parvum*, has emerged as an important public health concern. Because the infectious stage of *C. parvum* (oocysts) is resistant to conventional water treatment processes, public health agencies and water districts are actively seeking methods of reducing surface water contamination with this parasite. Protection of source water such as rivers and lakes has the potential to reduce the risk of transmission to humans and animals through drinking water, as well as through human recreational contact with untreated water. Given that the parasite readily infects a large number of mammalian hosts (Fayer et al. 1997), there are a number of possible contributing sources of oocysts present for any given watershed. Unfortunately,

Apply all the best science for true salmon recovery

Skagit Valley Herald Friday, December 1, 2000

By BILL REINARD

Inconsistencies demand that past and present salmon resource mismanagement end now. State and federal agencies along with tribes must begin responsible and comprehensive salmon recovery based upon all best available science.

Hundreds of millions of state and federal taxpayer dollars are being poured annually into habitat protection and restoration, the Skagit River instream flow rule proposal, restricting pending water rights, excessive farmland buffer demands, studies to breach the five Snake River dams, curtailing marine and freshwater construction projects, etc.

Environmentalists' pressures, along with the Washington Environmental Council's lawsuit continuing the attack on the logging industry, contribute to clouding the real issues.

If we are paying big-time for salmon recovery, why do we continue sports fisheries on the wild endangered king salmon, and tribes continue with 52 weeks a year net test fishery? Only \$4.3 million was the 1999 total ex-vessel value of combined commercial and tribal salmon and steelhead. Are we talking hidden agendas and taxpayer ripoff?

The maximum sustainable yield salmon harvest model must be abandoned. The Ricker model, once assumed correct, was adopted for commercial fisheries in the mid-1950s. The maximum sustainable yield model provided maximum harvest without understanding its limitations. Sources condemn the maximum sustainable yield model as inadequate. The model risks catastrophic decline as well as loss of genetic variability and has contributed to overfishing.

Physical habitat loss is a major factor in salmon decline, but another major factor is the failing of tribes and agencies to confront the issue of biological habitat loss: loss from the depleting of nutrients in our rivers. Interrain Pacific research assistant Ted Gresh indicates that only 3 per-



Voice of the Valley

Irresponsible behavior is of great benefit to agenda-driven groups.

cent of historic marine-derived biomass is being returned to our rivers by spawning salmon. Mark Wipfle, a Forest Service researcher in Alaska, reports

that we need as much as one salmon carcass per square meter along streams. I remember the situation locally as a child. If salmon are to recover, we must rebuild the nutrient reserve.

It is essential that we shift without delay to a minimum sustainable escapement model for salmon recovery. Simply put: Mother Nature's plan includes having enough of all species of salmon in the watershed to provide nutrients for the ecological system and to produce many fry to compete for space and rebuild genetic variability. Variability permits the better-fit to survive.

Ocean conditions are given little consideration as a third major factor in salmon decline. Jim Lichatowich in his 1999 book "A History of the Pacific Salmon Crisis" refers to much ocean research. During 1976 about 40 ocean variables dramatically showed a stepwise change off the Oregon coast. Silver salmon harvest collapsed in 1977. This could have been the beginning of our present cyclical bad ocean conditions which may now be starting a turn for the better.

Lichatowich states that during periods of low productivity off Oregon, Washington and Southern British Columbia, waters off Alaska were in a high productivity phase. The reverse was true as well. A north or south shifting in the Aleutian low-pressure system favors productivity in Alaska or Washington and Oregon respectively.

A recent study by Interrain Pacific

showed a most pronounced 1 percent return of salmon to our Pacific Northwest. Historically, we have a 15-16 percent return. British Columbia gets 19-26 percent while Alaska gets returns of 56-65 percent of the Eastern Pacific salmon.

The massive knowledge of the ocean is being ignored. That irresponsible behavior by salmon harvest managers and others is of great benefit to agenda-driven groups.

Ron Arnold in his 1999 book "Undue Influence" gives a warning. Governmental actions are being influenced by an interlocking triangle of agenda-driven federal employees, grant-driven environmental organizations, and action-dictating private funders.

The original proposed 50-foot farmers' buffer plan did not have a chance because power people are failing to use all the best science available to make good judgment calls and county government knowledge is limited. The information included in this commentary must convince the Growth Management Hearings Board that the original farmer-proposed buffer was adequate. Larger farm buffers will not restore healthy salmon runs.

The time has come for competent county citizens to become an active united force for fair play in accelerating salmon recovery and the Endangered Species Act delisting of king and other salmonids of the state. A special edition 2000 technical report co-authored by 15 credible fish biologists titled "Pacific Salmon and Wildlife, Ecological Contexts, Relationships and Implications for Management" is one more excellent salmon recovery guidance source. We must become proactive for salmon recovery and ESA delisting.

■ Bill Reinard, a Burlington resident, taught biology in Sedro-Woolley for 30 years, and served on the Skagit Fisheries Enhancement Group board for many years.

The Natural Heating and Cooling of Water

Larry Larson and Patricia A. Larson

In accordance with an Environmental Protection Agency (EPA) mandate established by the Clean Water Act (1972), many states of the Pacific Northwest are establishing water temperature standards and regulations to protect their most sensitive beneficial uses of water.

In application, a number of state regulations are being established that apply equally from head waters to state borders, regardless of stream or river location. This approach has raised questions about the appropriateness of the standards and whether they take into account 'natural' temperature fluctuations.

If the intent of a regulation is to maintain water temperatures within the range of natural temperature fluctuations and prevent heating by anthropogenic sources, then the natural pattern of heating and cooling must be established. The purpose of this paper is to provide a perspective regarding factors that must be taken into consideration to determine 'natural' temperature fluctuations for water bodies.

Climate as a Driver of the Thermal Environment

The first step in this process is to recognize the influence of global climate on the thermal environment of a stream. From a global perspective the Earth's atmosphere gains energy from the ocean and land masses. Differential heating of these surfaces by the Sun creates pressure systems, climatic patterns, and ocean currents that circulate over the globe redistributing energy and water. As a result, the rise of average surface-air temperatures typically lag 4 to 8 weeks behind the period of maximum solar radiation (summer solstice), shifting the period of maximum summer heating from June into July and August (Trewartha 1968).

On a watershed scale, both air and soil serve as large thermal reservoirs that are directly influenced by these global patterns of heating and cooling. These reservoirs are large in comparison to flowing streams. In many respects their relationship resembles a narrow layer of water flowing between two hot water bottles. In this situation one would anticipate that the temperature of the layer of water would be dependent upon, not independent of the temperature of these thermal reservoirs, and would provide a direct influence on the upper and lower temperature limit that water can achieve.

Energy Exchange and Natural Systems

Energy exchange is described by The First and Second Law of Thermodynamics (Halliday and Resnick 1988). These laws state that we can transform but not create nor

destroy energy and that energy exchange occurs from areas of high temperature toward areas of lower temperature.

Table 1 provides an illustration of the temperature patterns that can be observed in Northeastern Oregon in the summer between a stream and its associated soil and air mass. During summer, air typically warms during the day to temperatures that are greater than the temperature (62°F) maintained beneath the soil surface (1 ft. depth). The water and soil, having a lower temperature receives energy from the air and sun as a day progresses. The daily temperature pattern of the water in a stream then is determined by its initial temperature at sunrise, the volume of water (depth); surface area, and how long it is exposed to the sun, air and soil.

Table 1. Temperature pattern of the air, water, and soil (1 ft. depth) in a riparian environment in NE Oregon at 3,000 ft. elevation in August.

Time	Air °F	Water °F	Soil °F
7 AM	57	57	60
8	55	57	60
9	58	58	60
10	61	59	60
11	64	60	60
11:30	63	61	60
NOON	63	61	60
1	67	62	60
2	68	63	60
3	70	65	60
3:30	72	67	61
4	72	67	61
5	73	67	61
6	74	67	61
7 PM	68	66	61
7:30	64	66	61
8	61	65	61
9	56	64	62
10	54	63	62
11	50	62	62
12	48	62	62

Air temperature can be used as an indicator of the thermal environment surrounding the layer of water. If the difference between the air temperature and the water temperature is large we can expect the rate of water heating to be more rapid than when the difference is small. Table 1 illustrates the daily pattern of warming that occurs in the thermal environment that surrounds a stream and the lag time that exists between daily peak solar radiation and maximum air, water, and soil temperature. Throughout the day, water temperature increases at a rate that is influenced by

the temperature of the air mass. This phenomenon occurs on all streams at all elevations. The size of the difference between air temperature and water temperature (the gradient) influences how fast water will heat and cool.

Should Streams Heat as You Move to Lower Elevations?

The daily temperature range of a stream is influenced by the environment through which it flows. Streams originating at high elevations in mountainous regions, flow through a warming environment as the water flows to lower elevations. For most people this warming trend is observed in changes in air temperature. The rate of air temperature change typically ranges between 3.2°F and 5.5°F per 1,000 feet of elevation (Satterlund and Adams 1992) and is described as the adiabatic rate of heating and cooling. Similarly a pattern of temperature change can be observed in the soil (1 ft. depth) as you travel from high to low elevations.

Figure 1 shows daily low water temperatures at two elevations on the same stream. These water temperatures were recorded each day at 6 am during August. Water temperatures taken at 6 am have stabilized with the thermal environment of the watershed overnight and approach ambient conditions. In this example the differences between the water temperatures observed at the two elevations on a daily basis, fall within the anticipated differences of the adiabatic rate. The differences between the recorded low temperatures, are between 3.2°F and 5.5°F per 1,000 feet of elevation difference.

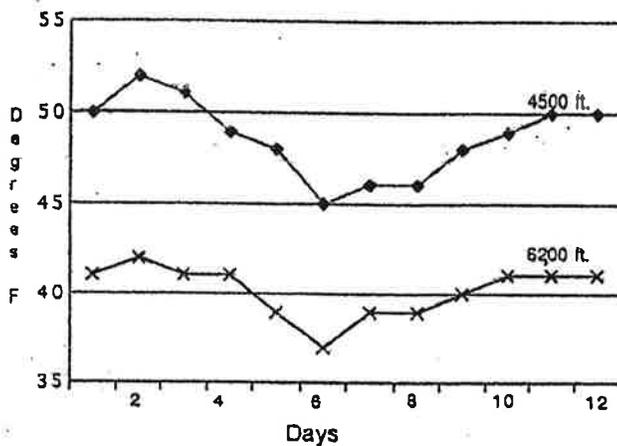


Fig. 1 Daily low water temperatures measured at two elevations for 12 consecutive days in August at 6 am.

Combining Elevation and Flow

Figure 2 shows water temperature data taken on the same stream as it drops approximately 1,700 feet in elevation and travels 4.1 miles. If a tennis ball was maintained in

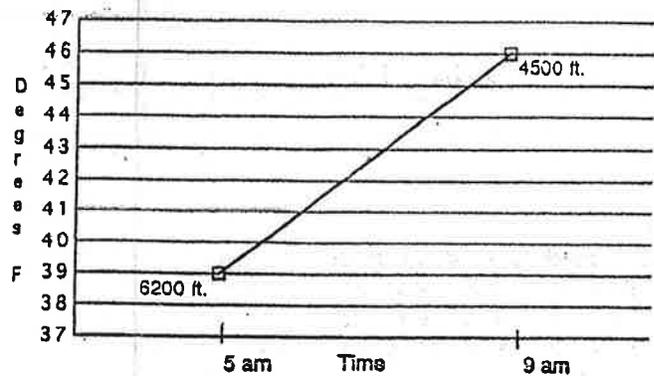


Fig. 2. Water temperature increase over a 1,700 ft. elevation drop and a 4 hr. flow period. Temperatures were recorded at 5 and 9 am with air temperature differences of 47°F and 58°F respectively.

the current of the stream at 6,200 feet it would take 4 hours for it to reach the 4,500 ft. elevation with a stream flow of 1.5 ft/sec. In this example air temperature increased at a rate that falls within the anticipated adiabatic rate of 6.4°F to 11°F during the 4 hour time period.

If we were to continue to observe the pattern of air temperatures, we would find that the top and bottom locations increase 10°F and 20°F between 9 and 10 am respectively. Water during that same period increased only 1 degree at each location. This is a daily phenomena that occurs on clear summer days. At 10 am the sun reaches an altitude in the sky when maximum solar heating begins to take place.

Generally air heats slowly between 5 am and 10 am while the water remains fairly constant. By 10 am when air temperature increases 10°F to 20°F due to the increased solar angle, a steep gradient is established between the air and water temperatures. During the next 5 hours the water temperature increases 2–3 degrees each hour depending on the increase in the thermal environment as indicated by air temperature during the same time period.

Water temperature data collected at a single site can only describe a volume of water at a specific time as it flows over the thermometer's location. To understand how much that volume of water heats during a day, at least 2 sites must be monitored. The natural heating and cooling of water within a watershed can then be described using rate of flow to estimate the influence of the thermal environment on water during a time period.

Time and Temperature Gradients

At any point along the stream the gradient between air temperature and water temperature will vary from hour to hour. Maximal heat transfer occurs when the gradient is steepest.

Generally water at higher elevations accumulates energy at a different rate than those at lower elevations (Fig. 3). Higher elevations have lower water temperatures at sunrise and greater average gradients during the day. This might

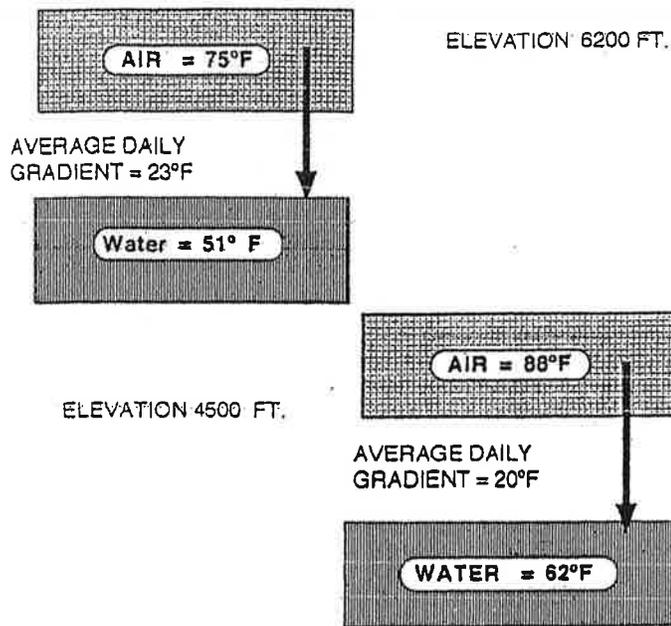


Fig. 3. Gradients of the difference between air and water temperature at 2 elevations. The arrows represent the thermal gradient from air to water at 2 pm. The average daily gradient is the average of the air and water temperature differences measured at hourly intervals.

suggest that the water temperatures would be higher than a similar body at lower elevations. This is not the case. Water heating at higher elevations is restricted to a short time period. This is due to a rapid thermal cycling of the local environment which results in less energy accumulation. Given this, water temperatures at lower elevations will have a greater increase in temperatures than those at higher elevations.

When all these processes are combined (elevation, time, rates of heating and cooling, and the difference between air temperature and water temperature) the framework of the thermal environment in which a stream is flowing is described. However, as recognized in the principles of thermodynamics and the examples provided in this paper, modification of one or more of the thermal sources will result in a different rate of heating or cooling.

Observations

1. Climates produce weather systems that determine the patterns of heating and cooling within a watershed environment.

2. Water temperatures are influenced by the thermal reservoir that surrounds the water body. Air temperature can be used as an index of that thermal environment. Air and stream temperatures, at a minimum, must be measured at each data collection site to establish the relationship between the stream and its environment.

3. A portion of stream temperature change can be associated with the thermal environment and rates of adiabatic temperature change. The lower elevations not only have warmer water, but they have warmer air temperatures on a

daily basis. The adiabatic rates of air mass temperature change is 3.2°F to 5.5°F difference for each 1,000 ft. of elevation.

4. The difference between the air temperature and the water temperature influences the rate at which the water will warm or cool. The smaller the differences are between air and water temperature the longer it will take for the water to heat or cool.

5. The rate of flow of a stream must be determined to understand the entire process of how a stream heats and cools. Flow determines how long a body of water is influenced by a particular thermal environment. Downstream air temperatures are warmer than upstream because of lower elevations. Flow rates must be monitored during each sample period, between each monitoring site to establish how long the water is exposed to a thermal environment.

6. Two measurements are required at a minimum to estimate the thermal evolution of a stream: 1) the flow rate and, 2) the gradient between air and water temperature. The rate of flow determines how long the water is exposed to a particular air mass (at a specific temperature). The gradient determines the rate at which heat energy is transferred.

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Robby Eckroth

From: Kaia Hayes <kaiah@re-sources.org>
Sent: Monday, July 28, 2025 1:46 PM
To: PDS comments
Cc: Eddy Ury
Subject: Skagit County 2025 Critical Areas Ordinance Update

Honorable County Commissioners,

RE Sources is a non-profit organization founded in 1982. We work to protect the health of northwest Washington's people and ecosystems through the application of science, education, advocacy and community action. We have hundreds of supporters and many community partners in Skagit County and we submit these comments in affirmation of their values and priorities.

Please accept our comments on the 2025 update to the Critical Areas Ordinance:

We commend Skagit County for its work to update the Critical Areas Ordinance as a vital piece of successfully implementing the Comprehensive Plan. We strongly support the ordinance additions that propose strengthened riparian buffers, affirm the regular review and inclusion of Best Available Science (BAS) to inform protection criteria, and the use of a "No Net Loss" approach to mitigating impacts to critical areas.

We also support the comments submitted by the **Swinomish Indian Tribal Community** and **Evergreen Islands**, and urge the commission to integrate their important feedback into the final version expected to be adopted by the Commission on August 4th.

These comments include:

- The need for additional and more substantial public engagement and **Tribal consultation**, and the request to support a productive mediation process with the WA Department of Commerce to address the Tribe’s remaining concerns.
- Protection of existing well users in areas impacted by **saltwater intrusion** and denial of new permits in areas of Chloride exceedance
- Addition of the suggested WA Department of Ecology criteria to the list of criteria in 14.24.240(2) Buffer Width Averaging to **ensure consistency with BAS**.
- **Removal** of proposed changes to the ordinance that are **not aligned with Best Available Science (BAS)**, including:
 - Remove the proposed exemptions for Category 4 wetlands and smaller wetlands less than 1000 sq ft.
 - Remove timber-related exemptions and amend to reflect the latest WA Department of Fish and Wildlife science and use of Riparian Management Zones to mitigate impacts to critical areas.
 - Remove activities like docks and bulkheads– consistent with the Shoreline Master Plan in review by WA Department of Ecology.

A Strong Critical Areas Ordinance is Essential to Skagit's Long-Term Planning Goals

At the core of “resilience” is the need to prepare our natural and human systems to survive, and even thrive, in the changing conditions of the decades to come. Sea level rise, riverine flooding, groundwater impacts, wildfires, and drought are already faced by our Skagit communities today— and best science shows that the frequency and intensity of these events will only compound. We understand and support the need to respond to these challenges with innovative, engineered solutions— **and** we also recognize that they are necessary, but not sufficient to secure a vibrant future for NW Washington.

Much more far-reaching and cost-effective are the variety of multi-benefit [Natural Climate Solutions \(NCS\)](#) that leverage the ability of our natural systems to buffer against the impacts mentioned above— by restoring and enhancing system function in key areas like riparian shorelines and wetlands, aquifer recharge areas, and naturally shoreline-armoring coastal ecosystems. Scientific and economic research show that investing broadly in working *with* natural systems, and **then** filling in gaps with appropriate engineered solutions, offers the best, most effective, and least costly approach to securing broad regional resilience.

The Critical Areas Ordinance directly determines the extent and quality of the natural system function available to us to leverage for NCS approaches. The ordinance’s ability to adequately protect critical areas dictates the magnitude of impact we stand to have on building regional resilience through these lower cost, proactive NCS solutions— **and our ability to shrink the gap remaining to fill with costly engineered solutions and reactive actions like disaster cleanup, emergency relocation, and losses to lives and property.**

Conclusion

Our work now, to navigate the short-term trade-offs and compromises associated with developing adequate environmental protections for critical areas, ensures that a future Skagit county can continue to embody the values and character of the region we are sustained by today. **One of the most critical of these is a viable Agricultural land base that sustains Skagit's Ag economy and heritage in perpetuity.** Embracing a long-range approach— and supporting those impacted in the shorter term by investments in the watershed’s natural ability to buffer serious long term impacts to the land base like flooding and saltwater intrusion— **is likely the only way our region will successfully protect enough of Skagit Valley's farmable acreage to support a viable future for the agricultural sector;** which is staggeringly imperiled by the sheer proportion of farmland rendered unproductive by projected flooding in the Skagit Climate Science Consortium’s [Flood Scenario Map](#), even in the most intensive mitigation scenarios.

Thank you again for your service and integration of public feedback into these consequential decisions that shape our shared future.

Sincerely,

Kaia Hayes
Land & Water Policy Manager

Eddy Ury

Climate & Energy Policy Manager

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Kaia Hayes

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We are on the ancestral homelands of the Coast Salish Peoples, whose tribal treaty rights we support and for whose enduring care of the lands and waters we are deeply grateful.

Robby Eckroth

From: Tim Trohimovich <Tim@futurewise.org>
Sent: Monday, July 28, 2025 2:00 PM
To: PDS comments
Subject: Re: Skagit County 2025 Critical Areas Ordinance Update
Attachments: wdfw00026.pdf

Dear Staff and Commissioners:

Here is the referenced enclosure.

Thank you again for considering our comments.

Tim Trohimovich, AICP
Director of Planning & Law
Futurewise
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From: Tim Trohimovich <Tim@futurewise.org>
Sent: Monday, July 28, 2025 1:58 PM
To: Skagit County PD&S Comments <pdscomments@co.skagit.wa.us>
Subject: Skagit County 2025 Critical Areas Ordinance Update

Dear Staff and the Board of County Commissioners:

Thank you for the opportunity to comment on the Second Draft Critical Areas Ordinance Update. Futurewise supports the update, the ordinance, and the recommended improvements. We do have some recommendations set out below.

Futurewise works throughout Washington State to support land-use policies that encourage healthy, equitable and opportunity-rich communities, and that protect our most valuable farmlands, forests, and water resources. Futurewise has members and supporters throughout Washington State including Skagit County. Our recommendations follow.

Please clarify when critical areas review is required in Skagit County Code Section 14.24.080 consistent with the requirements of SCC 14.24.080(1)(d)(i) on pages 11 – 14 of 78.

Skagit County Code Section (SCC) 14.24.080(1)(d)(i) is proposed to be amended to provide that standard critical areas review is required if (with the deletions omitted):

(i) Critical areas or their buffers are present within 300 feet, or a distance otherwise specified in this Chapter, from the proposed activity or may be affected by the proposed activity.

We support this amendment because it recognizes that some fish and wildlife buffers are wider than 300 feet and it also recognizes that activities can have other adverse effects on critical areas such as discharging storm water into downstream wetlands, rivers or lakes. [1] For example, “[b]uilding within 150 m (492 ft) of a loon nest should be avoided year-round to maintain a permanent buffer around nests.” [2] The common loon is a sensitive species found in Skagit County. [3]

Unfortunately, the amendments to SCC 14.24.080(3) and (4) only require review within 200 feet. They also omitted the standard of whether a critical area may be affected by the proposed activities. These changes significantly weaken the protections in the critical areas regulations and can adversely impact critical areas functions and values. The Growth Management Act (GMA) “requires that the regulations for critical areas must protect the ‘functions and values’ of those designated areas. [RCW 36.70A.172(1).] This means all functions and values.” [4]

To address this problem we recommend that SCC 14.24.080(3) and (4) use the same language as SCC 14.24.080(1)(d)(i) as proposed to be amended. This will help protect critical area functions and values.

SCC 14.24.230(5) which allows the use of a previous buffer should require the current buffer widths if additional uses or more intensive uses are being permitted. See page 36 of 78.

Current wetland science supports the buffers in SCC 14.24.230. [5] SCC 14.24.230(5) allows the use of existing buffers that do not meet the current buffer requirements for new or expanded uses. We appreciate and support the additional limits being proposed. However, this accommodation should not apply where more intensive uses or additional uses that will adversely impact the wetland are being allowed. If SCC 14.24.230(5) applies in this circumstance the critical areas regulations will violate the Growth Management Act requirement that critical areas regulations must also at least “protect[s] critical areas by maintaining existing conditions.” [6]

Futurewise supports SCC 14.24.350, the Instream Flow Rules, and recommends they be updated to comply with RCW 36.70A.590 and RCW 90.44.050. See pages 51 – 56 of 78

Futurewise supports SCC 14.24.350 Instream Flow Rules. RCW 36.70A.070(1) provides that “[t]he land use element shall provide for protection of the quality and quantity of groundwater used for public water supplies.” RCW 36.70A.070(5)(c)(iv) provides that “[t]he rural element shall include measures that apply to rural development and protect the rural character of the area, as established by the county, by: ... Protecting surface water and groundwater resources.” The Growth Management Act (GMA) in RCW 36.70A.590 also provides that:

For the purposes of complying with the requirements of this chapter [the GMA] relating to surface and groundwater resources, a county or city may rely on or refer to applicable minimum instream flow rules adopted by the department of ecology under chapters 90.22 and 90.54 RCW. Development regulations must ensure that proposed water uses are consistent with RCW 90.44.050 and with applicable rules adopted pursuant to chapters 90.22 and 90.54 RCW when making decisions under RCW 19.27.097 and 58.17.110.

Development regulations must comply with the GMA including the critical areas regulations. [7] These development regulations are required because overuse of surface or ground water often harms senior water rights holders and fish and wildlife habitat. For example:

Although domestic water use in rural areas uses a small amount of water, the cumulative impact of many domestic water users can together impair streamflows, especially in tributaries. Hydrogeologic studies and computer models show that domestic wells impact streamflows in the Skagit Basin. [8]

To comply with RCW 36.70A.070(1), RCW 36.70A.070(5)(c)(iv), and RCW 36.70A.590, the critical areas regulations should adopt regulations to ensure development complies with the water codes and the applicable instream flow rules.

RCW 36.70A.590 requires the policies and development regulations to ensure that proposed water uses are consistent with RCW 90.44.050. To comply with RCW 90.44.050 for residential permit exempt wells, the policies and development regulations must require that the County when determining if a development, land division, or use qualifies for a permit exempt well under RCW 90.44.050 ensure that the water used by the parent parcel that existed in 2002, any lots created from the parent parcel, and any development built on or after 2002 on those lots does not in total exceed the 5,000 gallons a day allowed by RCW 90.44.050. Under the State Supreme Court's *Campbell and Gwinn* decision, each lot is entitled to one 5,000 gallon per day permit exempt withdrawal for single or group domestic uses under RCW 90.44.050.^[9] A "developer may not claim multiple exemptions for the homeowners."^[10] So each lot that existed in 2002, the year the *Campbell and Gwinn* decision was decided, is entitled to one permit-exempt withdrawal under RCW 90.44.050.

As lots are subdivided or developed over time, part or all of the permit exempt withdrawals are used by the lots created or the development authorized. To qualify for a permit-exempt groundwater withdrawal authorized under RCW 90.44.050, the lot must have some remaining water from the parent parcel's single 5,000 gallon per day permit exempt withdrawal for single or group domestic uses.

Therefore, the required development regulations can only authorize the use of a permit exempt-well or well system for single or group domestic uses if the water use does not exceed the 5,000 gallons a day allowed by RCW 90.44.050 including the parent parcel that existed in 2002, any lots created from the parent parcel, and any development built on or after 2002. To comply with RCW 36.70A.590, SCC 14.24.350 must include this important limitation. Therefore, we recommend SCC 14.24.350 limit each lot that existed in 2002 to one permit-exempt withdrawal under RCW 90.44.050 including the water used by any land divisions or developments and also comply with RCW 36.70A.590.

This regulation also helps to protect families that buy lots and houses that rely on permit exempt wells. Developments that are approved in violation of RCW 36.70A.590 and RCW 90.44.050 do not have a legal water right. Their current and future water use is not legal.

Adopt stream, lake, and marine buffer widths that consistent with the current best available sciences and that protect the functions and values of salmon habitat. Please see SCC 14.24.530(1) on pages 68 — 70 of 78

The southern resident orcas depend on the chinook salmon to live and recover their numbers.^[11] The *2022 State of Salmon in Watersheds* report rated the Puget Sound Chinook salmon as "in crisis," the Governor's Salmon Recovery Office's worst rating.^[12] The Puget Sound Steelhead are also "in crisis."^[13] Other salmon and steelhead are also declining.^[14] The key factors causing the decline in salmon and steelhead include habitat degradation.^[15] An analysis by the National Oceanic and Atmospheric Administration and the State of Washington Department of Fish and Wildlife ranked the Northern Puget Sound Fall Chinook salmon from the Nooksack, Elwha, Dungeness, Skagit, Stillaguamish, and Snohomish Rivers as the highest in importance as food sources for the southern resident orcas.^[16] New Year Eve saw the death of another orca calf and once again the calf's mother is carrying her around Puget Sound for all of us to see.^[17] The Washington State Academy of Sciences concluded that "[c]learly, there have been net losses of species and habitats in Washington. The committee is reasonably confident that without policy changes, these types of losses will continue and will contribute to the disappearance of distinct habitats and ecosystem types from Washington's terrestrial and aquatic landscapes."^[18] For the sake of the chinook salmon and the southern resident orcas we can and must better protect their habitat.

"Preserving habitat is far less expensive than restoring degraded habitat."^[19] We are not achieving no net loss of riparian vegetation that is necessary to protect salmon habitat. This is in part because the critical areas regulation buffers for rivers, streams, and shorelines are too narrow.

The State of Washington Department of Fish and Wildlife has developed new recommendations for protecting riparian areas. "Under WAC 365-190-130(4)(b), the [State of Washington] Department [of Fish and Wildlife]'s priority species habitat information is considered best available science."^[20] The updated management

recommendations document that fish and wildlife depend on protecting riparian vegetation and the functions this vegetation performs such as maintaining a complex food web that supports salmon and maintaining temperature regimes to name just a few of the functions.[21]

The updated *Riparian Ecosystems, Volume 1: Science synthesis and management implications* scientific report concludes that the “[p]rotection and restoration of riparian ecosystems continues to be critically important because: a) they are disproportionately important, relative to area, for aquatic species, e.g., salmon, and terrestrial wildlife, b) they provide ecosystem services such as water purification and fisheries (Naiman and Bilby 2001; NRC 2002; Richardson et al. 2012), and c) by interacting with watershed-scale processes, they contribute to the creation and maintenance of aquatic habitats.”[22] The report states that “[t]he width of the riparian ecosystem is estimated by one 200-year site-potential tree height (SPTH) measured from the edge of the active channel or active floodplain. Protecting functions within at least one 200-year SPTH is a scientifically supported approach if the goal is to protect and maintain full function of the riparian ecosystem.”[23] For Skagit County, this generally requires 200-foot buffers on streams, rivers, and shorelines that are home to salmon and other fish species and 100-foot buffers on other streams and shorelines measured from the channel migration zone edge or active flood plain. The buffers should be updated to include these buffers.

SCC 14.24.600, SCC 14.24.610, and SCC 14.24.630 should be updated to protect people and property from sea level rise. Please see page 76 of 78

Sea level rise is a real problem that is happening now. Sea level is rising and floods and erosion are increasing. In 2012 the National Research Council concluded that global sea level had risen by about seven inches in the 20th Century.[24] A recent analysis of sea-level measurements for tide-gage stations, including the Seattle, Washington tide-gauge, shows that sea level rise is accelerating.[25]

The report *Projected Sea Level Rise for Washington State – A 2018 Assessment* projects that for a low greenhouse gas emission scenario there is a 50 percent probability that sea level rise will reach or exceed 1.6 feet by 2100 in Skagit County at Latitude 48.3 degrees north and Longitude -122.4 degrees west.[26] *Projected Sea Level Rise for Washington State – A 2018 Assessment* projects that for a higher emission scenario there is a 50 percent probability that sea level rise will reach or exceed 2.1 feet by 2100 in Skagit County at Latitude 48.3 degrees north and Longitude -122.4 degrees west.[27] Projections are available for all of the marine shorelines in Skagit County.[28]

The extent of the sea level rise currently projected for Skagit County can be seen on the NOAA Office for Coastal Management Digitalcoast Sea Level Rise Viewer available at: <https://coast.noaa.gov/digitalcoast/tools/slr.html>. A copy of the map from the viewer showing two feet of sea level rise was enclosed with Futurewise’s May 8, 2025, emails with the filename: “Skagit Cty 2 ft Sea Level Rise.pdf.”

Projected sea level rise will substantially increase flooding. As Ecology writes, “[s]ea level rise and storm surge[s] will increase the frequency and severity of flooding, erosion, and seawater intrusion—thus increasing risks to vulnerable communities, infrastructure, and coastal ecosystems.”[29] Not only our marine shorelines will be impacted, as Ecology writes “[m]ore frequent extreme storms are likely to cause river and coastal flooding, leading to increased injuries and loss of life.”[30]

Zillow recently estimated that 31,235 homes in Washington State may be underwater by 2100, 1.32 percent of the state’s total housing stock. The value of the submerged homes is an estimated \$13.7 billion.[31] Zillow wrote:

It’s important to note that 2100 is a long way off, and it’s certainly possible that communities [may] take steps to mitigate these risks. Then again, given the enduring popularity of living near the sea despite its many dangers and drawbacks, it may be that even more homes will be located closer to the water in a century’s time, and these estimates could turn out to be very conservative. Either way, left unchecked, it is clear the threats posed by climate change and rising sea levels have the potential to destroy housing values on an enormous scale.[32]

Sea level rise will have an impact beyond rising seas, floods, and storm surges. The National Research Council wrote that:

Rising sea levels and increasing wave heights will exacerbate coastal erosion and shoreline retreat in all geomorphic environments along the west coast. Projections of future cliff and bluff retreat are limited by sparse data in Oregon and Washington and by a high degree of geomorphic variability along the coast. Projections using only historic rates of cliff erosion predict 10–30 meters [33 to 98 feet] or more of retreat along the west coast by 2100. An increase in the rate of sea-level rise combined with larger waves could significantly increase these rates. Future retreat of beaches will depend on the rate of sea-level rise and, to a lesser extent, the amount of sediment input and loss.[33]

These impacts are why the Washington State Department of Ecology recommends “[l]imiting new development in highly vulnerable areas.”[34]

Unless wetlands and shoreline vegetation can migrate landward, their area and ecological functions will decline. [35] If development regulations are not updated to address the need for vegetation to migrate landward in feasible locations, wetlands and shoreline vegetation will decline. According to Ecology “[d]evelopment of coastal areas and shoreline armoring (e.g., bulkheads, seawalls) prevent habitat areas from reestablishing inland” in response to sea level rise.[36] Ecology provides more detailed documentation of these adverse impacts:

The prospect of more flooding, erosion, and storm damage may lead communities and property owners to seek to build seawalls, dikes, and tidal barriers. The construction and placement of these structures will have a direct and immediate impact on natural shoreline environments. These structures will also lead to the progressive loss of beach and marsh habitat as those areas are squeezed between the rising sea and a more intensively engineered shoreline. Predicted decreases in size or transitions in tidal marshes, salt marshes, and tidal flats will affect the species these habitats support. It is predicted that while some species may be able to locate alternate habitats or food sources, others will not (Glick, 2007).

Shellfish, forage fish, shorebirds, and salmon are among those identified as examples of species at risk (Glick, 2007). Sea level rise will also lead to other changes in coastal ecosystems, such as shifting of stream mouths and tidal inlets, reconfigured estuaries and wetlands, and more frequently disturbed riparian zones.[37]

“Loss of salt marsh and related habitats may be significant in systems constrained by surrounding development.” [38] This loss of shoreline vegetation will harm the environment. It will also deprive marine shorelines of the vegetation that protects property from erosion and storm damage by modifying soils and accreting sediment. [39] This will increase damage to upland properties. Enclosed with this letter are maps showing the extent of wetlands at mean higher high water and at two feet of sea level rise in western Skagit County. [40] A comparison of these maps shows that there will be migration of wetlands in Skagit County if the wetlands are not blocked by development.

Flood plain regulations are not enough to address sea level rise for three reasons. *Projected Sea Level Rise for Washington State – A 2018 Assessment* explains two of them:

Finally, it is worth emphasizing that sea level rise projections are different from Federal Emergency Management Agency (FEMA) flood insurance studies, because (1) FEMA studies only consider past events, and (2) flood insurance studies only consider the 100-year event, whereas sea level rise affects coastal water elevations at all times.[41]

The third reason is that flood plain regulations allow fills and piling to elevate structures and also allow commercial buildings to be flood proofed in certain areas. While this affords some protection to the structure, it does not protect the marshes and wetlands that need to migrate.

Because of these significant impacts on people, property, and the environment, “[n]early six in ten Americans supported prohibiting development in flood-prone areas (57%).”^[42] It is time for Washington state and local governments to follow the lead of the American people and adopt policies and regulations to protect people, property, and the environment from sea level rise. This is why RCW 36.70A.070(9)(e)(i)(C) requires county and city comprehensive plans to “[a]ddress natural hazards created or aggravated by climate change, including sea level rise, landslides, flooding, drought, heat, smoke, wildfire, and other effects of changes to temperature and precipitation patterns.” RCW 36.70A.040(3) requires counties and cities development regulations that are consistent with and implement the comprehensive plan and to address these natural hazards. We recommend the addition of the following regulations as part of the critical areas update:

X. New lots shall be designed and located so that the buildable area is outside the area likely to be inundated by sea level rise in 2100 and outside of the area in which wetlands and aquatic vegetation will likely migrate during that time.

X2. Where lots are large enough, new structures and buildings shall be located so that they are outside the area likely to be inundated by sea level rise in 2100 and outside of the area in which wetlands and aquatic vegetation will likely migrate during that time.

X3. New and substantially improved structures shall be elevated above the likely sea level rise elevation in 2100 or for the life of the building, whichever is less.

^[1] *Best Available Science Review Skagit County Critical Areas Ordinance Update* p. 29, p. 34, pp. 39 – 42 (Feb. 24, 2025) last accessed on July 28, 2025, at:

<https://www.skagitcounty.net/PlanningAndPermit/Documents/compplan2025/Skagit%20County%20BAS%202.24.2025%20-%20FINAL.pdf#page=40.24>.

^[2] Jeffrey C. Lewis, Ruth Milner, and Morie Whalen, *Common Loon* p. 1-2 in E. Larsen, J. M. Azerrad, N. Nordstrom editors, *Management Recommendations for Washington’s Priority Species, Volume IV: Birds* (Washington Department of Fish and Wildlife, Olympia, Washington, USA: 2004) last accessed on July 28, 2025 at:

<https://wdfw.wa.gov/publications/00026> and enclosed in a separate email with the filename: “wdfw00026.pdf.”

^[3] *Best Available Science Review Skagit County Critical Areas Ordinance Update* p. 48 (Feb. 24, 2025).

^[4] *Whidbey Env’t Action Network v. Island Cnty.*, 122 Wn. App. 156, 174–75, 93 P.3d 885, 894 (2004).

^[5] Washington State Department of Ecology Shorelands and Environmental Assistance Program, *Wetland Guidance for Critical Areas Ordinance (CAO) Updates: Western and Eastern Washington* pp. 20 – 25 (Olympia, Wash.: Oct. 2022, Publication #22-06-014) last accessed on July 28, 2025, at:

<https://apps.ecology.wa.gov/publications/SummaryPages/2206014.html> and enclosed with Futurewise’s May 8, 2025, emails with the filename: “2206014.pdf.”

^[6] *Swinomish Indian Tribal Cmty. v. W. Washington Growth Mgmt. Hearings Bd.*, 161 Wn.2d 415, 430, 166 P.3d 1198, 1206 (2007), as corrected (Nov. 28, 2007), as corrected (Apr. 3, 2008).

[7] *Kittitas Cnty. v. E. Washington Growth Mgmt. Hearings Bd.*, 172 Wn.2d 144, 164, 256 P.3d 1193, 1203 (2011) citing RCW 36.70A.130(1); accord RCW 36.70A.290(2).

[8] State of Washington Department of Ecology Water Resources Program, *Water Availability for Skagit Basin Landowners: Frequently asked questions WRIA 11 Nisqually Watershed Water Availability* p. 3 (Publication 13-11-006, Revised Aug. 2023) last accessed on July 28, 2025, at: <https://apps.ecology.wa.gov/publications/documents/1311006.pdf> .

[9] *State Dep't of Ecology v. Campbell & Gwinn, L.L.C.*, 146 Wn.2d 1, 14, 43 P.3d 4, 110 (2002).

[10] *Id.*

[11] NOAA Fisheries, *Southern Resident Killer Whale Priority Chinook Salmon Stocks - Questions and Answers* webpage last accessed on July 28, 2025, at: <https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/southern-resident-killer-whale-priority-chinook-salmon> and enclosed with Futurewise's May 8, 2025, emails with the filename: "Southern Resident Killer Whale Priority Chinook Stocks Q and A.pdf."

[12] Washington State Recreation and Conservation Office, Governor's Salmon Recovery Office, *2022 State of Salmon in Watersheds Executive Summary* p. 7 (Feb. 2023) last accessed on) last accessed on July 28, 2025, at: <https://stateofsalmon.wa.gov/wp-content/uploads/2023/02/SOS-ExecSummary-2022.pdf>.

[13] *Id.*

[14] *Id.* p. 6.

[15] *Id.* pp. 14 – 15.

[16] National Oceanic and Atmospheric Administration and the State of Washington Department of Fish and Wildlife, *Southern Resident Killer Whale Priority Chinook Stocks* p. 6 (June 22, 2018) last accessed on July 28, 2025, at: https://media.fisheries.noaa.gov/dam-migration/srkw_priority_chinook_stocks_conceptual_model_report__list_22june2018.pdf and enclosed in Futurewise's May 8, 2025, emails with the filename: "srkw_priority_chinook_stocks_conceptual_model_report__list_22june2018.pdf."

[17] Lynda V. Mapes, *Mother orca Tahlequah once again carrying her dead calf* *The Seattle Times* (Jan. 1, 2025 at 6:41 pm) last accessed on July 28, 2025, at: <https://www.seattletimes.com/seattle-news/climate-lab/mother-orca-tahlequah-once-again-carrying-her-dead-calf/>.

[18] Washington State Academy of Sciences, *Assessment of No Net Loss and Recommendations for Net Ecological Gain Metrics, Indicators, and Monitoring: Prepared for the Washington State Department of Fish and Wildlife* p. 4 (June 2022) in Washington Department of Fish and Wildlife (WDFW), *Net Ecological Gain Standard Proviso Summary Report* (Dec. 2022) bold in the original last accessed on July 28, 2025, at: <https://wdfw.wa.gov/sites/default/files/publications/02357/wdfw02357.pdf> and enclosed with Futurewise's May 8, 2025, emails with the filename: "wdfw02357.pdf."

[19] Washington State Recreation and Conservation Office Governor's Salmon Recovery Office, *2022 State of Salmon in Watersheds Executive Summary* p. 15 (Feb. 2023).

[20] *Whidbey Env't Action Network v. Growth Mgmt. Hearings Bd.*, 14 Wn. App. 2d 514, 526, 471 P.3d 960, 968 (2020).

[21] Timothy Quinn, George F. Wilhere, and Kirk L. Krueger, technical editors, *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* pp. 265 – 68 & p. 270 (A Priority Habitat and Species Document of the Washington Department of Fish and Wildlife, Olympia, WA: Updated July 2020) last accessed on July 28,

2025, at: <https://wdfw.wa.gov/publications/01987/> and enclosed with Futurewise’s May 8, 2025, emails with the filename: “wdfw01987.pdf.” This report was peer-reviewed. *Id.* at pp. 11 – 12. See also Terra Rentz, Amy Windrope, Keith Folkerts, and Jeff Azerrad, technical editors, *Riparian Ecosystems, Volume 2: Management Recommendations* (A Priority Habitat and Species Document of the Washington Department of Fish and Wildlife, Olympia, WA: Dec. 2020) last accessed on July 28, 2025, at: <https://wdfw.wa.gov/sites/default/files/publications/01988/wdfw01988.pdf> and enclosed with Futurewise’s May 8, 2025, emails with the filename: “wdfw01988.pdf.”

[22] Timothy Quinn, George F. Wilhere, and Kirk L. Krueger, technical editors, *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* p. 270 (A Priority Habitat and Species Document of the Washington Department of Fish and Wildlife, Olympia, WA: Updated July 2020).

[23] *Id.* at p. 271.

[24] National Research Council, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* p. 23, p. 156, p. 96, p. 102 (2012) last accessed on May 6, 2025, at: <https://www.nap.edu/download/13389>.

[25] William and Mary Virginia Institute of Marine Science, U.S. West Coast Sea-Level Trends & Processes Trend Values for 2024 last accessed on May 6, 2025, at: https://www.vims.edu/research/products/slrc/compare/west_coast/index.php.

[26] University of Washington Climate Impacts Group, *Visualization #1: Projected sea level change by year for Projected sea level change by year Lat 48.3 Long 122.4 Skagit County*, accessed on April 1, 2022, at: <https://cig.uw.edu/our-work/applied-research/wcrp/sea-level-rise-data-visualization/> and enclosed with Futurewise’s May 8, 2025, emails with the filename: “Projected sea level change by year Lat 48.3 Long -122.4 Skagit Cty.pdf.” The methodology used for these projections is available in Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E, *Projected Sea Level Rise for Washington State – A 2018 Assessment* (A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project: updated 07/2019) last accessed on July 28, 2025, at: https://cig.uw.edu/wp-content/uploads/sites/2/2019/07/SLR-Report-Miller-et-al-2018-updated-07_2019.pdf and enclosed with Futurewise’s May 8, 2025, emails with the filename: “SLR-Report-Miller-et-al-2018-updated-07_2019.pdf.”

[27] University of Washington Climate Impacts Group, *Visualization #1: Projected sea level change by year for Projected sea level change by year Lat 48.3 Long 122.4 Skagit County*.

[28] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E., *Projected Sea Level Rise for Washington State – A 2018 Assessment* p. 6 & p. 9 of 24 (A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project: updated 07/2019).

[29] State of Washington Department of Ecology, *Preparing for a Changing Climate Washington State’s Integrated Climate Response Strategy* p. 90 (Publication No. 12-01-004: April 2012) last accessed on July 28, 2025, at: <https://fortress.wa.gov/ecy/publications/publications/1201004.pdf>.

[30] *Id.* p. 17.

[31] Krishna Rao, *Climate Change and Housing: Will a Rising Tide Sink all Homes?* Zillow webpage (Jun. 2, 2017) last accessed on July 28, 2025, at: <http://www.zillow.com/research/climate-change-underwater-homes-12890/>.

[32] *Id.*

[33] National Research Council, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* p. 135 (2012).

[34] State of Washington Department of Ecology, *Preparing for a Changing Climate Washington State's Integrated Climate Response Strategy* p. 90 (Publication No. 12-01-004: April 2012).

[35] Christopher Craft, Jonathan Clough, Jeff Ehman, Samantha Joye, Richard Park, Steve Pennings, Hongyu Guo, and Megan Machmuller, *Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services* *Front Ecol Environ* 2009; 7, doi:10.1890/070219 p. *6 last accessed on May 6, 2025, at: <https://www2.clark.wa.gov/files/dept/community-planning/shoreline-master-program/proposal-comments-received/futurewise-data-cd/craft-et-al-2009.pdf#page=1.00&gsr=0>. *Frontiers in Ecology and the Environment* is a peer-reviewed scientific journal. *Frontiers in Ecology and the Environment Journal Overview* webpage last accessed on May 6, 2025 at: <https://esajournals.onlinelibrary.wiley.com/hub/journal/15409309/aims-and-scope/read-full-aims-and-scope>. Both enclosed with Futurewise's May 8, 2025, emails with the filenames: "Craft et al 2009.pdf" and "Frontiers in Ecology and the Environment - Journal Overview" respectively.

[36] Washington State Department of Ecology, *Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy* p. 68 (Publication No. 12-01-004: April 2012).

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[38] *Id.* p. 4.

[39] R. A. Feagin, S. M. Lozada-Bernard, T. M. Ravens, I. Möller, K. M. Yeagei, A. H. Baird and David H. Thomas, *Does Vegetation Prevent Wave Erosion of Salt Marsh Edges?* 106 *Proceedings of the National Academy of Sciences of the United States of America* pp. 10110-10111 (Jun. 23, 2009) last accessed on May 6, 2025, at: <http://www.pnas.org/content/106/25/10109.full> and in a separate email with the filename: "10109.full.pdf." This journal is peer-reviewed. *Id.* p. 10113.

[40] Enclosed in enclosed with Futurewise's May 8, 2025, emails with the filenames: "Marsh Skagit Cty MHHW.pdf" and "Marsh Migration Skagit Cty 2 ft Sea Level Rise.pdf." Three maps of the same view are needed to show the three parts of the legend, so that is why there are three pages in the Marsh Migration Skagit Cty 2 ft Sea Level Rise.pdf.

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Thank you for considering our comments. The enclosure "wdfw00026.pdf" will be sent in a separate email.

Tim Trohimovich, AICP (he/him)
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MANAGEMENT RECOMMENDATIONS FOR WASHINGTON'S PRIORITY SPECIES – VOLUME IV: BIRDS



Washington
Department of
**FISH and
WILDLIFE**

Eric M. Larsen, Jeffrey M. Azerrad, and
Noelle Nordstrom, Technical Editors

May 2004

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*Front and back cover illustrations by Darrell Pruett.
Design by Jeffrey M. Azerrad.*

Management Recommendations for Washington's Priority Species

Volume IV: Birds

Eric M. Larsen, Jeffrey M. Azerrad, Noelle Nordstrom, Technical Editors

May 2004

Washington Department of Fish and Wildlife
600 Capitol Way N
Olympia, WA 98501-1091

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Appendix A. Contacts to assist in evaluating the use of herbicides, pesticides, and their alternatives

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Appendix 2. Ferruginous hawk rapid assessment protocol

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Many individuals contributed to the preparation of this volume. Special thanks goes to Steve Penland and Elizabeth Rodrick for their constant support during the volume's publication. The work could have never been completed without the generous contributions of numerous individuals that authored and/or peer-reviewed individual chapters in this volume. Special thanks goes out to Joseph Buchanan for providing a technical review of numerous chapters.

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INTRODUCTION

Fish and wildlife are public resources. Although the Washington Department of Fish and Wildlife (WDFW) is charged with protecting and perpetuating fish and wildlife species, the agency has very limited authority over the habitat on which animals depend. Instead, protection of Washington's fish and wildlife resources is currently achieved through voluntary actions of landowners and through the State Environmental Policy Act (SEPA), Growth Management Act (GMA), Forest Practices Act (FPA), Shoreline Management Act (SMA), and similar planning processes that primarily involve city and county governments. Landowners, agencies, governments, and members of the public have a shared responsibility to protect and maintain fish and wildlife resources for present and future generations; the information contained in this document is intended to assist all entities in this endeavor.

The Washington Department of Fish and Wildlife has identified those fish and wildlife resources that are a priority for management and conservation. Priority habitats are those habitat types with unique or significant value to many fish or wildlife species. Priority species are those fish and wildlife species requiring special efforts to ensure their perpetuation because of their low numbers, sensitivity to habitat alteration, tendency to form vulnerable aggregations, or because they are of commercial, recreational, or tribal importance. Descriptions of those habitats and species designated as priority are published in the Priority Habitats and Species (PHS) List.

PHS Management Recommendations

The department has developed management recommendations for Washington's priority habitats and species to provide planners, elected officials, landowners, and citizens with comprehensive information on important fish, wildlife, and habitat resources. These management recommendations are designed to assist in making land use decisions that incorporate the needs of fish and wildlife. Considering the needs of fish and wildlife can help prevent species from becoming extinct or increasingly threatened and may contribute to the recovery of species already imperiled.

Agency biologists develop management recommendations for Washington's priority habitats and species through a comprehensive review and synthesis of the best scientific information available. Sources include professional journals and publications, symposia, reference books, and personal communications with professionals on specific habitats or species. Management recommendations are reviewed within the Department and by other resource professionals and potential users of the information. The recommendations may be revised if scientists learn more regarding a priority habitat or priority species.

Because PHS management recommendations address fish and wildlife resources statewide, they are generalized. Management recommendations are not intended as site-specific prescriptions but as guidelines for planning. Because natural systems are inherently complex and because human activities have added to that complexity, management recommendations may have to be modified for on-the-ground implementation. Modifications to management recommendations should strive to retain or restore characteristics needed by fish and wildlife. Consultation with fish and wildlife professionals is recommended when modifications are being considered.

The locations of priority habitats and species are mapped statewide. The maps represent WDFW's best knowledge of Washington State's fish and wildlife resources based on research and field surveys conducted over the past 20 years. Management recommendations should be addressed whenever priority habitats and species occur in a particular area whether or not the WDFW maps show that occurrence. These maps can be used for initial assessment of fish and wildlife resources in an area, but they should also be supplemented with a field survey or local knowledge to determine the presence of priority habitats or priority species. The PHS data show WDFW's knowledge of important fish and wildlife resources but cannot show the absence of these resources.

In summary, management recommendations for Washington’s priority habitats and species...

<u>Are:</u>	<u>Are not:</u>
Guidelines	Regulations
Generalized	Site specific
Updated with new information	Static
Based on fish and wildlife needs	Based on other land use objectives
To be used for all occurrences	To be used only for mapped occurrences

Goals

Management recommendations for Washington’s priority habitats and species are guidelines based on the best available scientific information and are designed to meet the following goals:

- Maintain or enhance the structural attributes and ecological functions of habitat needed to support healthy populations of fish and wildlife.
- Maintain or enhance populations of priority species within their present and/or historical range in order to prevent future declines.
- Restore species that have experienced significant declines.

Format

Management recommendations for each priority species are written in six primary sections:

General Range and Washington Distribution –	Summarizes information on the geographic extent of the species in Washington and throughout its range.
Rationale –	Outlines the basis for designating the species as priority.
Habitat Requirements –	Delineates the species’ known habitat associations.
Limiting Factors –	Specifies factors that may limit the species’ distribution and abundance in Washington.
Management Recommendations –	Provides management guidelines based on a synthesis of the best available scientific information.
Key Points –	Summarizes the most important elements of the species’ biology and associated management recommendations.

Management recommendations for Washington's priority habitats and species are intended to be used in conjunction with mapped and digital data which display important fish, wildlife, and habitat occurrences statewide. Data can be obtained by calling the PHS Data Request Line at (360) 902-2543. For more information visit the PHS Website at <http://wdfw.wa.gov/hab/phspage.htm>. Questions and requests for additional PHS information may be directed to:

Priority Habitats and Species
WDFW Habitat Program
600 Capitol Way N
Olympia, WA 98501-1091

SPECIES STATUS DEFINITIONS

State Listed and Candidate Species

State Endangered - Any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state. Endangered species are legally designated in WAC 232-12-014.

State Threatened - Any wildlife species native to the state of Washington that is likely to become endangered within the foreseeable future throughout a significant portion of its range within the state, without cooperative management or the removal of threats. Threatened species are legally designated in WAC 232-12-011.

State Sensitive - Any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened in a significant portion of its range within the state, without cooperative management or the removal of threats. Sensitive species are legally designated in WAC 232-12-011.

State Candidate - Wildlife species that are under review by the Department for possible listing as endangered, threatened or sensitive. A species will be considered for State Candidate designation if sufficient evidence suggests that its status may meet criteria defined for endangered, threatened or sensitive in WAC 232-12-297. Currently listed State Threatened or State Sensitive species may also be designated as State Candidate species if evidence suggests that their status may meet criteria for a higher listing of State Endangered or State Threatened. State Candidate species will be managed by the Department, as needed, to ensure the long-term survival of populations in Washington.



Common Loon

Gavia immer

Last updated: 1999

Written by Jeffrey C. Lewis, Ruth Milner, and Morie Whalen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Common loons breed in North America from the Aleutian Islands and Bering Sea coasts, east throughout Canada and south to the northern tier of the lower 48 United States. In western North America, common loons winter along the Pacific coast from southern Alaska to Baja California.

Migrant loons arrive from the north to winter along Washington's coast, the Columbia and Snake rivers, and on lakes in northeastern Washington. Summer populations are very small (see Figure 1). Single breeding pairs have been confirmed on lakes in King, Whatcom, Chelan, Ferry, and Okanogan counties.

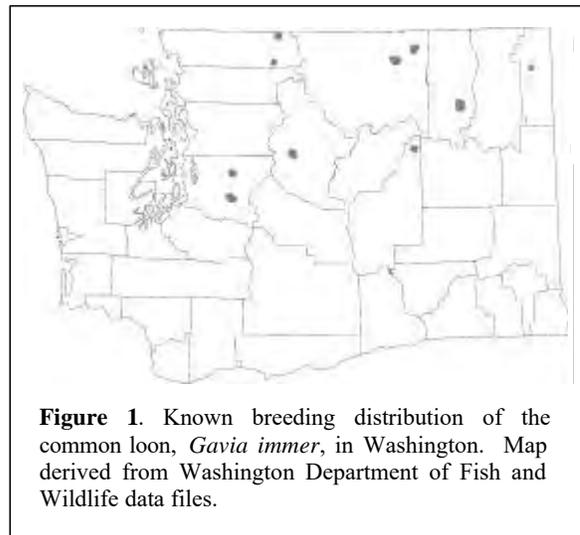


Figure 1. Known breeding distribution of the common loon, *Gavia immer*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

The common loon is a State Candidate species. This species is vulnerable to shoreline alteration and development, fluctuation of water levels during nesting (e.g., reservoir draw downs and filling), human disturbance in the vicinity of nesting areas, and encroachment by logging and road building.

HABITAT REQUIREMENTS

Nesting and Brood Rearing

Common loons breed on larger lakes (>12 ha [29.6 acres] in Alaska; Ruggles 1994) in forested areas and nest on shorelines of islands and the mainland. Nesting also may occur within 1.5 m (5 ft) of shore on masses of emergent vegetation (Vermeer 1973, Strong et al. 1987). Loons may use several types of nests, including nests constructed of vegetation; nests located on hummocks, stumps, and beaver lodges; artificial platforms; and nests scraped out of sand, gravel, or leaves (Belant and Anderson 1991). Several studies have shown that loons prefer to nest on islands (Vermeer 1973, McIntyre 1975, Ream 1976, Titus and Van Druff 1981), and breeding success may be higher on insular sites (McIntyre and Mathisen 1977, Titus and Vandruff 1981). Nest site fidelity has been reported (Strong et al. 1987). In Alaska, reproductive pairs were often found on lakes that were hydrologically connected to other lakes, had medium to high macrophyte cover, and had >50% of the shoreline suitable as nesting habitat (Ruggles 1994). Brood or nursery habitat used by adults and loon chicks is comprised of shallow, protected areas of lakes with abundant aquatic vegetation near the shore (McIntyre 1983).

Feeding

Common loons require a healthy fish population on which to feed. Studies of loon feeding habits on their breeding grounds are limited, though Vermeer (1973) found that lakes where breeding loons were present were also used by successful anglers. Common loons were absent from many lakes and sloughs that offered poor fishing to anglers.

LIMITING FACTORS

Loon abundance and reproductive success is dependent upon the availability of undisturbed shoreline or island nesting sites. Fluctuations of water levels and other disturbances at nest sites have been responsible for nest failures, and therefore limit reproductive success. Protection of the forage base and water quality is essential.

Human Impacts

Heavy recreational use may be a key factor in the decline of loon productivity because the birds are susceptible to disturbance during nesting. Titus and Vandruff (1981) found that loons nesting on lakes where motorboats were absent had greater egg-hatching rates than those nesting on lakes where motorboats occurred. Vermeer (1973) found more breeding pairs in areas with fewer resorts, cottages, and campsites. Heimberger et al. (1983) showed that breeding success declined as the number of cottages within 150 m (492 ft) of nests increased. Lake size may affect the influence human disturbance has on loon nesting. Some studies have shown that loons have equal or greater reproductive success on larger lakes with substantial human disturbance than smaller lakes with little or no human disturbance (Jung 1991, Caron and Robinson 1994, Ruggles 1994). It appears that loons may acclimate to heightened disturbance levels while occupying the greater number of undisturbed coves and bays of larger lakes.

Loons appear susceptible to heavy metal poisoning (especially mercury in low pH lakes) through consumption of contaminated fish (Scheuhammer and Blancher 1994, Meyer et al. 1995). Fortunately, much of this mercury is sequestered into feathers during the molt and shed in the succeeding molt (Burger et al. 1994). However, heightened levels of mercury can negatively affect loon reproductive success (Burger et al 1994, Scheuhammer and Blancher 1994, Meyer et al. 1995).

MANAGEMENT RECOMMENDATIONS

Protection of loons and their habitat during pair-bonding, egg laying, and initial brood rearing (1 April through 15 July) is important for reproductive success. Brood-rearing areas or nurseries are also important to protect after 15 July. Because common loons may re-use nests from year to year, protection of known nesting and brood-rearing areas is essential. Camping on islands can adversely affect loon productivity and may cause nest abandonment (Ream 1976). Campers and other visitors should be prevented from approaching within 150 m (492 ft) of nesting sites from 1 April through 15 July. A 150 m (492 ft) disturbance buffer is also recommended for brood-rearing areas (nursery pools) from 15 July to 1 September (R. Spencer, personal communication). Building within 150 m (492 ft) of a loon nest should be avoided year-round to maintain a permanent buffer around nests.

The absence of suitable nesting islands may limit the breeding activity of common loons. In areas where natural islands are unavailable, artificial islands can be provided. McIntyre and Mathisen (1977) created nesting islands by obtaining sedge mats from boggy lakes and binding the mats' edges with poles. Cedar log rafts were also found to be effective. Artificial nest sites have been used in Washington, primarily in reservoirs with fluctuating water levels (R. Spencer, personal communication). As breeding pairs of loons are not abundant in Washington, protection of all nest sites is important. Consequently, reservoirs where loons nest should maintain constant water levels when loons are laying and incubating eggs (a 30 day period).

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PERSONAL COMMUNICATIONS

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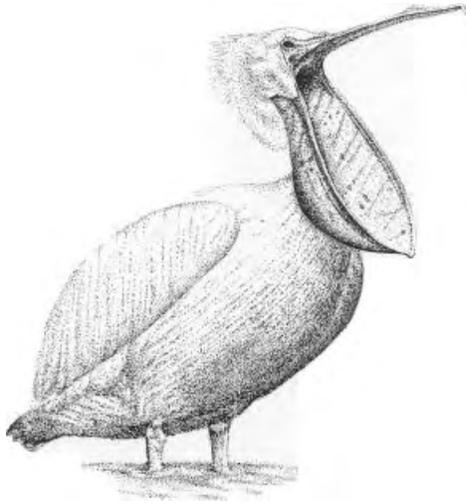
KEY POINTS

Habitat Requirements

- Common loons breed on large lakes in forested areas.
- A healthy fish population is required as a prey base.
- Nests are situated on shorelines, islands, or floating structures within 1.5 m (5 ft) of shore.
- Nests may be constructed on emergent vegetation, and nest sites may be reused.
- Common loons are very susceptible to nest disturbance. They are intolerant of recurrent disturbance within 150 m (492 ft) of nest sites.

Management Recommendations

- Protect known nest and nursery sites.
- Restrict disturbance of nest sites from 1 April to 15 July and brood-rearing nursery pools from 15 July to 1 September. Maintain a 150 m (492 ft) disturbance buffer around brood-rearing areas (nursery pools) from 15 July to 1 September.
- Erect no structures within 150 m (492 ft) of nesting sites. Avoid building within this distance year round to maintain a permanent buffer around nests.
- Provide artificial nesting islands (e.g., sedge mats and cedar log rafts) where appropriate (e.g., reservoirs).



American White Pelican

Pelecanus erythrorhynchos

Last updated: 1998

Written by Patrick J. Doran, Morie Whalen, Karen Riener, and Lisa Fitzner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

American white pelicans occur throughout the western, central, and southern parts of North America. These pelicans are colonial nesters, breeding primarily in the western and central United States and Canada, and wintering along the southern coast of the United States and in Mexico. Canada supports the largest population of breeding American white pelicans, with colonies located in Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan. In the United States, breeding colonies are located in California, Colorado, Idaho, Minnesota, Montana, Nevada, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming (Ackerman 1994; Sidle et al. 1985; J. Annear, personal communication).

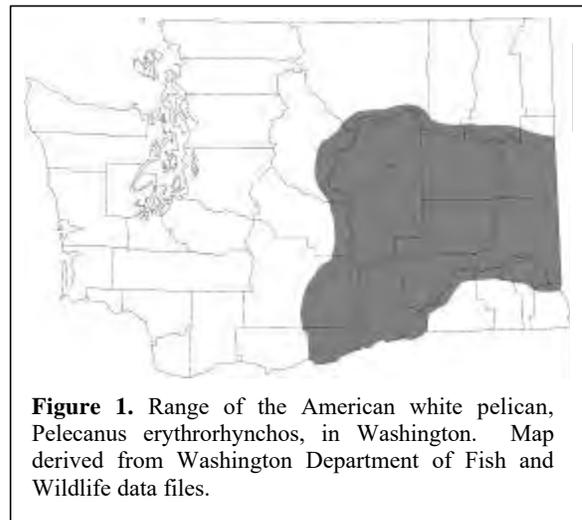


Figure 1. Range of the American white pelican, *Pelecanus erythrorhynchos*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

The population can be roughly split into 2 groups based upon differences in their ranges. The western group, which includes American white pelicans occurring in Washington state (see Figure 1), breeds to the west of the Rocky Mountains and winters along the Pacific Coast from central California to Mexico, mainly along Baja California and the western coast of Mexico (U. S. Fish and Wildlife Service 1984). Additionally, small numbers of American white pelicans winter on inland waters in Oregon and Washington (U. S. Fish and Wildlife Service 1984; L. Fitzner, personal communication; R. Friesz, personal communication). The migratory route of the western population takes in all states west of the continental divide and Mexico (U. S. Fish and Wildlife Service 1984).

Historically, American white pelicans were known to occur and presumed to have bred in eastern Washington on inland waters such as Sprague and Moses Lakes (Dawson and Bowles 1909). The first nesting record is from 1926 at Moses Lake, Grant County (Brown 1926). Jewett et al. (1953) stated that the Moses Lake colony continued for several years. From 1926 through 1994 there were no published records of American white pelicans breeding in Washington. In 1994 a breeding colony was established on Crescent Island, which was constructed for nesting birds in the Columbia River, Walla Walla County in 1985 (Ackerman 1994). American white pelicans have continued to nest on Crescent Island up to the date of this publication. In 1994 an estimated 30 nests produced approximately 50 juveniles, and in 1996 an estimated 25 nests produced approximately 35 young (Ackerman 1997). Nests and young were not counted in 1995. However, breeding was confirmed on the island and numbers were estimated to be similar to those in 1994 (Ackerman 1997). In 1997, the colony initiated nesting on nearby Badger Island. After high water

destroyed some of the nests, a portion of the colony returned to Crescent Island and initiated a second nesting attempt. At the time of this publication, American white pelicans were nesting on both Badger and Crescent Islands (Ackerman 1997).

In addition to the breeding colonies present on Crescent and Badger Islands, the inland waters of eastern Washington support a significant number of non-breeding American white pelicans throughout the year. Non-breeding American white pelicans can be found along the Columbia River from the Dalles through Chief Joseph pool. Numbers of these pelicans vary greatly during the summer, with peaks of up to 2000 birds observed in the potholes region of the Columbia Basin during late summer (R. Friesz, personal communication; J. Tabor, personal communication). Numbers of summer residents have declined substantially since 1990 (L. Fitzner, personal communication). Wintering concentrations, ranging from 40-300 birds, occur along the Columbia River from the mouth of the Walla Walla River to Priest Rapids (L. Fitzner, personal communication; E. Nelson, personal communication). Therefore, areas within Washington state may play an important regional role in sustaining non-breeding summer residents and birds which have dispersed from their breeding grounds in adjacent states and provinces.

RATIONALE

The American white pelican is a State Endangered species. In Washington, colonies of American white pelicans have disappeared from historical breeding areas (Dawson and Bowles 1909, Johnsgard 1955). Currently, only one breeding colony exists in Washington (Ackerman 1994, 1997). Suitable nesting habitat that is free from human disturbance is rapidly declining (Motschenbacher 1984), thus there are few opportunities for breeding populations of American white pelicans to become reestablished. Additionally, non-breeding and wintering populations occur in Washington throughout the year (R. Friesz, personal communication; L. Fitzner, personal communication).

HABITAT REQUIREMENTS

American white pelicans are colonial nesters that breed most often on isolated islands in freshwater lakes and occasionally on isolated islands in rivers. Islands free from human disturbance, mammalian predators, flooding, and erosion are required for successful nesting (U. S. Fish and Wildlife Service 1984, Koonz and Rakowski 1985). At 11 American white pelican breeding sites near Washington state, Motschenbacher (1984) reported a minimum nest island size of 0.3 ha (0.75 ac). The United States Fish and Wildlife Service (USFWS) recommends a minimum nest island size of 0.4 ha (1.0 ac) (U.S. Fish and Wildlife Service 1984). Preferred nesting substrates include gravel, sand, and soil (Evans and Knopf 1993). American white pelicans have also been known to nest on rocky outcroppings and dense stands of aquatic vegetation (e.g., hardstem bulrush [*Scirpus lacustris*]) (U. S. Fish and Wildlife Service 1984; Motschenbacher 1984). If vegetation is present within the nesting colony, it primarily consists of grasses, forbs, and shrubs (U. S. Fish and Wildlife Service 1984). At the Crescent Island colony in Washington, American white pelicans placed their nests on bare ground under willows (S. Ackerman, personal communication). Similar sites are used for loafing by both breeding and non-breeding birds.

American white pelicans require shallow water for foraging. Most feeding occurs between water depths of 0.3-2.5 m (1-8.3 ft) (Anderson 1991). Feeding mostly takes place along lake or river edges, in open areas within marshes, on or below rapids, and occasionally in deep waters of lakes and rivers (Evans and Knopf 1993). American white pelicans feed largely on nongame or "rough" fish, amphibians, and crustaceans (Brittell et al 1976, Lingle and Sloan 1980). Hall (1925) reported that adult pelicans consume 1.8 kg (4.8 lbs) of food per day. Therefore, an abundant prey base predominantly consisting of warm water fish is essential for American white pelican survival (Smith et al. 1984). Although foraging sites close to their breeding area are more advantageous than ones further away, American white pelicans are known to travel 50-80 km (31-50 mi) from nesting colonies to feed (Motschenbacher 1984, U.S. Fish and Wildlife Service 1984).

LIMITING FACTORS

The USFWS identifies 3 major factors that limit the success of breeding and non-breeding American White pelican populations: habitat destruction, utilization of wetlands and lakes for other purposes (e.g., irrigation, hydroelectricity, waterfowl production), and intentional or unintentional human disturbance of nesting colonies. They also cite several other potential factors that may limit American white pelican populations, including decreases or fluctuations in food supply and availability, shooting, mammalian predation at breeding colonies (especially coyotes), pesticide contamination, and powerline collisions (U.S. Fish and Wildlife Service 1984).

Habitat destruction and human disturbance appear to be the most important factors limiting American white pelican populations in Washington (Motschenbacher 1984). Currently, all 5 sites where breeding colonies were thought to have historically been located no longer exist or are in areas of high human activity (Motschenbacher 1984). Additionally, pool fluctuations on the Columbia River and other water bodies, which result in inconsistent water depths, may adversely affect habitat quality. Finally, American white pelicans are susceptible to pesticides and other toxic contaminants. Organochlorine pesticide residues and mercury concentrate in adult tissues and in pelican eggs (Evans and Knopf 1993). Aquatic pollution contribute to accumulations of toxic compounds in warm water fish species, which can adversely affect pelicans (Boellstorff et al. 1985; L. Blus, personal communication).

MANAGEMENT RECOMMENDATIONS

In Washington, management of American white pelican populations should focus on protection of breeding colonies and protection of feeding and loafing areas of both breeding and non-breeding birds.

Disturbance

Disturbance of nesting colonies may result in: abandonment of nests and colonies; egg breakage; depredation of nests by avian predators; exposure of young to temperature stress; and trampling of young (U. S. Fish and Wildlife Service 1984). In order to reduce the impacts of human disturbance at nesting sites, managers should:

- Close nest islands to trespass during the breeding season from 15 March through 31 August (U. S. Fish and Wildlife Service 1984).
- Establish a buffer zone of 400-800 m (0.25-0.5 mi) and up to 1600 m (1.0 mi) from the nesting island which is closed to human activity such as boating (especially power boating), fishing, water skiing, discharge of fire arms, wildlife observation (Knopf 1975, U. S. Fish and Wildlife Service 1984).
- Restrict air traffic to an altitude of 610 m (2000 ft) above breeding colonies to reduce disruption of nesting (U. S. Fish and Wildlife Service 1984).
- Close channels with dikes to restrict boating/fishing in breeding areas, creating sanctuaries.
- Retain stable water levels during the nesting season so that flood waters do not inundate nests, and low water levels do not allow the emergence of mainland to island bridges that can be crossed by predators (Findholt and Diem 1988).
- Protect nesting areas and potential nesting islands from mammalian predators such as coyotes (U. S. Fish and Wildlife Service 1984).

In addition to protecting active nest colonies, such as the Crescent and Badger Island sites, land managers should identify and protect loafing/roosting and feeding areas of both breeding and non-breeding birds. The availability of adequate foraging areas is also vital to the success of American white pelican populations. These pelicans are known to commute between 50-80 km (31-50 mi) between nesting and foraging sites (U. S. Fish and Wildlife Service 1984). In areas surrounding American white pelican colonies or in primary feeding areas for non-breeding, wintering, or migrating birds, managers should:

- Identify and survey American white pelican foraging areas to determine presence and abundance of fish species that may serve as a prey base for pelican populations (U. S. Fish and Wildlife Service 1984).

- Maintain and manage American white pelican foraging areas for the prey base fish species (U. S. Fish and Wildlife Service 1984).
- Maintain shallow water between 0.3-2.5 m (1.0-8.3 ft.) in depth at foraging areas (U.S. Fish and Wildlife Service 1984). Deeper waters may be necessary where water level fluctuations occur.
- Maintain abundant fish populations and a diversity of water bodies, such as lakes, sloughs, rivers, and marshes (Smith et al. 1984, Findholt and Anderson 1995a,b).
- Limit disturbance at foraging areas from hunting and fishing activities, boating, and other recreational activities (U. S. Fish and Wildlife Service 1984).

Reestablishment of Breeding Colonies

With the recent establishment of breeding colonies in Washington, the presence of large numbers of non-breeding summer birds, and population increases on a continental scale, there exists the potential for American white pelicans to become regular breeders in this state. In order to reestablish American white pelican nesting sites in Washington, sanctuaries that protect the birds from human disturbance are needed (Motschenbacher 1984). The sanctuary should contain a nesting island of at least 0.1 ha (0.25 ac), and preferably 0.4 ha (1.0 ac) or larger (U. S. Fish and Wildlife Service 1984) if water level fluctuations are common. Additionally, protected foraging areas with a sufficient prey base must be provided. Buffer zones, which exclude all human activities including boating, fishing, and water skiing, should be established as suggested above.

Contaminants

American white pelicans are susceptible to pesticides and other toxic contaminants. Currently, pesticide and mercury levels are not thought to be a significant problem in American white pelican populations. However, the U.S. Fish and Wildlife Service (1984) recommends monitoring of such contaminants. Fish, pelican eggs, and other biota should be sampled and analyzed for pesticides, dioxins, and other toxicants. Sources of these pollutants should be identified and regulated if necessary. Biocides, including those used in fish rehabilitation programs, should be avoided in American white pelican feeding areas, especially those near nesting colonies (L. Blus, personal communication).

Avoid using any insecticide (Smith 1987) or herbicide (Santillo et al. 1989) in American white pelican nesting or foraging habitat. Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to birds and fish and should be avoided (McEwen et al. 1972, Grue et al. 1983, Grue et al. 1986, Smith 1987). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A, which lists contacts that may be helpful when assessing pesticides and their alternatives.

Appropriate buffer widths for insecticide spray application near sensitive riparian and wetland areas range from 30-500 m (100-1650 ft) (Kingsbury 1975, Payne et al. 1988, Terrell and Bytnar-Perfetti 1989). When possible, leave a 500 m (1650 ft) (Kingsbury 1975) buffer around American white pelican nesting and foraging areas that is devoid of pesticides (Brown 1978, Smith 1987). Larger buffer areas may be necessary in areas where pesticide runoff affects a large area.

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KEY POINTS

Habitat Requirements

- Foraging occurs in shallow water 0.3-2.5 m (1.0-8.3 ft) deep.
- Breeding and stopover areas are clear of dense shrubbery or trees, include open aquatic habitats, and are free from human disturbance.
- American white pelicans nest on soil or sod.
- An abundant source of prey is essential, such as fish, amphibians, and crustaceans.

Management Recommendations

- Develop site-specific management plans for breeding areas.
- Identify, monitor, and protect primary feeding and loafing areas of breeding and non-breeding American white pelicans.
- Identify and survey American white pelican foraging areas to determine presence and abundance of fish species that may serve as a prey base for pelican populations.
- Maintain shallow water between 0.3-2.5 m (1.0-8.3 ft) in depth at foraging areas. Deeper waters may be necessary where water level fluctuations occur.
- Maintain or restore abundant fish populations in areas where American white pelicans feed.

- Prohibit boats and other human access within 400-800 m (0.25-0.5 mi) and up to 1,600 m (1 mi) of important foraging and breeding areas.
- Close nest islands to trespass during the breeding season from 15 March through 31 August.
- Restrict air traffic to an altitude of 610 m (2000 ft.) above breeding colonies to reduce disruption of nesting.
- Keep water levels stable during breeding season to protect nests from inundation or from predators which may cross land bridges during low water.
- Protect nesting areas and potential nesting islands from mammalian predators such as coyotes.
- Monitor for pesticides, dioxins, and other toxicants in prey fish.
- Avoid pesticide use in American white pelican habitat. If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A that lists contacts that may be helpful when assessing pesticides and their alternatives.
- When possible, leave a 500 m (1650 ft) buffer around American white pelican nesting and foraging areas that is devoid of pesticides. Larger buffer areas may be necessary in areas where pesticide runoff affects a large area.
- Appropriate buffer widths for insecticide spray application near sensitive riparian and wetland areas range from 30-500 m (100-1650 ft).
- Breeding sanctuaries should contain:
 - a nesting island of at least 0.1 ha (0.25 ac), and preferably 0.4 ha (1.0 ac) or larger if water level fluctuations are common.
 - protected foraging areas with sufficient prey
 - buffer zones that exclude human activities.



Great Blue Heron

Last updated: 2012

Written by Jeffrey M. Azerrad

GENERAL RANGE AND REGIONAL DISTRIBUTION

The Great Blue Heron's North American breeding range runs from southeast Alaska east to Nova Scotia and south to northwestern Mexico, the Yucatan Peninsula in Belize and Mexico, the West Indies, and Galapagos Islands (7). Herons overwinter from southern British Columbia, south to Venezuela.

Hérons are a permanent resident in all of Washington except the higher Cascade and Olympic ranges (Figure 1). In British Columbia, they are permanent residents along the entire coast and throughout Vancouver Island and the Haida Gwaii Archipelago¹. They also are residents in south-central British Columbia. Although herons breed at elevations as high as 1,100 meters (3,600 ft; 14), they mainly nest at lower elevations.

The region's largest colonies are within the range of the Pacific Great Blue Heron (*A. h. fannini*). This subspecies differs from inland herons and from herons near south-coastal Washington (*A. h. herodias*) in that they are smaller in size. They also generally begin breeding earlier in the spring (54). The range of these birds is isolated by the mountains east of Puget Sound and Georgia Basin. Pacific Great Blue Herons mostly occur close to the coast and inland along large rivers from Prince William Sound to Puget Sound (54).



Figure 1. The hatched area is the year-round range of the Great Blue Heron (*Ardea Herodias*) in Washington and British Columbia (55).

¹ This publication was written in cooperation with the [Great Blue Heron Working Group](#). Because the group is a made up of experts from Washington and British Columbia, we present information and guidance relevant to Washington and British Columbia.

RATIONALE

Great Blue Herons are highly vulnerable to human disturbance, predation, and competition for nesting habitat (40). Their habit of nesting in large groups makes herons especially susceptible to these types of impacts. A single event involving human disturbance can lead an entire colony to terminate a nesting attempt (21, 54, 55). Because herons breed in colonies of up to 500 nests (21), early termination of even one breeding attempt can lead to a considerable loss of offspring. This is especially a problem in Puget Sound and the Georgia Basin, where half the breeding population is concentrated into four large colonies (21). Recently the size of these large colonies in Puget Sound has increased as birds began to move out of smaller colonies (22).

Although herons are not a state-listed species in Washington, they are a species of special concern in British Columbia due to a decline in productivity, where the number of fledglings per active nest fell by nearly half since the 1970s (54). Although habitat loss and disturbance negatively impact individual colonies, we need more surveys to assess whether these factors are having an impact on regional heron populations.

HABITAT REQUIREMENTS

Great Blue Heron foraging, breeding, and [pre-nesting](#) habitats usually are in close proximity to each other (24). Foraging habitat often is adjacent to or within a few kilometers of the [nesting colony](#). Before nesting begins, herons will often congregate close to where they nest. The inter-relationships among these habitats require consideration to effectively protect a nesting colony.

PRE-NESTING HABITAT

Prior to nesting, herons may gather in groups. Surveyors have observed pre-nesting groups close to many of the region's heron colonies (A. Eissinger and I. Moul, personal communications). There is some debate as to how prevalent these groups are in the region. Although birds may not exhibit this behavior at every colony, more survey and research during the pre-nesting period will help us better understand these habitats.

The breeding season begins when adult herons gather at these pre-nesting sites (21). Along the coast, herons may occupy these sites while waiting for the tides to descend enough for food to become accessible (I. Moul, personal communication). Although not all of a colony's nesting birds will be found in a pre-nesting congregation area, the number of birds seen at these sites seems to correspond to the size of the nearby colony (A. Eissinger, personal communication).

Herons form pre-nesting congregations in various types of habitats. They congregate in both vegetated areas and on built structures (e.g., rooftops near Stanley Park and in Seattle's Kiwanis Ravine). Although in interior British Columbia and eastern Washington far fewer pre-nesting groups have been reported, Gebauer and Moul (24) noted interior-nesting herons gathering at larger lakes, wetlands, and watercourses prior to nesting. In coastal areas, herons often congregate in large estuaries and mudflats (24). At one of Washington's largest colonies at Birch Bay, pre-nesting congregations occur in fallow fields adjacent to the colony. Herons also assemble in day roosts near colonies in the pre-nesting period (21).

BREEDING AND NESTING HABITAT

Great Blue Herons often assemble in large and conspicuous colonies. Although some will nest as isolated pairs, most form colonies of a few pairs to many hundreds of birds (10). Larger and more productive colonies tend to form near large areas of high quality foraging habitat (5, 25, 27, 31), and especially near eelgrass beds (11, 54). Although herons sometimes nest on the ground, hu-

man-made structures, cliffs, and in shrubs (7, 10, 28; H. Ferguson, personal communication), nesting mostly occurs in trees like alder, cedar, hemlock, pine, Douglas-fir (*Pseudotsuga menziesii*), spruce, hawthorn, bigleaf maple (*Acer macrophyllum*), and cottonwood (*Populus balsamifera*). A shortage of suitable trees may lead herons to nest in shrubs or near the ground (28, 54). In coastal Washington and British Columbia, nesting largely occurs in areas with deciduous trees (M. Tirhi and R. Vennesland, personal communications). In British Columbia's interior Columbia River Basin, herons showed no preference for nesting in conifer or deciduous trees (35).

Ideal nesting habitat typically consists of mature forest (24). Although most colonies are found in forests free of human disturbance, some nesting occurs in areas of persistent human activity (10). An explanation for this may be that some areas lack undisturbed forest close to foraging habitat. In these places herons may be forced to select a disturbed forest because it is close to rich foraging habitat (31). In some regions they may select the best available habitat when optimal habitat is altogether lacking. Some herons may also become more acclimated to people (52). Although herons nest in disturbed areas, the presence of people has been linked to reduced nesting productivity (16, 24, 49, 53). Colony abandonment has also resulted from activities like land development and repeated human intrusions (43, 49, 53).

BREEDING SEASON FORAGING HABITAT

During the breeding season herons feed in the shallow margins of various coastal and freshwater habitats (24). Herons primarily nest near abundant sources of food (31). Although most colonies are within 3 kilometers (1.9 mi) of key foraging grounds, herons can nest anywhere within 10 kilometers (6.2 mi) of where they are foraging (9).

The presence of a nearby food source influences a colony in various ways. Food accessibility influences when a heron colony will begin breeding each year (8). Food also influences the size of nesting bird's **clutch** and **brood** (41, 42, 47). Although few have studied the relationship between food abundance and nesting, numbers of breeding herons likely decline with waning food supplies. A reliable food source also seems to affect reproductive performance (10, 31).

Along the coast, eelgrass meadows and other estuarine ecosystems supply most of the food that adult and juvenile herons require during the breeding season (10, 20). These herons feed on various small fish and marine invertebrates (10) such as gunnels, sculpin, shiner perch, mud shrimp, isopods, and crabs. Butler (9) concluded that coastal-nesting herons forage most efficiently in late spring when the tides are at their lowest levels and when prey tends to be abundant (10). This timing also corresponds to when the energy demands of juvenile herons hit their peak (1). Although coastal herons rely mainly on marine and estuarine waters for foraging, freshwater habitats also serve as an important source of food (24).

In contrast to coastal herons, interior herons feed alone and in small groups. This may be a result of foraging in areas of less abundant food. In southeast British Columbia and eastern Washington, breeding herons feed in wetland complexes, large rivers and creeks, and small lakes (35; H. Ferguson, personal communication). In southeast British Columbia, palustrine wetland complexes comprise 40% of the waters near colonies, while rivers, small lakes, and reservoirs made up another 50% (35). Given the proximity, herons may have an affinity for feeding in these waters.

NON-BREEDING SEASON FORAGING HABITAT

Although breeding season foraging more directly influences heron nesting, areas used for foraging outside the breeding period are also important. In fall and early winter, adult and juvenile herons often prey on small mammals in fallow, freshly plowed, or mowed fields and in grasslands

(9, 24; H. Ferguson and S. Pinnock, personal communications). Close to the coast, herons feed in ditches, old fields, marshes, and wetlands just following their dispersal from breeding areas (10). In October and November adults closer to the coast feed in marshes while juveniles feed in old-fields (5). These coastal herons later move back to tidal areas beginning in February and March. Great Blue Herons in interior areas forage along ice-free waters like creeks and lake shorelines. Non-breeding season foraging habitat may be a limiting resource for interior herons when frozen waterbodies or snow-covered fields restrict their access to prey (24).

LIMITING FACTORS

Activities like forestry and development have led to the loss and degradation of heron habitat, disturbance to nesting and foraging grounds, and to direct mortality (10, 40, 49). Forest removal and urban and industrial development are the chief causes of habitat loss in the Pacific Northwest (24, 51, 60). Increased human disturbance at breeding and foraging sites can lead to increased predation, lower breeding success, nest failure, and less efficient foraging (10, 24, 53). Although herons can nest in disturbed urban areas, disturbance can lead birds to terminate breeding attempts, especially when a disturbance occurs early in the nesting period or when it is a large or novel event (37, 52).

Avian predators also kill herons and compete for habitat. Bald Eagles are the heron's primary predator (10, 24, 53). A sharp increase in eagle populations has led to more colony incursions (55). In some areas, eagle predation and disturbance has led to an increase in nest and colony failure (13, 53). Depredation in particular appears on the rise in coastal heron colonies (50, 53) and attacks on adult herons may be leading to the temporary or permanent colony abandonment (21). Annual monitoring of colonies in interior British Columbia has shown eagles to be a cause of mortality and depredation (35). Eagles may also affect colony size further from the coast (H. Ferguson, personal communication). Although the recent rise in Bald Eagle abundance following their recovery has apparently exacerbated impacts at heron colonies, historically herons persisted when eagles were more common than they are today (46). But because interactions now occur in an altered landscape, there is uncertainty as to how herons will respond to the increased influence of eagles.

Other birds also seem to impact herons. The considerable ecological overlap of Double-crested Cormorants (*Phalacrocorax auritus*) and herons in interior British Columbia and eastern Washington suggests they potentially compete for limited nesting habitat (35; D. Norman, personal communication). Crows and ravens also prey on heron eggs and young (45).

Climate change will likely influence heron nesting and distribution. While we still do not know how severe the impacts will be, rising sea level and sea temperatures could affect nesting and foraging resources. A rise in sea level could inundate shallow coastal marshes (12), displacing herons from rich foraging grounds. Changing weather may also alter wading bird distributions (33).

MANAGEMENT RECOMMENDATIONS

HERON MANAGEMENT AREA

These recommendations are intended for use in what we have termed the [Heron Management Area \(HMA\)](#). An HMA consists of the nesting colony, [year-round](#) and [seasonal buffer](#), and foraging habitat (Figure 2). The HMA core zone consists of the colony and year-round buffer. Pre-nesting congregation areas are also part of the HMA. You should protect all these areas as disturbance to any part of an HMA can harm a colony.

The following guidelines will help you identify, map, and manage an entire HMA. We suggest you use the guidelines to protect any colony, no matter its size or status. Although you should not underestimate the value of smaller colonies, larger colonies generally merit highest priority. Give colonies with at least 20 nests close to coastal and estuarine habitat or along large rivers that drain into an estuary high priority (30). Since colonies inland tend to be smaller, regard all inland nesting aggregations as high priority.



Figure 2. Depiction of all the components of a HMA.

CORE ZONE IDENTIFICATION AND MAPPING

You should gather baseline information when planning a project near a heron colony. Because gathering data can lead to serious disturbance including failed nesting attempts (49, 56), you should only collect data in the [core zone](#) during the non-breeding season (Figure 3) when herons are absent. Although the non-breeding period generally runs from the beginning of September to mid-February, breeding activity can begin in late January and can conclude as late as mid-September (21; K. Stenberg, personal communication). Also, specific stages within the breeding season can vary geographically as well as from one colony to the next. For example, young in colonies south of Seattle often hatch in late March and fledge in June (38; K. Stenberg, personal communication). The fledging period in some colonies can also run for longer durations than the range shown in Figure 3 (K. Stenberg, personal communication). Because of this variability, draw on local knowledge of a colony to determine its true breeding period.

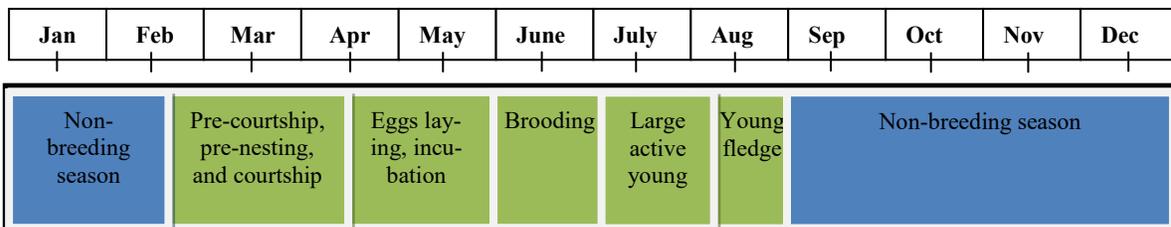


Figure 3. Chronology of the Great Blue Heron breeding and non-breeding periods (6, 10, 20, 21).

Just after the breeding season is the ideal time for nest counts and collecting habitat data. When a non-breeding season survey is impossible, you should not collect data in the core zone before the [brooding period](#) because colonies are more sensitive at that time (52). Conduct breeding season surveys late in the day when birds are less likely to leave their nests (56).

Begin your survey by locating all trees and structures with nests. Mark all nest trees at the colony's outer perimeter with flagging. Then mark their location on a map. Also flag and map trees with canopies overlapping a nest tree. You will use the marked trees to identify the colony's boundary. Knowing the location of the boundary will also help with post-project monitoring.

Because some nests occur in trees with canopies that overlap with other trees, locate which of the overlapping trees are furthest from the center of the colony for each outer perimeter nest. Using these peripheral trees as your guide, delineate the colony's outer boundary (Figure 4). Although there will be some subjectivity as you map this boundary, these nests will serve as your primary guide.

In some heron colonies outlying nests can be found in locations distant from where most of the colony's nests are concentrated. These satellite nests are typically represented by no more than a small handful of active or inactive nests located far¹ from the nearest neighboring nest in the heart of the colony. Although satellite nests are considered a part of the larger nesting colony, they usually will not be used to map the colony's outer boundary. But they should be protected. The best way to do this is by using them to identify the location of an alternate nesting stands. Alternate nesting stands serve important functions. We later discuss how to use satellite nests to identify a suitable location for an alternate nesting stand.

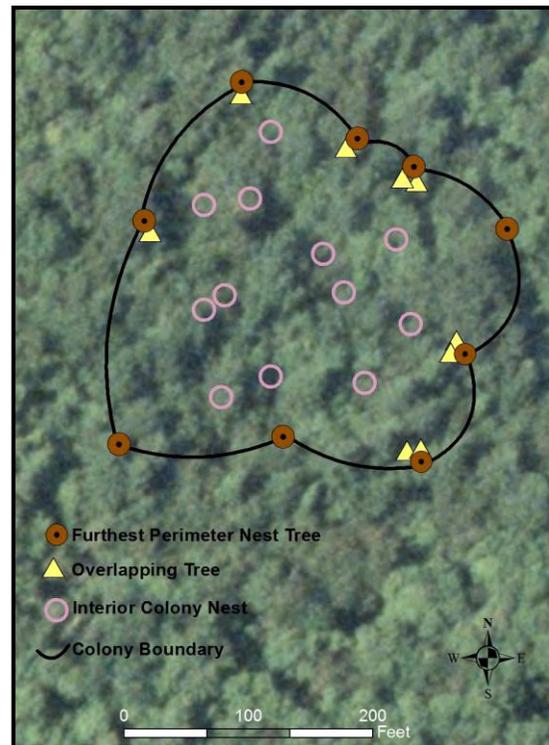


Figure 4. Boundary of the nesting colony demarcated using outer perimeter nests as a guide.

Buffers protect colonies by putting some distance between a colony and a potentially harmful activity (3, 7, 43, 51, 57). Some heron colonies require a relatively wide buffer given people as far as 250 meters (820 ft) away can cause birds to flush, and in some instances terminate a nesting attempt (3). Consequently, anyone working on a project near an existing colony should designate a buffer area to protect the colony.

Because colonies closer to human activity may tolerate more disturbance than colonies in a more undisturbed area (2, 52, 59), our recommended buffer widths vary with the surrounding levels of development. To delineate the year-round buffer, draw a circle around each outer nest tree using the buffer distances in Table 1. The outermost edge of each circle forms the outer limit of the year-round buffer (Figure 5)².

¹ For the purpose of this publication, a satellite nest is any nest located a distance of no less than twice the length of the colony's year-round buffer from its nearest neighboring nest.

² Mapping needs periodic updating since colonies are dynamic and the outer boundary of a colony can move over time.

Table 1. Recommended buffers for nesting colonies

Year-round Buffers ^a			
Meters	Feet	Setting	Percent built within a ¼ mile of the nest colony ^c
300	984	Undeveloped	0 - 2%
200	656	Suburban/Rural	2 - 50%
60 ^d	197	Urban	≥ 50%
Seasonal Buffers ^e			
Meters	Feet	Land Use Activity	Time of Year
200	656	Unusually loud activities ^f	February to September
400	1,320	Extreme loud activities like blasting	

a Buffer guidelines based on 3, 4, 7, 15.

b Rationale for setting-specific buffers based on observed heron tolerance variations associated with land use levels (49, 52)

c Cutoff percentages among undeveloped, urban, and suburban/rural as defined in 36, 49.

d When birds in an urban area exhibit behavior indicative of a low tolerance to people, assign the 300 meter buffer regardless of setting.

e Seasonal buffer begins at the outer edge of the year-round buffer when specified land uses occur near a colony in the breeding season.

f These activities generates sounds exceeding 92 decibels when the sound reaches the outer boundary of the nesting colony (58).

CORE ZONE MANAGEMENT

A colony with an adequate buffer and with room to move or expand increases its longevity and productivity (16, 21). A buffer acts as a physical and visual barrier to potentially intrusive activities. Buffers can also protect nest trees from being blown down (34). The buffer area also provides habitat that birds can use when they need to move from one nest tree to another.

For the greatest protection, certain actions should not occur near a colony. Specifically, clearing vegetation, grading, and construction should never occur in the core zone (24, 49, 51). Trails should also be directed away from the core zone or be closed off to access in the breeding season.

Although these activities are not recommended in the year-round buffer, when you have exhausted all options we strongly recommend you do the following when situating your project in a colony's core zone. First, you should site your project as far as possible from nests. You should also find a location where the nests will receive the greatest visual screening possible from all project disturbances. Screening is important as it helps ensure disturbance is minimized by removing visual cues (R. Vennesland, personal communication). Because disturbance is linked to reduced nesting productivity (16, 24, 49, 53), screening should provide some added protection. You should also carry out your project during the non-breeding season and mitigate for your project's infringement into the core zone.

Limited low impact recreation such as hiking, trail biking, or dog walking can occur in a core zone. However, these activities should only occur in the non-breeding season when no herons are present. Although we do not encourage any vegetation removal in the core zone, limited vegetation removal may be acceptable so long as it is part of a project primarily intended to enhance wildlife habitat (e.g., eradicating invasive understory vegetation) or to treat a fire-prone stand. Although vegetation removal may be okay in these limited instances, avoid these activities during the breeding season. Forest enhancement should also be done under the careful supervision of a wildlife biologist who understands heron behavior and ecology. When treating an overstocked or densely vegetated fire-prone stand, aim to avoid noticeable loss of visual screening to the nests.

We recommend using fences to exclude human entry into the colony's core zone (16, 51). But with that in mind make sure the fence will not cut off access to other wildlife (see [Fencing with Wildlife in Mind](#)). Construct your fence in the non-breeding season and with minimal disturbance to vegetation. You can also plant of dense thickets of vegetation to keep people out of a colony's core zone (see [Appendix B](#) for thicket-forming plants). Place signs around the outer edge of the year-round buffer explaining why entry is discouraged. Although we encourage the use of fencing or a vegetation barrier, we recognize these may not be feasible options for colonies surrounded by multiple small landowners.

Great Blue Herons are less tolerant of disturbance in the pre-courtship and courtship periods (mid-February to mid-April). They progressively becoming less likely to leave or abandon a nesting attempt after their eggs hatch (2, 32, 43, 52). Consequently, we discourage disturbance early in the breeding period. Where a core zone contains pre-existing structures like a home or a road, the type and level of use should not exceed intensities that customarily have occurred in the breeding period (51).

Any activity situated between the outer edges of the year-round and breeding season buffers should begin with a plan to identify where it will cause the least disturbance. Because herons seem most sensitive to actions in their line of sight, keep any work that will increase the presence of people, domestic animals, or vehicles out of view of the colony. To accomplish this, you should site your project where it will receive the greatest screening by way of vegetation or topography. Screening is especially vital when you have sited your project near the outer perimeter of the year-round buffer area. The best trees for screening will be at least as tall as a colony's tallest nesting tree. Whenever possible, these trees should also be of the same species as the dominant nesting trees. This way they will not only serve as a screen, but will provide the secondary benefit of being potential nesting trees.

SEASONAL BUFFER, PRE-NESTING AREAS, AND ALTERNATE NEST SITES

Other components of the HMA are the seasonal buffer, pre-nesting habitat, and alternate nesting stands. Identify these important areas whenever planning for a project in the vicinity of a colony. Because WDFW has not mapped pre-nesting congregation areas and alternate nesting stands in our Priority Habitat and Species database, you should identify these sites during the development of a [habitat management plan](#) (HMP).

Demarcate a seasonal "quiet" buffer of 200 meters (656 ft) if any unusual or loud activity will occur in the breeding season (Table 1; 3). This seasonal buffer begins at the outer edge of the year-round buffer. If blasting (or any similarly loud activity) will occur in the breeding season, we recommend you designate a 400 meter buffer (1,320 ft; 48).

The presence of a pre-nesting congregation of herons often signals the start to the breeding season. These congregations generally are close to the nesting colony (≤ 1 km) and are discernable by a concentration of birds outside the nesting colony between February and March, and as early as January. You should map any known pre-nesting use area. Because we know little as to how pre-nesting habitat disturbance affects a colony, you should take a precautionary approach to managing these areas. We recommend minimal disturbance of any area where herons congregate prior to nesting due to their greater sensitivity early in the breeding season (2, 52, 57).

Although our recommendations focus on protecting the active colony, you also should identify and conserve potential nesting stands to preserve active nesting colonies in an area. Nesting herons periodically relocate their colonies and alternate nesting stands provide places to relocate

(51). We recommend retaining several forested alternate nesting stands of at least 4 hectares (10 ac) with dominant trees at least 17 meters (56 ft) high near breeding colonies (29, 39).

There are several strategies for finding the ideal places for an alternate nesting stand. Because herons sometimes nest in outlying trees away from where most nesting birds are concentrated, alternate nesting stands can be centered on these remote satellite nests. The satellite nest typically is represented by one, two, or several active or inactive nests located well beyond the nearest neighboring nest. We recommend using satellite nests to site an alternate nesting stand when they are located at least twice the year-round buffer distance from the nearest neighboring nest.

Another strategy is using former heron colony sites. When these sites are near an active colony, they may be designated as alternate nesting stands. But before choosing a former nesting site, consider the circumstances of the former colony site's demise. Above all, it probably is not suitable to designate a former nesting site if the site was likely vacated because of a nearby disturbance with permanent (e.g., housing development) or long-term (e.g., clear cut) effects.

If you cannot find a former nesting site or satellite nest, identify all nearby forest stands where structure and tree species composition is similar to the active nesting stand. The alternate nesting stand should be within a kilometer of the active colony and within 3 kilometers (1.9 mi) of foraging habitat. Preferably this should be the same foraging habitat used by the active colony.

FORAGING HABITAT

Because breeding herons need nearby foraging habitat, conserving potential foraging habitat is key. Similar to pre-nesting concentration areas and alternate nesting habitat, identify foraging habitat when developing your HMP. Although some herons forage further away, most herons feed within 3 kilometers (1.9 mi) of their colony.

Map all bodies of water within a 3 kilometer (1.9 mi) radius of a nesting colony (up to 10 km from colonies with ≥ 100 nests) as an initial step to identify potential foraging habitat. The perimeter and shallow portion of waterbodies are especially important for foraging. Although herons will not feed along every nearby waterbody, these waters will likely include foraging habitat. For colonies in the outer coast, Puget Sound, and Georgia Basin, publicly available data can help you pinpoint potential marine nearshore foraging habitat (Table 2). WDFW's multiyear heron foraging count in Puget Sound gives a snapshot of foraging during the 2003-04 breeding season. This is the region's only survey specifically of nearshore marine and estuarine foraging habitat.

Land use activities along the nearshore can adversely affect habitat where herons feed in concentrations. These habitats include eelgrass and kelp beds, shorelines, and wetlands (23). Dredging, filling, grading, or otherwise altering nearshore and riparian habitat can interrupt feeding and harm food supplies (23). Therefore, we recommend you not disturb key foraging habitat between March and September (R. Butler, personal communication). To protect foraging habitat, establish adequate riparian buffers such as those recommended by Knutson and Naef (34). You should also minimize certain activities where herons feed:

- removal of aquatic vegetation, especially native eelgrass.
- use of all watercraft within 180 meters (590 ft) of shallow waters where herons forage (44).
- logging mature forest close to nearshore foraging habitat (24).
- removing perch trees adjacent to foraging areas (51).
- draining, filling, or dredging wetlands or marshes (3).
- building close to riparian shorelines (34).

In addition to these measures, the Aquatic Habitat Guidelines Working Group's recommendations offer ways of limiting nearshore disturbances from overwater structures, shoreline armoring, and riparian alterations in Puget Sound (see [Envirovision et al. 2010](#)). Because these activities affect the species that herons feed on, you should review this publication before beginning one of these activities within 3 kilometers of any Puget Sound heron colony.

Because inland herons tend to feed in a dispersed manner, their foraging habitat often is not as obvious as in coastal areas. Although inland breeding herons do not restrict their foraging at one or two areas of concentrated feeding, the shallow margins of lakes, rivers, and wetlands that they do use are still vital. In fact, these habitats not only are important to herons, but to most of the region's other species as well (34). Consequently, we recommend using WDFW's [PHS Riparian management recommendations](#) and Washington Department of Ecology's [Wetland's Guidance Manual](#) to protect riparian habitats along lakes, rivers, and wetlands.

Table 2. Sources of GIS data that can aid in locating potential nearshore Great Blue Heron foraging habitat.

Database ^a	Description	Data Limitations ^b	Acquiring Data
Washington			
Priority Habitat and Species database	Documented locations of eelgrass beds and other nearshore habitats.	<ul style="list-style-type: none"> Database only includes a small subset of the locations of nearshore priority habitats in Washington. 	PHS on the Web
Shorezone Washington	Inventory of Washington's saltwater shorelines from 1994-2000. Information was collected by helicopter at low tide.	<ul style="list-style-type: none"> Not designed to capture small features. Shoreline units divided based on geology, not biology. Thus, biotic elements (e.g., eelgrass) may occur in the middle of a unit, or span several units. If biota is recorded as present, a user can be confident the feature was present during the flight. If a feature is <i>not</i> recorded, it is not necessarily absent. 	Washington Department of Natural Resource Data Web Portal
WDFW Puget Sound Heron Foraging Count	Aerial foraging count carried out in Puget Sound from 2003-2004.	<ul style="list-style-type: none"> A static dataset with no confirmed timeline for an update. 	Contact Data Steward for WDFW's Washington Survey Data Management (WSDM) system
Skagit and Whatcom county Intertidal Habitat Inventories	Vegetation classified using multispectral imagery from 1995-1997: eelgrass, brown algae, kelp, green algae, mixed algae, salt marsh, spit and berm vegetation, and red algae.	<ul style="list-style-type: none"> Vegetation type was classified using dominant vegetation. Other vegetation types may be present in abundances <30%. Low density vegetative cover (<25%) likely escaped detection. Subtidal vegetation that does not form a canopy may not be distinguished and conclusions regarding the presence or absence of this vegetation should not be drawn based on this data set. Vegetation patches < 16 m² are likely not detected. 	Washington Department of Natural Resource Data Web Portal
National Wetland Inventory	Information on the extent and status of wetlands in the United States.	<ul style="list-style-type: none"> Prepared from analysis of high altitude imagery. Accuracy of interpretation depends on image quality, experience of image analyst, and amount of ground-truthing conducted. 	Wetlands Mapper
British Columbia			
Shorezone British Columbia	Tool for identifying coastal biological communities in BC	<ul style="list-style-type: none"> Similar to Shorezone Washington data limitations. 	ess.info@gov.bc.ca
Coastal Resource Information System	Locations of kelp and eelgrass beds in BC		British Columbia CRIS Web Portal
Eelgrass Bed Mapping Application	Locations of kelp and eelgrass beds in BC	<ul style="list-style-type: none"> Details at www.cmNBC.ca/atlas_gallery/eelgrass-bed-mapping 	Community Mapping Network
Eelgrass mapping review: eelgrass mapping initiatives in coastal BC	A report of known eelgrass mapping and monitoring projects in BC	<ul style="list-style-type: none"> Surveys and mapping carried out after 2003 are not identified in the report. Report likely to have inadvertently left out some pre-2003 eelgrass mapping efforts. 	Dunster 2003

^a These inventories should be used only as screening tools. They are not site-specific, and should not replace site-specific surveys. However, they can all complement site-specific surveys by providing regional context.

^b Each of these databases represent a snapshot over a given time period and do not show changes in condition or status over time.

FORMER NESTING COLONIES

Because herons occasionally move back to seemingly abandoned nesting sites, we recommend you protect these sites. In Washington, documented re-nesting has occurred in sites over 10 years after being “abandoned” (C. Anderson, personal communication). Although entry for uses that will not alter the look of the habitat like hiking and dog walking is okay when no nesting herons are present, all other recommendations applying to an active colony should remain in effect for at least 10 years after nesting has ceased at the site of any former colony.

MANAGEMENT OF URBAN COLONIES

Although herons mostly nest away of urban settings, colonies occur in urban areas in Washington, British Columbia, and throughout the species’ North American range. Herons may tolerate everyday human activities, but in general birds often suspend nesting when they perceive the activity is a threat (17, 49). Although we do not know the threshold for what constitutes a threat, a seemingly benign stimulus like a pedestrian can lead a colony to terminate a nesting attempt (53).

In this update to the Great Blue Heron management recommendations we have further recognized differences in managing urban versus non-urban colonies. The primary approach is the tiered set of buffers (Table 1). In urban and suburban landscapes project planners should learn of any existing disturbances before beginning a project near a heron colony. That way a planner can identify an appropriate size and scope for a project. As a rule of thumb, new activities should not add to the intensity of disturbance a colony has historically tolerated and adapted to.

To see if a project will increase the level of disturbance from historical levels, we recommend you begin by documenting the intensity of all existing disturbances. We do not recommend any new activities that will lead to an increase in the intensity of disturbance. An increase in intensity can occur when a new activity is sited closer to a colony than that of existing activities. Increased intensity can also happen when the magnitude of a proposed disturbance is out of proportion to all existing disturbances located the same distance from a colony. To illustrate this point, consider a colony where herons have historically persisted where the footprint of the closest home is 60 meters from the colony. If a new home is sited 30 meters away, this would constitute an increase in intensity because the new home’s influence on the colony would be greater than that of the existing home. Other ways of increasing the intensity of disturbance include upzoning or changing or converting to a more intensive land use practice.

Where development already exists within our recommended year-round buffer zone (Table 1), we do not recommend any further infringement within this zone. Where further infringement will occur, new disturbances should not take place in the breeding season and we do not recommend large or novel events occurring at any time (52). Any further infringement should not happen without first developing a plan to mitigate for the loss of habitat.

CARRYING OUT THE HERON RECOMMENDATIONS

These guidelines are to be applied wherever herons nest in Washington. They may also be applicable throughout the heron’s North American breeding range. To protect heron colonies, these guidelines should be incorporated into the regulatory and non-regulatory framework of local communities throughout the region. Another way of protecting habitat is through land acquisition by organizations (e.g., land trusts) whose mission includes wildlife habitat conservation.

Two of Washington’s laws most influential to regulating Great Blue Heron habitat at the local level are the Shoreline Management Act and the Growth Management Act. Counties and cities

are encouraged to designate Great Blue Heron as a species of local importance and to adopt these management recommendations to support protection of this priority species.

Although effective heron conservation requires regulatory protections, non-regulatory incentives should also be put in place to protect herons. Some non-regulatory options in Washington include [transfer of development rights](#)¹ (TDR), current use taxation (via the development of a [Public Benefit Rating System](#)), and [Conservation Futures](#). [Local land trusts](#)² can also help property owners protect heron habitat through incentives such as conservation easements.

Each of these options can protect herons by giving landowners monetary or other incentives to avoid harmful activities. Communities with TDR programs allow certain landowners to transfer their right to develop in exchange for monetary compensations. In this program landowners with important wildlife habitat could receive eligibility to transfer their development rights to a less environmentally sensitive location. Participants in a PBRs program could also receive an economic incentive for limiting certain land use activities for the purpose of protecting a colony. Conservation Futures or other conservation funding or easement programs may also be designed to give preference points to properties with nesting herons. Counties and cities should adopt some or all of these options as a way to balance regulatory with non-regulatory protections for the Great Blue Heron and other sensitive species.

While many local governments protect the nesting colony, habitats that indirectly benefit a colony sometimes go unprotected. To protect pre-nesting habitat, alternate nesting stands, and foraging habitat, incentives can provide a set of useful tools. Local governments should offer incentives to landowners who want to permanently protect any type of breeding season habitat. Specifically, proposals near breeding season habitat deserve high priority when choosing between candidates for new Conservation Futures sites. Land trusts should also consider these areas when developing their conservation portfolios.

Habitat Management Plans. – A habitat management plan (HMP) should be developed whenever a land use proposal is submitted for an area in or near the core zone of an HMA. An HMP is a detailed report that outlines and documents where there is habitat, any planned incursions or habitat impacts, and a strategy for limiting impacts. Using our management recommendations as a guide, an HMP should describe the:

- resources, including active or historical nesting sites, pre-nesting congregation areas, and potential foraging sites.
- past, present, and future land uses.
- habitat features and processes potentially impacted by the proposal.
- habitat enhancement or mitigation measures, including quantitative goals and objectives.
- objectives that carefully balance the needs of the species with that of the landowner.
- implementation plan with maps, as-built drawings, and operation and maintenance plan.
- specific prescriptions and project timing to best meet the species' needs and to promote the health of their habitat.
- a schedule for periodic monitoring, and a contingency plan with corrective actions if conservation or mitigation actions do not lead to a desired outcome.

¹ In Canada TDRs are more commonly referred to as Transfer of Development Credits.

² A list of land trusts in British Columbia can be found at <http://landtrustalliance.bc.ca/members.html>.

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GLOSSARY

Breeding Season	This is the period when herons begin gathering in pre-nesting aggregations near the colony and concludes when young of the year have fledged.
Brood	A collective term for the offspring produced by an individual breeding female.
Brooding Period	The first days of a juvenile bird's life.
Clutch	Collection of eggs in a single nest.
Core Zone	This encompasses the area where herons are nesting as well as the adjacent year-round buffer zone.
Habitat Management Plan	A detailed report that outlines and documents the location of the important habitat area, any incursions or impacts into the habitat by a proposed land use action, and ways to limit any impacts to the habitat and to associated species.
Heron Management Area	This is the area that includes all key elements needed to sustain a colony of nesting Great Blue Herons. This includes the area where herons are nesting, year-round and seasonal buffer areas, the pre-nesting concentration area(s), and the foraging habitat that nesting herons are using during the breeding season.
Nesting Colony	The area where a group of heron nests are located.
Seasonal "Quiet" Buffer	An area just adjacent to the outer edge of the year-round buffer. Within this area certain loud activities such as blasting or the use of chain saws is not recommended.
Pre-nesting Habitat	Where herons gather in groups prior to initiating nesting. Pre-nesting often occurs along larger lakes, wetlands, watercourses, and fallow fields.
Year-round Buffer	An area set between the outer edge of the nesting colony and the inner perimeter of the seasonal buffer. Within this area most land use activities are not recommended at any time of the year.



Cavity Nesting Ducks

Barrow's Goldeneye - *Bucephala islandica*
Common Goldeneye - *Bucephala clangula*
Hooded Merganser - *Lophodytes cucullatus*
Bufflehead - *Bucephala albeola*
Wood Duck - *Aix sponsa*

Last updated: 2000

Written by Jeffrey C. Lewis and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

These five species of cavity-nesting ducks vary in distribution. The breeding and wintering ranges of the Barrow's goldeneye (*Bucephala islandica*) and the bufflehead (*Bucephala albeola*) extend from Alaska to California. The wood duck (*Aix sponsa*) and hooded merganser (*Lophodytes cucullatus*) winter south of Alaska and breed from British Columbia southward. The common goldeneye winters from Alaska to California and breeds in isolated areas of Washington northward to Alaska (Bellrose 1976).

Washington is one of a very few states where all 5 species are known to breed (Matt Monda, personal communication). The Barrow's goldeneye is widespread and breeds within the Cascades and in north-central Washington (see Figure 1). A unique population of Barrow's goldeneye nest in cavities within the talus slopes and basalt cliffs surrounding Lake Lenore and Alkali Lake in central Washington (Matt Monda, personal communication). Buffleheads are only known to breed south of Spokane on Turnbull National Wildlife Refuge and at Big Meadow Lake in Pend Oreille County (see Figure 2; Smith et al. 1997). The common goldeneye breeds in a few isolated areas in northeastern Washington (see Figure 3). Breeding areas for hooded mergansers and wood ducks are more widespread, primarily in the western part of the state, but they also breed in eastern Washington where adequate habitat occurs (see Figure 4; Smith et al. 1997). In addition, large concentrations of

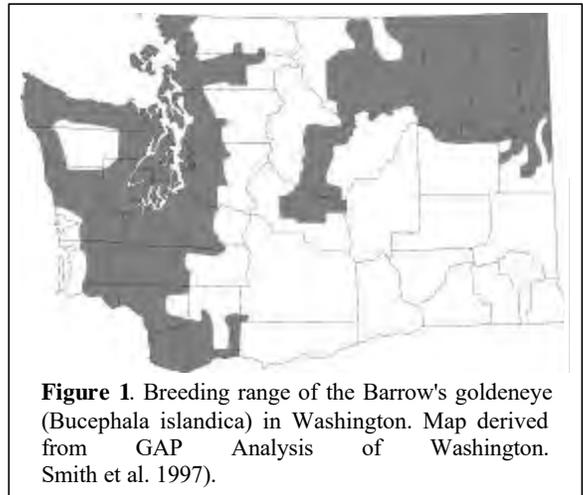


Figure 1. Breeding range of the Barrow's goldeneye (*Bucephala islandica*) in Washington. Map derived from GAP Analysis of Washington. Smith et al. 1997).

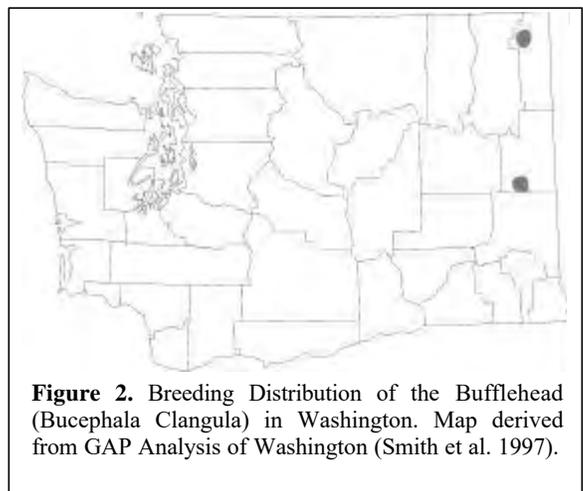


Figure 2. Breeding Distribution of the Bufflehead (*Bucephala Clangula*) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

breeding wood ducks occur in the Yakima valley (see Figure 5; Matt Monda, personal communication).

All five species can be found in larger numbers during migration. Though wood ducks typically winter further south than Washington, significant wintering numbers can be found in the Yakima Valley and the Columbia River estuary. Goldeneyes and buffleheads winter in large numbers on Puget Sound and larger rivers. Hooded Mergansers are less common but winter in a wide variety of habitats (Matt Monda, personal communication).

RATIONALE

Cavity-nesting ducks provide recreation to hunters and bird watchers, and they are vulnerable to loss of nesting habitat. These species require nesting cavities within trees and snags, which are commonly lost through commercial forestry, firewood cutting, and shoreline development. All but the wood duck exhibit low productivity and low population sizes, breed for the first time at an older age, and are poor pioneers of unoccupied habitats (Goudie et al. 1994). Common goldeneye and bufflehead are the least common breeding ducks in the state. Loss of suitable nesting sites will eliminate use of an area by breeding birds.

HABITAT REQUIREMENTS

In Washington, cavity-nesting ducks nest primarily in late-successional forests and riparian areas adjacent to low gradient rivers, sloughs, lakes, and beaver ponds (Thomas 1979, Brown 1985, Parker 1990). Animal matter can comprise over 75% of the diets of the hooded merganser, bufflehead, common goldeneye and Barrow's goldeneye. These species feed primarily on aquatic insects, mollusks, crustaceans, and small fish (Gauthier 1993, Dugger et al. 1994, Fitzner and Gray 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Wood ducks up to 6 weeks old depend on animal matter, while older ducklings and adult wood ducks feed on aquatic and emergent plants, acorns, grain, and other seeds (Bellrose and Holm 1994).

Nest Site Characteristics

These 5 species of ducks nest almost exclusively in tree cavities, which offer protection from weather and predators. They are secondary cavity nesters, using cavities created by large woodpeckers or by decay or damage to the tree. Cavity use is dependent on the proximity of suitable brood habitat, predator levels, and competition (and perhaps brood parasitism) from the other cavity-nesting species (Peterson and Gauthier 1985, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995). Nest site fidelity is common,



Figure 3. Breeding distribution of the common goldeneye in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).



Figure 4. Breeding distribution of the hooded merganser (*Lophodytes cucullatus*) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

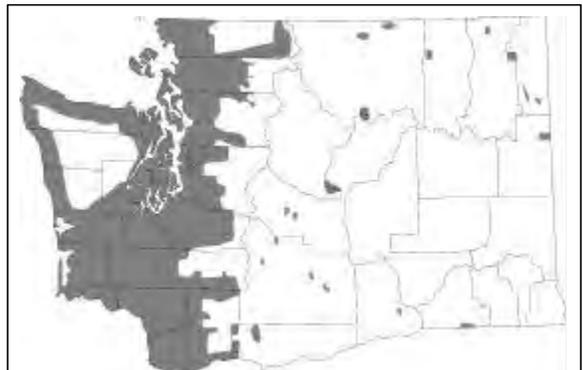


Figure 5. Breeding range of the wood duck (*Aix sponsa*) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

especially at successful nests (Dow and Fredga 1984, Hepp and Kenamer 1992, Gauthier 1993, Dugger et al. 1994). Population levels of cavity-nesting ducks can be related to the availability of nesting sites (Dow and Fredga 1984, Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995).

In general, minimum cavity dimensions that will accommodate all 5 species include an entrance hole at least 9 cm (3.5 in) in diameter, with the internal cavity 25 cm (10 in) deep and 19 cm (7.5 in) in diameter (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995). The bufflehead, however, appears to prefer smaller cavity entrances (6.5 cm diameter [2.5 in]; flicker nests are ideal) which may reduce nest-site competition and brood parasitism from larger ducks (especially goldeneyes) (Gauthier 1993). Hooded mergansers have less specific nest-cavity preferences, but they prefer nest sites that are within or very near brood habitat (Dugger et al. 1994). Nest trees should have a diameter at breast height (dbh) of 30 cm (12 in) (Soulliere 1988), but all 5 species typically use nest trees >60 cm (24 in) dbh. These ducks will use tree cavities that occur above 20 m (66 ft), but they generally use cavities 2-15 m (6-49 ft) above the ground or water. The canopy around a cavity is generally open and does not overhang the entrance (Bellrose 1976). Optimal density of potential nest trees is 12.5/ha (5/ac) (Sousa and Farmer 1983).

Brood Habitat

Shallow wetlands within 0.8 km (0.5 mi) of cavities provide optimal brood habitat for all cavity-nesting ducks. Wood ducks typically use habitats with 50-75% overhanging woody vegetation and/or emergent vegetation for brood escape cover (Sousa and Farmer 1983); all 5 species use downed logs or low islands for loafing (Webster and McGilvrey 1966, Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Both goldeneye species and the bufflehead typically use more open water with less emergent vegetation as brood habitat (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995). Common goldeneyes prefer acidic and fishless waters where there is little or no competition from fish for aquatic insects (Gauthier 1993, Poysa and Virtanen 1994, Eadie et al. 1995).

LIMITING FACTORS

Population levels of cavity-nesting ducks can be limited by the availability of suitable nesting sites, adequate brood escape cover, foraging areas, nest predation, and nest parasitism (Dow and Fredga 1984, Gauthier 1993, Bellrose and Holm 1994, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Human disturbance of nesting ducks may affect productivity. Destruction of cavity trees can eliminate these species from an area (Matt Monda, personal communication).

The use of herbicides or pesticides near wetlands may affect cavity-nesting ducks by lowering the numbers of invertebrates, and by adversely affecting aquatic and emergent vegetation. All of these ducks are known to accumulate toxins in their tissues, especially in areas where toxins are elevated, such as downstream from mines, pulp and paper mills (Blus et al. 1993, Swift et al. 1993, Vermeer et al. 1993, Champoux 1996).

MANAGEMENT RECOMMENDATIONS

An adequate supply of nest cavities is the key to supporting populations of cavity-nesting ducks in Washington. Land management activities designed to promote healthy populations of these 5 duck species should ensure a continuous supply of available nest cavities.

Snags and cavity trees near suitable wetlands should be preserved and created to achieve a minimum density of 12.5 potential nest cavities/ha (5/ac) (McGilvrey 1968). Snags and cavity trees should have a minimum diameter of 30 cm (12 in), although a diameter of 60 cm (24 in) is preferred (McGilvrey 1968).

In general, the following nest cavity characteristics will accommodate all five species and should be considered when evaluating potential nest sites:

- an elliptical entrance hole at least 9 cm (3.5 in) in diameter (buffleheads may prefer smaller cavity entrances that are 6.5 cm diameter [2.5 in])
- an internal cavity 25 cm (10 in) deep and 19 cm (7.5 in) in diameter (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995)
- cavities 2-15 m (6-49 ft) above the ground or water are generally preferred, although cavities above 20 m (66 ft) in trees will be used
- the canopy around a cavity should be open and not overhang the entrance (Bellrose 1976)

Large woody debris and downed logs should be present, as well as low islands for breeding and brood use (McGilvrey 1968). Flooded timber should not be logged, and woody vegetation along the shores of nesting and brood areas should be retained. In some situations, flooding standing or downed timber may be used to create snags and brood habitat (McGilvrey 1968).

Predator-proof nest boxes for cavity nesting ducks can be used in areas where natural cavity sites are limited but other habitat requirements are met (Bellrose 1976). However, it is unknown how nest boxes affect natural selection or species fitness over time. In some situations, it may not be suitable to consider nest boxes as permanent substitutes for natural cavities. The decision to provide nest boxes to supplement existing cavities or nest boxes should consider occupancy rates of existing suitable nest sites.

Wood duck boxes should be designed and placed following the recommendations of Bellrose and Holm (1994). Boxes for the other four species should follow the guidelines provided by Lumsden et al. (1980) and Gauthier (1993). Nest boxes for cavity nesting ducks are commonly made out of rough-cut lumber. Other materials that can be used include sheet metal and slab wood (Bellrose and Holm 1994).

To minimize the impacts of brood parasitism, predation, and starling use, nest boxes for wood ducks should be placed far enough apart so that one is not visible from the other. (Bellrose and Holm 1994, Semel and Sherman 1995). Bellrose and Holm (1994) recommend a minimum of 46 m (150 ft) between nest box structures. Nest box placement can affect clutch size, rates of brood parasitism, and hatching success in wood ducks. Traditionally placed nest boxes that are grouped together with highly visible entrances often suffer from higher rates of brood parasitism and produce less ducklings over time than nest boxes placed in trees out of sight of each other (Bellrose 1976, Semel and Sherman 1995).

In areas supporting wood ducks, mast-producing (nut producing) trees and shrubs, such as oaks (*Quercus garryana*) and hazelnuts (*Corylus cornuta*), should be maintained.

The use of pesticides or herbicides may negatively affect these species. If pesticide or herbicide use is planned for areas where cavity-nesting ducks occur, refer to Appendix A for useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

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PERSONAL COMMUNICATION

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KEY POINTS

Habitat Requirements

- Cavity-nesting ducks use natural cavities with minimum entrance size of 9 cm (3.5 in) in diameter and minimum internal dimensions of 25 cm (10 in) deep and 19 cm (7.5 in) diameter. Smaller entrances (~6.5 cm [2.5 in]) are preferred by buffleheads.
- Nest trees usually have a minimum dbh of 30 cm (12 in), although 60 cm (24 in) is preferred.
- Natural cavities 2-15 m (6-49 ft) above ground or water are typically used by all 5 species; however, use of cavities over 20 m (66 ft) is not unusual.
- Optimal density of potential nest cavities is 12.5/ha (5/ac), within 0.8 km (0.5 mi) of suitable brood habitat.
- Ideal wood duck brood habitat consists of shallow wetlands with 50-75% cover and abundant downed logs or low islands. Goldeneyes, buffleheads, and to some extent hooded mergansers do not require the amount of emergent vegetation typical of wood duck brood habitat.

Management Recommendations

- Predator-proof nest boxes for cavity nesting ducks can be used in areas where natural cavity sites are limited but other habitat requirements are met. However, in some situations, it may not be suitable to consider nest boxes as permanent substitutes for natural cavities. The decision to provide nest boxes to supplement existing cavities or nest boxes should consider occupancy rates of existing suitable nest sites.
- Wood duck boxes should be designed and placed following the recommendations of Bellrose and Holm (1994). Boxes for the other four species should follow the guidelines provided by Lumsden et al. (1980) and Gauthier (1993).
- To minimize the impacts of brood parasitism, predation, and starling use, nest boxes for wood ducks should be placed far enough apart so that one is not visible from the other. Bellrose and Holm (1994) recommend a minimum of 46 m (50 yd) between nest box structures.
- Snags and cavity trees 30 cm (12 in) (60 cm [24 in] preferred) near suitable wetlands should be maintained to achieve a minimum density of 12.5 potential nest cavities/ha (5/ac).
- Mast-producing trees and shrubs (e.g., oaks, hazelnuts) should be maintained.
- Large woody debris and downed logs should be present, as well as low islands for breeding and brood use.
- Avoid logging flooded timber and leave woody vegetation along the shores of nesting and brood areas. In some situations, flooding standing or downed timber may be used to create snags and brood habitat.
- The use of pesticides or herbicides may negatively affect these species. If pesticide or herbicide use is planned for areas where cavity-nesting ducks occur, refer to Appendix A for contacts useful for assessing pesticides, herbicides and their alternatives.

Harlequin Duck

Histrionicus histrionicus

Last updated: 1999



Written by Jeffrey C. Lewis and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Harlequin ducks winter along the Pacific Coast from the Aleutian Islands to northern California and along the Atlantic Coast. Their breeding and summer range extends from the coastal mountains of Alaska to California, along the northern Rocky Mountains to northwestern Wyoming, and along the north Atlantic Coast, southern Greenland, and Iceland (Bellrose 1980).

In Washington, harlequins historically breed in the Olympic Mountains, the Cascades, and the Blue and Selkirk Mountains (see Figure 1; Jewett et al. 1953, Schirato 1994); however, their presence in the Blue Mountains is now in question (Schirato 1994). Wintering areas include northern Puget Sound, northern Hood Canal, the Strait of Juan de Fuca, San Juan Islands, and the outer coast. Significant numbers of harlequins that breed in Washington molt and winter in the Strait of Georgia, British Columbia (I. Goudie, personal communication). Also, some harlequins that molt and winter in Washington breed in interior British Columbia, Alberta, Idaho, Wyoming, and Montana.

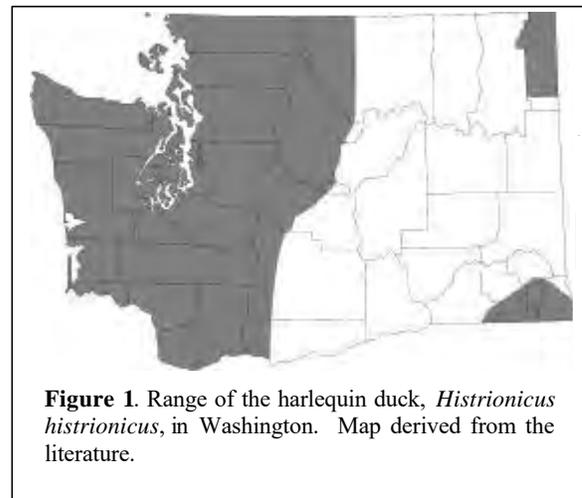


Figure 1. Range of the harlequin duck, *Histrionicus histrionicus*, in Washington. Map derived from the literature.

RATIONALE

The harlequin duck is a Washington State Game species that provides year-round recreation for consumptive and non-consumptive users. This species is limited by low productivity, older age at sexual maturity, and low intrinsic rate of population growth (Goudie et al. 1994). They are also sensitive to human disturbance (Cassirer and Groves 1994), which is likely to decrease their productivity.

HABITAT REQUIREMENTS

During the nesting season (April-June), adult harlequin ducks require fast-flowing water with loafing sites nearby. Streams usually have substrate that ranges from cobble to boulder, with adjacent vegetated banks. They have been found more often at distances >50 m (164 ft) from roads or trails, and in stream reaches with mature and old growth forest cover (Cassirer and Groves 1994). Whereas harlequins generally appear to avoid certain types of human disturbances, some anecdotal evidence has shown that individuals may use and even nest in areas that are regularly

visited by humans (Cassirer et al. 1993). Harlequins often nest on the ground (Bengtson 1972), however, cavities in trees and cliff faces also serve as nest sites (Cassirer et al. 1993). Midstream loafing sites are an important part of suitable habitat (Cassirer and Groves 1994). Since adult females show fidelity to nest sites, it is unlikely that they will relocate to new nesting areas once they are disturbed (Wallen and Groves 1989). However, radio-tagged harlequins have used new nest sites after a nest failure the previous year (Cassirer et al. 1993).

Broods remain near nesting areas for the first few weeks after hatching, then move downstream during the summer (Kuchel 1977, Wallen 1987, Cassirer and Groves 1989). Broods prefer low-gradient streams with adequate macroinvertebrate fauna (Bengtson and Ulfstrand 1971). Preferred prey include crustaceans, molluscs, and aquatic insects (Cottam 1939). Aquatic insect larvae appear to make up the bulk of the diet for juveniles and for adults during the breeding season (Cassirer and Groves 1994).

During winter, harlequins forage and loaf along boulder-strewn shores, points, gravel substrates, and kelp beds. Prey species occur chiefly on rock substrate (70%) and gravel substrate (22%) (Vermeer 1983). Most wintering harlequins occur within 50 m (164 ft) of shore in saltwater areas (Gaines and Fitzner 1987).

LIMITING FACTORS

Low benthic macroinvertebrate abundance may limit the productivity of harlequin ducks (Bengtson and Ulfstrand 1971). Human disturbance discourages nesting at traditional sites and thereby decreases productivity. A high tendency for individuals to breed at the same location year after year may result in a separation of populations with little chance to replenish stable or declining populations. Populations are highly sensitive to additional mortality from such causes as hunting, oil pollution, or food contamination. Additional mortality sources exceeding 5% appear to be unsustainable (Goudie et al. 1994).

MANAGEMENT RECOMMENDATIONS

Maintain woody debris and riparian vegetation in and adjacent to streams. A 50 m (164 ft) buffer along nesting streams is necessary to recruit suitable large organic debris for loafing sites and to ensure cover for nesting females and protective cover from predators (Murphy and Koski 1989). A larger buffer may be necessary on second growth stands. Logging activity in the riparian corridor should be avoided (Cassirer and Groves 1989, 1994).

Stream alterations that would cause greater surface runoff, changing water levels, or lower macroinvertebrate levels should be avoided (Kuchel 1977).

Human disturbance should be managed during the breeding and brood-rearing season (April-August). To limit disturbance, trails or roads should be farther than 50 m (164 feet) from streams used by harlequin ducks and should not be visible from the stream (Cassirer and Groves 1989). Fishing, rafting, and canoeing activities should be limited on streams used by nesting harlequins (Wallen 1987), especially in streams <20 m (66 ft) in width. The April through August nesting and brood-rearing period are the critical months to reduce disturbance.

Rocky shoreline areas used during winter should be protected. Disturbances at traditional coastal molting sites should be limited.

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PERSONAL COMMUNICATIONS

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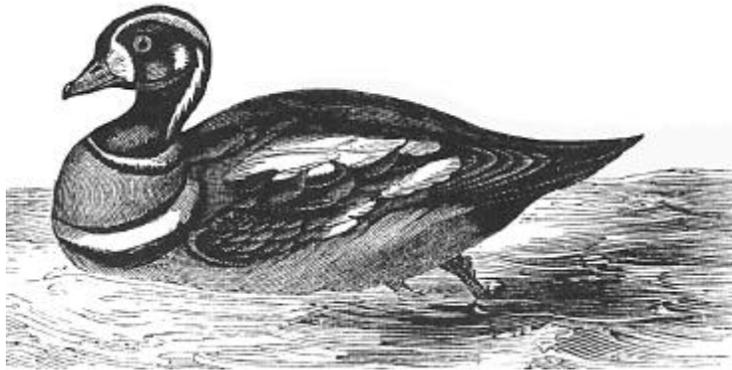
KEY POINTS

Habitat Requirements

- In the summer, adult harlequin ducks require fast-flowing streams with clear water, loafing sites, and dense bank vegetation.
- Broods require low gradient streams with an adequate macroinvertebrate food supply.
- During the nesting season, harlequin ducks require areas with little or no human disturbance.
- Harlequin ducks winter along rocky marine shorelines, frequently using kelp beds.

Management Recommendations

- Manage human disturbance during the breeding and brood-rearing season (April-August).
- Protect rocky shoreline areas used during winter. Limit potential disturbance at traditional coastal molting sites.
- Maintain woody debris and riparian vegetation in and adjacent to streams.
- A 50 m (164 ft) buffer along nesting streams is necessary to recruit suitable large organic debris for loafing sites. A larger buffer may be necessary on second growth stands. Provide nesting and hiding cover within this buffer.
- Logging activity in the riparian corridor should be avoided.
- Stream alterations that would cause greater surface runoff, change water levels, affect water quality, or lower macroinvertebrate levels should be avoided.
- To limit disturbance, trails or roads should be farther than 50 m (164 ft) from streams used by harlequin ducks, and should not be visible from the stream. Also fishing, rafting, and canoeing activity should be limited on streams used by nesting harlequins, especially if such streams are <20 m (66 ft) wide.



Northern Goshawk *Accipiter gentilis*

Last revised: 2003



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Written by Steven M. Desimone and David W. Hays

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The northern goshawk (*Accipiter gentilis*) is holarctic in distribution, occupying a wide variety of boreal and montane forest habitats throughout Eurasia and North America (Palmer 1988, Johnsgard 1990). Three subspecies of the goshawk are recognized in North America (Johnsgard 1990, James and Palmer 1997), but only the northern goshawk (*A.g. atricapillus*) is known in Washington.

Northern goshawks can occur in all forested regions of Washington (see Figure 1). As of 2003, there were 338 documented breeding territories in the state (Washington Department of Fish and Wildlife [WDFW], unpublished data). The exact number is not known, because monitoring is not currently being conducted. The number of historical breeding sites lost due to habitat alteration and the number of new territories in suitable habitat are also unknown. About 50% of the documented breeding territories occur in the eastern Cascades, 27% in the western Cascades, 12% in other forested areas of northeast and southeast Washington, and 10% in the Olympic Peninsula (WDFW, unpublished data). Breeding birds formerly occurred in the Puget trough (Jewett et al. 1953). Less than one percent of recent breeding records have been recorded from this area and southwest Washington (south of the Puget Sound and west to the coast). Wintering goshawk populations in Washington include resident birds (Bloxtton 2002; WDFW, unpublished data) and migrants that move into the state during winters when food shortages occur in their territories (Squires and Reynolds 1997). Overall, densities of territorial pairs in Washington appear to be lower than elsewhere in the western United States (Table 1) but this is partly dependent on habitat quality.

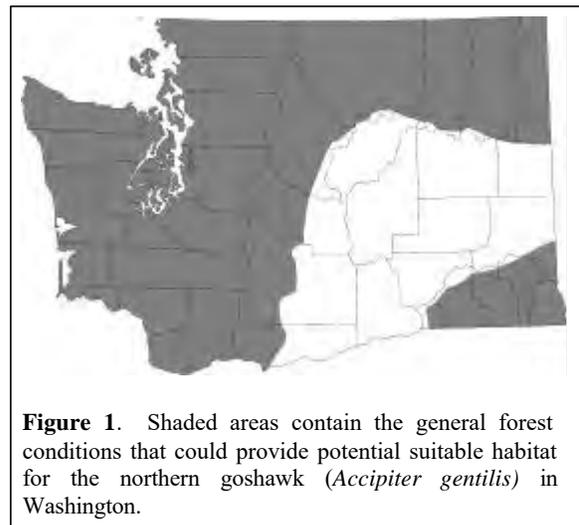


Figure 1. Shaded areas contain the general forest conditions that could provide potential suitable habitat for the northern goshawk (*Accipiter gentilis*) in Washington.

Table 1. Density estimates of northern goshawk territories in the western United States. Forest management in the study areas ranged from intensive to minimal timber harvest.

Study	Number of pairs	Mean distance (km) to nearest-neighbor	Density (territories/1000 ha)	Spacing (ha/pair)	Reference
Western Washington industrial forest	3	-	0.04-0.13	-	Bosakowski et al. 1999
Upper Yakima River, Washington	1	-	0.1 ^{a, b}	9091	Wagenknecht et al. 1998
	4	-	0.5 ^{a, c}	2083	
	5	-	0.5 ^{a, d}	1852	
Eastern Oregon National Forests	20	4.4	0.7	1538	DeStefano et al. 1994
Eastern Oregon	4	5.6	-	2750	Reynolds and Wight 1978
Klamath National Forest, California	21	3.3	0.6 - 1.1	1750 - 935	Woodbridge and Detrich 1994
North Kaibab NF, Arizona	100	2.5	2.0	491	Reynolds 1997, Reynolds and Joy 1998

^a Estimate calculated with one year of survey data in each forest type; ^b Open Douglas-fir/ponderosa pine; ^c mixed conifer-lodgepole pine; ^d mixed Douglas-fir, grand fir, western hemlock

RATIONALE

The northern goshawk is a Federal Species of Concern and State Candidate species in Washington because of concerns about its population status. Although a decline in populations of northern goshawks has been suggested based on reduced nesting in areas of extensive harvest of mature forest (Crocker-Bedford 1990, 1995; Ward et al. 1992), Kennedy (1997) found no evidence to support the contention that goshawk populations in the western United States were declining, increasing, or stable. Kennedy (1997) acknowledged, however, that population declines might not be apparent due to insufficient sampling techniques. In Washington, goshawks appear to have been largely extirpated from urbanized landscapes and from some areas that are moderately developed or intensively managed for timber on short rotations (WDFW, unpublished data). There are no studies evaluating the population status of the goshawk in the Pacific Northwest. Because goshawks build multiple nests within nesting territories that are often used by other raptor species (Moore and Henny 1983, Buchanan et al. 1993; S. Desimone, unpublished data), the loss of goshawks might indirectly affect other forest species.

HABITAT REQUIREMENTS

Research in western North America suggested that the home range of breeding goshawks can be split into three functional divisions: the nest area or areas, the post-fledging family area (PFA), and the foraging area; the sum of these areas compose a northern goshawk's home range (Reynolds et al. 1992) (Figure 2). Habitat information relevant to each of these scales is provided below.

Nest Area

The nest area (in some studies referred to as the *nest stand*) is composed of one to several forest stands that contain the active and alternate nest structures (Figure 2). Usually occupied by breeding goshawks from March until

September, nest area boundaries are determined by the movement and behavior of the adults and newly fledged young, and by the locations of prey plucking areas and roosts that are usually within the nest area. (Reynolds et al. 1982). The term “occupied” is defined by the presence of at least one adult goshawk in the area or territory during a breeding season surveys (Desimone 1997; Finn et al. 2002a, b). The size of nest areas ranged between 8-12 ha (20-30 ac) (Reynolds 1983, Crocker-Bedford and Chaney 1988, Reynolds et al. 1992), but other studies suggest that nest areas can be larger (39 ha [96 ac; Finn et al. 2002a] up to 115 ha [284; Woodbridge and Detrich 1994]).

Within the nest area, the nest site is defined for this document as the immediate vicinity surrounding the nest tree, usually = 1.0 ha (2.5 ac; see McGrath et al. 2003). Goshawks in Washington nest almost exclusively in coniferous forest, although a few nests have been found in smaller aspen (*Populus* spp.) groves within the larger coniferous forest landscape in Okanogan County, Washington (WDFW, unpublished data; S. Desimone, personal observation).

Stand age. Studies in North America indicate that goshawks typically select mature or old forest habitat for nesting (Reynolds et al. 1982, Moore and Henny 1983, Fleming 1987, Crocker-Bedford and Chaney 1988, McGrath 1997, Daw and DeStefano 2001; Finn et al. 2002a, b). Research in Washington and Oregon has shown links between nest stand occupancy and forest stand age. Finn et al. (2002a) found late-seral forest consistently averaged 64-75% of the nest areas (39 ha [96 ac]), PFA (177 ha [437 ac]) and home ranges (1886 ha [4660 ac]) of occupied goshawk territories on the Olympic Peninsula, and the average age of trees at occupied nest stands in managed and unmanaged forest were 147 years (95% CI 97-198) (Finn et al. 2002b). These forests are generally characterized by large sawtimber, >50% canopy closure, two or more canopy layers, gaps in the canopy, abundance of large diameter crowns, and the presence of shade tolerant trees. Most goshawk nests in eastern Washington (Finn 1994, McGrath 1997; J. Buchanan, unpublished data) and Oregon (Reynolds et al. 1982, Desimone 1997, Daw and DeStefano 2001, McGrath et al. 2003) were in mature or older forest. In eastern Oregon, Daw and DeStefano (2001) showed that goshawk nest stands were negatively associated with regenerating and young (average diameter at breast height [dbh]: 12-22 cm [5-9 in]) forest at the nest stand scale (10 ha [25 ac]). In east-central Washington and eastern Oregon, McGrath (1997) determined that increasing the amount of early-seral forest by 1% within specified areas surrounding the nest tree would decrease the odds of the site being suitable for nesting by 10%.

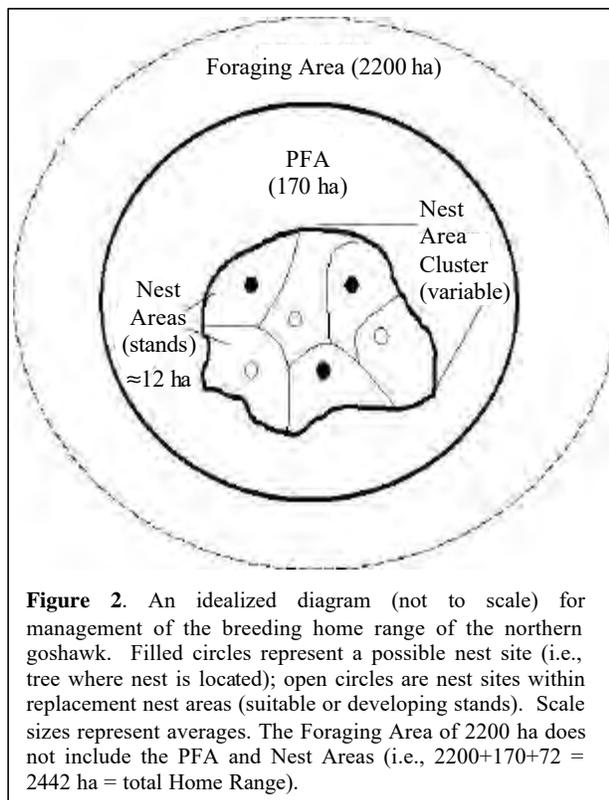


Figure 2. An idealized diagram (not to scale) for management of the breeding home range of the northern goshawk. Filled circles represent a possible nest site (i.e., tree where nest is located); open circles are nest sites within replacement nest areas (suitable or developing stands). Scale sizes represent averages. The Foraging Area of 2200 ha does not include the PFA and Nest Areas (i.e., $2200+170+72 = 2442$ ha = total Home Range).

Finn (unpublished data) studied landscape patterns and habitat patch features around 25 goshawk nests in the upper Yakima River basin from 1992-1996. They found that the landscape surrounding nests was more homogeneous and contained less seedling/sapling and forest edge than what was available at the combined nest areas scale (32 ha [79 ac]) and at the post-fledging family area scale (210 ha [519 ac]). At the foraging range scale (3,566 ha [8,812 ac]), no differences were found between areas used by goshawks versus other areas in the landscape.

Tree density. Goshawk nest areas generally have a high density of large trees. On the Olympic Peninsula, the average diameter of trees within occupied nest areas was 59 cm (23 in; 95% CI 51 - 67cm) (Finn et al. 2002b). These stands had more large-diameter (≥ 63 cm [25.7 in; 95% CI 22-59 cm]) trees than unoccupied historic nest areas. In the Olympic Peninsula and western Cascades, dominant and co-dominant trees in nesting stands averaged 43-48 cm (17-19 in) dbh and generally exceeded 27 m (89 ft) in height (Fleming 1987). On average, there were 482 trees/ha (195 trees/acre) >6 cm dbh (2.4 in) within nest stands in eastern Oregon (Reynolds et al. 1982). Finn (1994)

found that goshawk nest stands contained more snags and down woody material, had greater basal area, and an increased number of tree species than random plots in Okanogan County, Washington.

Canopy attributes. Researchers have used various methods to measure forest canopy and this may influence the ability to compare different data sets. Despite this, the overwhelming majority of stands used by nesting goshawks have relatively closed canopies (i.e., >50%) and are often characterized by multiple canopy layers. In western Washington, Fleming (1987) found goshawk nests in stands with an average canopy closure of about 60-65%. Additionally, nest stands had one to three canopy layers with generally poor development of understory vegetation. Similarly, Finn et al. (2002b) found that canopy closure in occupied nest areas averaged 78% in the Olympic Peninsula. Occupied nest areas had relatively greater canopy depth (i.e., the difference between the average maximum and minimum overstory height; Finn et al. 2002a) as compared to unoccupied historic nest areas. The odds of occupancy at historical nest areas increased with increasing overstory canopy depth (Finn et al. 2002a). Greater canopy depth coupled with low shrub density best discriminated occupied nest areas versus unoccupied historic nest areas (Finn et al. 2002a). This research also showed that occupancy of a stand by goshawks decreased by 47% with each 10% increase in understory shrub cover. Overall, increasing early-seral forest cover was associated with decreasing goshawk occupancy at historical nest stands on the Olympic Peninsula (Finn et al. 2002a).

Canopy attributes east of the Cascades are relatively similar to the previously discussed west-side attributes. Goshawk nest stands in eastern Oregon typically had multi-layered canopies with green foliage occurring a few meters to over 40 m (131 ft) above the ground, and the tops of understory trees overlapped with the lower crowns of overstory trees (Reynolds et al. 1982). In Okanogan County, average overstory canopy closure in nest stands was 75% (Finn 1994), and canopy closure in the eastern Cascades averaged 74% in stands where spotted owls exploited goshawk nests for breeding (J. Buchanan, personal communication). In east-central Washington, canopy closure averaged 73% (McGrath 1997). In eastern Oregon, mean canopy closure was 60% (Reynolds et al. 1982) and 88% (Moore and Henny 1983) within nest stands.

Size. The sizes of goshawk nest areas in the Pacific Northwest are variable. On the Olympic Peninsula, occupied goshawk nest areas averaged 33 ha (82 ac) (range: 12-69 ha [30-170 ac]) (Finn et al. 2002b). The conclusions of Finn et al. (2002a) indicated that the composition of nest areas was largely (about 67%) late-seral forest.

In eastern Oregon, Reynolds and Wight (1978) found that the size of nest areas or stands varied with topography and the availability of large trees in dense patches of at least 10 ha (25 ac). Woodbridge and Detrich (1994) found that goshawk territories in northern California contained one to five different forested nesting stands (average = 2). These nest stands were homogeneous in composition, age, and structure relative to the surrounding forest (Woodbridge and Detrich 1994). Stands <10 ha (25 ac) typically contained one or two nests that were occasionally occupied by goshawks, whereas stands >20 ha (49 ac) often contained several nests that were frequently occupied (Woodbridge and Detrich 1994).

Spacing and number of nests. Established pairs of goshawks have multiple nest areas that are often structurally similar within a home range (Reynolds et al. 1992). Goshawks may build =10 nest structures within a territory that can be occupied over multiple generations (Crocker-Bedford 1990; S. Joy and T. Fleming, personal communications). In western Washington, the distance between alternate nests of the same territory averaged 536 m (1759 ft) (S. Finn, unpublished data). In more arid forested habitats such as pine and mixed conifer, the average distance between alternate nests within a territory ranged between 245 and 273 m (804-896 ft) (Reynolds et al. 1994, Woodbridge and Detrich 1994, Desimone 1997).

Nest tree and nest site. Nest structures in western Washington are often in Douglas-fir (*Pseudotsuga menziesii*), with western hemlock (*Tsuga heterophylla*) used to a lesser extent (Fleming 1987, Finn 2000). Nests in deciduous trees are uncommon (Fleming 1987; S. Finn and T. Bloxton, unpublished data). Deciduous trees used for nesting west of the Cascade mountain crest (e.g., red alder [*Alnus rubra*]) were generally found in the sub-canopy and isolated in coniferous forest stands comprised of less than 2% deciduous species (Finn et al. 2002b). Goshawks in eastern Washington and Oregon nest in Douglas-fir, ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), grand fir (*Abies grandis*) and occasionally aspen (Finn 1994,

McGrath 1997; WDFW, unpublished data). In areas of heavy mistletoe infection, goshawks will use mistletoe “brooms” as a nesting substrate (Moore and Henny 1983, Buchanan et al. 1993, Finn 1994). They may also occasionally nest in dead trees (Moore and Henny 1983; S. Desimone, unpublished data). Average nest tree size in the Pacific Northwest is >53 cm (21 in) dbh (range: 25-172 cm [10-68 in]) (Moore and Henny 1983, Fleming 1987, Bull and Hohmann 1994, McGrath et al. 2003; S. Finn, unpublished data). Goshawks build fairly large, bulky stick nests (about 0.6-0.9 m [2-3 ft] outside diameter), and nest placement is usually in the lower third of the forest canopy and relatively close to the tree trunk (Reynolds et al. 1982, McGrath 1997, Finn 2000).

Basal area at the nest site is usually higher than that of the surrounding stand. McGrath (1997) measured vegetation attributes around 82 active goshawk nests in eastern Oregon and central Washington east of the Cascade crest. At the nest site scale (1 ha [2.5 ac]), higher basal area best discriminated nest sites from random sites. Nest sites had higher average basal area/tree, and greater live stem density compared to random sites (McGrath 1997). In Montana and northern Idaho, 0.04 ha (0.1 ac) plots around nest sites (n=17) had an average of about 6 trees/plot that were >30 cm dbh (64 trees/ac >12 in) (Hayward and Escano 1989). In northeastern Oregon, Moore and Henny (1983) reported an average of 208 trees/ha >32 cm dbh (84 trees/ac >13 in) surrounding 34 nests.

Goshawks pluck the hair or feathers of their prey before consuming or bringing it to the nest for incubating/brooding females or young. Consequently, established ‘plucking posts’ (i.e., perches used to pluck captured prey) may be present within the nest area and are typically within 100 m (328 ft) of an active nest (S. Desimone, unpublished data).

Water and topography. It is unclear whether goshawks prefer to nest close to water, but close proximity to water may improve nesting conditions in drier forest types based on the results of several studies (see Reynolds et al. 1982, Hargis et al. 1994, Squires and Reynolds 1997). Bathing by a brooding goshawk in hot dry climates may help to maintain proper humidity in the nest during incubation, and may aid in thermoregulation (Hennessy 1978). However, Crocker-Bedford and Chaney (1988) found no association with water in Arizona where actual breeding density was high. Overall, goshawk nests in western Washington generally averaged >200 meters (654 ft) from perennial water (WDFW, unpublished data). On the Olympic Peninsula, water bodies were an average of 232 m (761 ft) from nest sites (S. Finn, unpublished data). Other studies found that goshawk nests were generally within 200-300 m (656-984 ft) of permanent water sources in Idaho (Hayward and Escano 1989), northeastern Oregon (Bull 1992), and in the eastern Cascades of Washington (McGrath 1997). However, McGrath (1997) found that eastern Oregon nest sites averaged =335 m (1099 ft) from water. Goshawk nests in east-central Washington and Oregon were generally associated with low topographic position (i.e., lower 1/3 or bottom of drainage; McGrath et al. 2003; J. Buchanan, personal communication), most likely because the larger trees at lower elevations provided a more favorable microclimate. McGrath et al. (2003) found only a single nest near a ridge top east of the Cascades, and Bull (1992) found no goshawk nests near ridge tops in eastern Oregon.

Nest area cluster. Woodbridge and Detrich (1994) suggested that the aggregate of all nest stands and alternate nests within a goshawk pair’s territory form a “cluster” of nest stands (i.e., “nest stand cluster”; see Figure 2). For this document, the aggregate of nest areas will be referred to as the “Nest Area Cluster” (NAC). A pair’s NAC generally does not overlap with NACs of neighboring territories. NACs are variable in size and their size is believed to be less than that of the PFA (Woodbridge and Detrich 1994). It is possible the NAC coincides with PFAs, but this has not been verified. The occupancy of nesting stands (or nesting areas) by marked territorial adults was used as a basis for the NAC concept (Woodbridge and Detrich 1994).

On the Klamath National Forest in California, NACs ranged between 11 and 114 ha (26-282 ac) (Woodbridge and Detrich 1994). Occupancy rates of clusters <20 ha (49 ac) were typically less than 50%. However, occupancy at clusters that were 40 ha (99 ac) and 41-61 ha (100-151 ac) were 75-80% and about 90%, respectively, and nearly 100% of clusters >61 ha (151 ac) were occupied. Overall, long-term territory occupancy was positively correlated with the size of clusters and with larger proportions of mature forest (Woodbridge and Detrich 1994). This larger percent of area in older forest appears to provide more opportunities to maximize a pair’s chance of maintaining occupancy.

Mid- and late-successional habitat is strongly associated with goshawk sites at the NAC scale. In eastern Oregon, Desimone (1997) found that substantial amounts of mid- (average dbh of 23-53 cm [9-21 in]) and late-successional

(average dbh >53 cm [21 in]) forest at the NAC scale (52 ha [128 ac]) were important to the persistence of goshawks in historic territories. Occupied areas during that study had more forest area with these characteristics than historic territories without goshawks. Within the 52 ha (128 ac) surrounding historic nests, habitat around recently occupied sites was not significantly different from occupied historic sites at the time they were last known to be active. The historic sites where no goshawks were located had significantly lower amounts of combined mid-age and late-successional forest within the NAC. It was concluded that recent site conditions within the NAC that most resembled the historic conditions contributed to the persistence of goshawks in a territory over time (Desimone 1997).

Post-fledging Family Area

The Post-fledging Family Area (PFA) contains the nest area(s) and is an area of concentrated use by adult females and developing juveniles after fledging and prior to natal dispersal (Reynolds et al. 1992, Kennedy et al. 1994). The PFA surrounds and includes nest area habitat (Kennedy et al. 1994), and provides foraging opportunities for adult females and fledgling goshawks, as well as hiding cover for fledglings (Reynolds et al. 1992). The parameters used to calculate the PFA included the average core area used by nesting females as well as the average distance juveniles dispersed from the nest tree over a specified time period (Kennedy et al. 1994). PFAs in New Mexico were high-use core areas used by breeding females that averaged 168 ha (415 ac; Kennedy et al. 1994), and may have corresponded to the defended areas of goshawk pairs (Reynolds et al. 1992). Similarly, high-use areas of adult breeding females (post-hatching) in western Washington averaged about 143 ha (353 ac) (S. Finn, unpublished data). These values are similar to the average of 168 ha (415 ac) reported by Kennedy et al. (1994) for core-use areas of breeding females.

Studies on the use of habitats by northern goshawks in the PFA indicate the importance of structurally complex forests. McGrath (1997) measured structural stages on the eastern Cascades within 83 and 170 ha (205 and 420 ac) areas around recently active nests. He found that “stand initiation phase” (clearcut/sapling stage) accounted for 7% (range 0-23%) of the 83 ha (205) plot and 10% of the 170 ha (420) plot; both values were significantly smaller than random sites. In the southwestern United States, the PFA contained 40% (by area) mature and old forest with >40% canopy closure (Reynolds et al. 1992). In eastern Oregon (with forest types similar to the southwestern U.S.) PFAs consisted of an average of 22% (Desimone 1997) and 29% (Daw and DeStefano 2001) dense canopy, late-seral (>50% canopy closure and =20 trees/ha >53cm) forest. In western Washington, PFAs contained an average of 72% (95% CI = 59-84) mature (>10% of trees >53 cm [21 in] dbh) coniferous forest (Finn et al. 2002a). PFAs consisted of forests with a dense cover of trees and an abundant number of snags and down logs (Reynolds et al. 1992).

Foraging Areas (breeding season) and Home Range

Foraging areas are the various habitats where goshawks secure prey. Foraging areas also define the goshawk's home range during the breeding season. Home range (HR) size estimates for goshawk pairs in western states (other than Washington) ranged between 569-3774 ha (1400-9321 ac) (Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Kennedy et al. 1994). The average HR size on managed forest landscapes in western Washington was 3710 ha (9164 ac) (range 844 to 10,730 ha [2084-26500 ac]) (Bloxtton 2002). Males generally had larger HRs than females, while HRs of non-breeders tended to be larger than that of breeders. Two years of unusually wet conditions was thought to partly explain variability in foraging distances from nests of male goshawks (Bloxtton 2002).

Goshawks forage in a variety of forest types. Limited information describing goshawk foraging habitat is available for Washington. Bloxtton (2002) found that goshawks tended to hunt in stands with larger diameter (= 50 cm [20 in]) trees, and they avoided stands in the sapling and pole stages. Kill sites had greater basal area (average = 52 m²/ha), snag density (average = 77 snags/ha = 13 cm dbh [31 snags/ac = 5 in]), large tree density (average = 62 trees/ha >50 cm dbh [25 snags/ac = 20 in]) and higher average dbh (32 cm [13 in]) than random sites. Bloxtton (2002) reported that a disproportionately high number of goshawk kill sites were in forests with a 25-36 cm (10-14 in) quadratic mean dbh (Qdbh; i.e., the dbh of a tree with average basal area in a stand) as well as in mature (35-51 cm [14-20 in] Qdbh) and old-growth (>51 cm [20 in] Qdbh) structural classes. Also, 96% of kill sites had canopy closures = 60% (average = 77%). Bloxtton (2002) noted that young (< 30 years) forests generally did not provide

appropriate conditions (i.e., large trees with well developed canopies, adequate flight space beneath the canopy) for goshawk hunting.

In ponderosa pine forests of northern Arizona, breeding male goshawks preferred to forage in mature forests with higher basal areas and higher densities of trees >41 cm (16 in) dbh (Beier and Drennan 1997). In winter, foraging sites used by the same birds had higher canopy closure and more trees between 20-40 cm (8-16 in) dbh as compared to random sites (Drennan and Beier 2003). Based on these findings, one could conclude that in landscapes where the coverage of older forest has decreased, foraging areas and home ranges would become larger and territories more widely spaced (see Crocker-Bedford 1998).

Goshawks in the Cascade Range of northern California selected closed canopy mature and old-growth stands for foraging (>51 cm [21 in] average dbh and >40% canopy closure) (Austin 1993). Greater basal area, more large trees (>46 cm [18 in] dbh), and higher canopy closure characterized areas of goshawk use in eastern California as compared to random sites (Hargis et al. 1994).

Studies in the western United States (Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Desimone 1997, Patla 1997, Daw and DeStefano 2001; Finn et al. 2002a, b) indicate that mid- to late-successional forested habitats comprise a significant proportion of the total home range area. Average habitat composition of the HR (1886 ha [4660]) was 64% (95% CI 54-78) "late-seral" forest on the Olympic Peninsula (Finn et al. 2002a). Historical goshawk sites were more likely to be occupied in landscapes (i.e., home ranges) dominated by large uniform patches in late-seral stages.

Diet

Goshawks are considered opportunistic foragers (Beebe 1974), as exhibited by the wide range of prey taken in the United States (Squires and Reynolds 1997). Douglas' squirrel (*Tamiasciurus douglasii*), grouse, and snowshoe hare (*Lepus americanus*) were the most frequently represented prey species (representing 54% of all prey in the eastern slope of the Cascade range and Okanogan county and 41% in the Olympic peninsula and west slope of Cascade range) (Watson et al. 1998). Chipmunks (*Tamias* spp.), northern flying squirrel (*Glaucomys sabrinus*), Steller's jay (*Cyanocitta stelleri*), northern flicker (*Colaptes auratus*) and small woodpeckers (Picidae) each constituted >3% of the goshawks diet by frequency. Passerine bird species (e.g., American robin [*Turdus migratorius*]) accounted for 28% of west-side and 18% of the east-side prey by frequency (Watson et al. 1998). Goshawks in the northeastern Cascades took the highest proportions of grouse, while those in the Olympics took the fewest. Combined grouse and snowshoe hare accounted for the majority of all prey biomass consumed. Similar prey species and ratios were documented in eastern Oregon (Reynolds and Meslow 1984, Bull and Hohman 1994, Cutler et al. 1996).

In northeastern Washington and the Blue Mountains, the red squirrel (*T. hudsonicus*) replaces the Douglas' squirrel as an important food item (Hayward and Escano 1989, Patla 1997; D. Base and S. Fitkin, personal communications). In Klickitat County, a western gray squirrel (*Sciurus griseus*) was observed being taken by an immature goshawk in ponderosa pine/Garry oak (*Quercus garryana*) habitat (M. Linders, personal communication).

Bloxton (2002) studied goshawk foraging behavior and prey use among 15 territories in an intensively managed forest landscape in western Washington. He found that grouse (ruffed and blue combined) and band-tailed pigeon (*Columbia fasciata*) were the predominant prey by frequency, followed by Steller's jay, snowshoe hare, thrushes (Turdidae), woodpeckers, Douglas' squirrel, northern flying squirrel, other rodents, and birds. Grouse and hares probably represented the majority of biomass consumed.

Given the importance of snowshoe hare in Washington goshawk diets, it is possible that goshawk territory occupancy could fluctuate in response to cyclical changes in snowshoe hare abundance (e.g., see Doyle and Smith 1994). However, the variety of prey species identified suggests that Washington's goshawks are not dependent on hare and grouse abundance because of opportunistic feeding on other prey species (Watson et al. 1998).

Dispersal

Dispersal data for adult goshawks in the western U.S. is limited. The cycling population patterns of snowshoe hare and grouse are believed to influence periodic southward movement of goshawks from northern Canada (Squires and Reynolds 1997). Although some goshawks appear to disperse short distances during the non-breeding season, most populations are believed to be non-migratory (Johnsgard 1990, Squires and Reynolds 1997, Bloxton 2002, Drennan and Beier 2003). These short-distance movements are likely a response to prey availability during winter (Keane and Morrison 1994, Reynolds et al. 1994, Squires and Ruggiero 1995, Drennan and Beier 2003; T. Bloxton, personal communication). In western Washington, female goshawks had higher winter site fidelity to their breeding areas compared to their mates (Bloxton 2002). Adult northern goshawks are not believed to make significant movements to seek new breeding sites (Detrich and Woodbridge 1994, Doyle and Smith 1994, Reynolds and Joy 1998).

Limited information is available about dispersal patterns in Washington. In one unpublished study, four immature goshawks were captured, marked, and released near Chelan, Washington, in autumn; they occupied transitional areas between coniferous forest and either subalpine parkland or lower elevation shrub-steppe savannah. Monitored until their deaths (average survival time: 13 weeks), they remained within 150 km of their banding site (J. Smith, personal communication).

LIMITING FACTORS

Generally, the two most significant limiting factors to the long-term productivity and survival of raptors are the availability of suitable prey and nesting habitat (Newton 1979). Although the effects of timber harvesting on goshawks in the United States are not fully understood, there is evidence to suggest that harvest impacts nest site selection (Reynolds 1989, Crocker-Bedford 1990, Ward et al. 1992, Woodbridge and Detrich 1994, Desimone 1997; Finn 2002a, b), and potentially, nesting rates (Crocker-Bedford 1990, 1995). In addition, nesting goshawks appear to be largely absent from some extensive forested landscapes in western Washington that have been intensively managed on rotations =50 years (WDFW, unpublished data). Fragmentation of suitable habitat potentially increases interaction with competing raptors (e.g., red-tailed hawks [*Buteo jamaicensis*], great horned owls [*Bubo virginianus*]) (Moore and Henny 1983, Crocker-Bedford and Chaney 1988, Crocker-Bedford 1990, Kenward 1996). The impact of regulated falconry on wild raptor populations is thought to be minimal (Conway et al. 1995, Kenward 1997, Mosher 1997), but is largely unknown for goshawks (Squires and Reynolds 1997).

MANAGEMENT RECOMMENDATIONS

Management recommendations for goshawks in Washington before the publication of this volume largely relied on the Northern Goshawk Scientific Committee's (GSC) recommendations developed for forests in the southwestern United States (Reynolds et al. 1992). The GSC recommendations were prescriptions that reflected a balance of different forest age classes to provide "desired forest conditions" needed to sustain goshawk populations and an adequate prey population in the U.S. Forest Service's (USFS) Southwestern Region (Reynolds et al. 1992). Many of the following recommendations for Washington are still based, at least in part, on the GSC guidelines because there is currently limited information for northern goshawks in the Pacific Northwest. However, where appropriate, some of the following prescriptions are based on recent research in western Washington.

Certain general forest types listed in the GSC guidelines may be similar to some forest types in eastern Washington (e.g., ponderosa pine and higher elevation mixed conifer) and the guidelines may be more applicable to these forest types east of the Cascade crest (S. Desimone, personal observation; R. Anthony and R. Reynolds, personal communications). Although eastern Washington vegetation data have not been fully evaluated in goshawk studies, some information exists that can be used to make limited comparisons (see Finn 1994, McGrath 1997). However, the GSC guidelines have not been assessed in Washington, particularly for moist forest types west of the Cascade crest (e.g., western hemlock/Douglas-fir and Sitka spruce zones). Also, eastern Washington lodgepole pine, moist Douglas-fir/grand fir/western larch, and true fir/Engelmann spruce (*Picea engelmannii*) forest stands have not been

assessed. Overall, the GSC does not recommend applying specific management prescriptions outside of the southwestern United States. Rather, they recommend the application of general GSC model concepts elsewhere (R. Reynolds, personal communication). In addition, Anthony and Holthausen (1997) caution that the appropriateness of the PFA and foraging area estimates need to be tested for applicability to the Pacific Northwest.

Nest Areas

Nest areas should be approximately 12 ha (30 ac) in size (Reynolds et al. 1992). At least three suitable nest areas should be protected per home range (Reynolds et al. 1992). In addition, at least three replacement areas should be present per home range, for a total of 72 ha (180 ac) (Table 2). If only one nest area is known, additional stands and replacement areas within the PFA management areas should be identified and protected. Alternate nest areas selected by managers should be structurally similar to known nest areas (Reynolds et al. 1992). Replacement nest areas are needed because goshawk nest areas are subject to disturbances such as fire and windthrow. Selection of nest areas should prioritize active or most recent nest areas over historical areas. Nest areas should be delineated using known nests and plucking posts where possible. In mixed conifer and ponderosa pine forests of eastern Washington, data from Table 2 can be evaluated with stand-specific and area data to estimate local habitat needs. All nest areas should be located within approximately 0.8 km (0.5 mi) of the goshawk pair's adjacent nest areas (Reynolds et al. 1992).

Table 2. Size recommendations for areas within goshawk home range as reported by the Goshawk Scientific Committee (Reynolds et al. 1992).

Attribute	Home Range Components		
	Nest Area	PFA	Foraging Area ^a
Total areas	6	1	1
Suitable nest areas	3	N/A	N/A
Replacement nest areas	3	N/A	N/A
Size in hectares (acres)	12 (30) each	170 (420)	2,185 (5,400)
Management season	Oct - Feb	Oct - Feb	Oct - Feb

^a Foraging area figures do not include the nest areas and PFA.

Human presence should be minimized in active nest areas during the nesting season (1 March - 30 September) (Reynolds et al. 1992). Broadcasting calls for survey purposes should not be implemented until June 1 (for recommended survey protocol guidelines and information, contact WDFW's goshawk specialist in Olympia). Data on human disturbances are lacking; however, in the absence of such data, the disturbance guidelines established for other raptors should be observed: activities such as road building, logging, site preparation and herbicide and pesticide application should not occur within 0.8 km (0.5 mi) of active nests during the nesting season (e.g., Washington Forest Practices Board 2001). On known occupied territories, if the active nest is not located during the year of management activity, then a 0.8 km (0.5 mi) radius from the geographic center of previous known nest sites should be protected. Road densities should be minimized in the vicinity of nest areas and should be managed within the context of adaptive management (a systematic process for continually improving management practices by learning from the outcomes of earlier practices) (Reynolds et al. 1992).

An average canopy closure of 70-80% for both western and eastern Washington nest areas should be retained (McGrath 1997, Finn et al. 2002b). Activities conducted within suitable and replacement nest areas should be limited to those designed to enhance stand development and maintain habitat structure (Reynolds et al. 1992). Selective overstory removal, patch harvests, or clearcut harvests resulting in complete removal of trees or the reduction of large stem density and canopy volume over a landscape compromises goshawk nesting habitat (Ward et al. 1992, Crocker-Bedford 1995, Desimone 1997; Finn et al. 2002a, b). Activities in nest areas that are detrimental to desired nesting structure for goshawks should not occur at any time in areas managed for goshawks (Reynolds et al. 1992). All intact forest patches in late stages of forest development within the nest area should be retained (Daw

and DeStefano 2001, Henjum et al. 1996). Fidelity of some goshawks to nest areas in winter (T. Bloxton, personal communication) underscores the importance of protecting mature and old forested habitat in nest areas to sustain resident prey populations.

No overstory or regeneration harvest should take place within the NAC at any time (Woodbridge and Detrich 1994, Desimone 1997, Daw and DeStefano 2001). For the Olympic Peninsula, controlled understory thinning to enhance development of stands for desirable nest characteristics should be carefully monitored so that dominant overstory trees are not removed and deep overstory canopy attributes are maintained (see Finn et al. 2002b); average canopy closure should remain $\approx 70\%$. Thinning may help younger stands develop characteristics conducive to nest habitat sooner than if left unmanaged. However, their potential for use by goshawks will be negated if the newly enhanced stands are not allowed to exist over an extended time period (e.g., 20-70 years) beyond a harvest rotation age (depending on stand age and site conditions). Thinning and stand enhancements for nest areas should be done within the context of local forest conditions and within an adaptive management framework.

Post-fledging Family Area (PFA)

The size of the PFA should be approximately 170 ha (420 ac) in addition to the identified suitable and replacement nest areas (Reynolds et al. 1992). This area should be delineated and centered on active and alternate nest areas (i.e., the nest area cluster [Woodbridge and Detrich 1994]), and include as much mature and old forest as possible (Desimone 1997, Daw and DeStefano 2001).

In western Washington and moist forests east of the Cascade crests, canopy closure in the PFA should average $\geq 70\%$ (Finn et al. 2002a, b), and $\geq 60\%$ in the drier pine-dominated forests east of the Cascades (Finn 1994, McGrath 1997, Wagenknecht et al. 1998). Preference should be given to stands that are similar in structure to the nest area (Reynolds et al. 1992, Daw and DeStefano 2001). Forest management should emphasize the retention and enhancement of complex forest structure and desirable canopy closure (Finn et al. 2002a, b). PFA attribute information for eastern Washington forests is virtually unknown; therefore, forest management should avoid reducing or further fragmenting existing late-seral forest in PFAs (Beier and Drennan 1997, Daw and DeStefano 2001) until more data are collected. If possible, the PFA should not contain $>10\%$ seedling/sapling or early forest cover (Finn et al. 2002a). Retaining snags and down logs will likely enhance goshawk prey abundance (Reynolds et al. 1992).

Foraging Area (Home Range)

The GSC recommends that 60% of the foraging habitat be equally divided between mid-aged (20%), mature (20%), and old (20%) successional classes of forest by area based on work in the southwestern United States (Reynolds et al. 1992). These percentages might not be adequate in western Washington, because the average proportion of late-seral forest in foraging areas was at least 1.5 times that of the southwest in certain forest types (Finn et al. 2002a). In addition, goshawks made most kills in mature and older closed-canopy forest in western Washington (Bloxton 2002). Goshawks also occupied landscapes where $\geq 54\%$ of the foraging area (i.e., home range) was comprised of late-seral forest, and averaged no more than 11% seedling/sapling or early forest stages (Finn et al. 2002a). Based on these findings, it is recommended at least 60% of the foraging area be retained in mature and old forest. This is in addition to the mature and old forest area that should be retained in nest areas and PFAs.

Snags are important resources for sheltering birds and mammals that are goshawk prey. Large-diameter snags and logs should be retained within managed goshawk foraging areas to provide cover for important prey species. While no information exists for goshawk foraging areas in ponderosa pine forests in eastern Washington, we recommend the retention of at least 5 large (≥ 46 cm dbh [18 in], ≥ 9.1 m [30 ft] in height) snags/ha (2 large snags/ac), and at least 7 large (≥ 30 cm [12 in] diameter, ≥ 2 m [7 ft] in length) downed logs/ha (3 logs/ac) based on the guidelines of Reynolds et al. (1992). At least 7 large snags/ha (3/ac) with at least 12 large downed logs/ha (5/ac) should be retained in interior-fir forests (Reynolds et al. 1992). These criteria are recommended until more local information is obtained for eastern Washington.

Few studies have documented snag abundance within goshawk home range habitat in western Washington. Foraging habitat patches should be structurally similar to mimic suitable nesting habitat as well as the habitat of

preferred prey. Based on Bloxton (2002), average snag density in intensively managed habitats should average 14 snags/ha >30 cm (6 snags/ac >12 in); however, additional research is needed.

Landscape Management

Planning in Pacific Northwest forests should occur at the landscape scale because site-by-site management will not maintain viable populations (Kennedy 1991, Bright-Smith and Mannan 1994, Hargis et al. 1994). Conservation and management strategies should consider multiple spatial scales (e.g., watershed, forest-wide, territory, etc.) and potential overlap between adjacent territories. Emphasis should be placed on retaining vegetative diversity and sufficient amounts of mature forested habitat for goshawk nesting and foraging (Crocker-Bedford 1990, Reynolds et al. 1992, Bright-Smith and Mannan 1994, Hargis et al. 1994, Beier and Drennan 1997, Crocker-Bedford 1998, Finn et al. 2002a, Drennan and Beier 2003).

Because of limited information on the habitat requirements of goshawks (especially in eastern Washington), it is recommended that habitat manipulations occur using adaptive management techniques. More direct observational data of goshawk habitat use will be required to develop management plans, predict the species distribution, and aid in the assessment of habitat for goshawks on a landscape-level in eastern Washington (Dewhurst et al. 1995, Braun et al. 1996).

Forest Management

Although largely untested, recommendations for silvicultural manipulations within goshawk home ranges have been proposed. The GSC recommended forest manipulations to benefit goshawk prey (Reynolds et al. 1992). Merrill (1989) and Lilieholm et al. (1993, 1994) recommended the use of a stand density index to manage goshawk habitat in Utah and Idaho. They provided recommendations on desirable stand conditions as well as some specific examples of stand management.

Forest stands in lower elevations of western Washington begin to develop suitable nesting habitat characteristics at about 50 years (Bosakowski et al. 1999, Finn et al. 2002b). However, current timber rotations on industrial lands are approximately 35-50 years (Finn et al. 2002b; F. Silvernail, personal communication). The net result may be the sustained loss of suitable nesting and foraging habitat in intensively managed forests in Washington. We concur with researchers (e.g., Merrill 1989; Lilieholm et al. 1993, 1994; Bloxton 2002, Finn et al. 2002a) who recommend that portions of intensively managed forested landscapes surrounding existing late-seral forest patches be allowed to mature beyond industrial rotational ages (e.g., 70-120 years on the Olympic peninsula and lowland western Washington) to benefit goshawks. Such practices would ensure that some suitable nesting and foraging habitat is available across the managed landscape. Existing occupied marbled murrelet (*Brachyramphus marmoratus*) habitat, which is composed primarily of late forest structure (Ralph et al. 1995), may potentially provide some interim goshawk nest sites (WDFW, unpublished data). However, the potential of these patches to provide adequate PFA and foraging habitat to sustain potential goshawk nest areas is limited to the size and adjacency of mature forests that are within the range of the murrelet in western Washington (i.e., generally within 80 km [50 mi] of marine waters).

To promote the development of nest habitat in western Washington, managers should thin young (30-35 years) conifer stands by removing the understory trees to a density of 345-445 trees/ha (140-180 trees/ac) (Finn et al. 2002a). This forest practice will accelerate tree growth and should eventually result in a deep overstory canopy and a low density of shrub cover if the stand is allowed to mature beyond 50-70 years.

Because goshawks have a strong fidelity to high quality nest areas, there can be a temporal lag before birds respond to habitat changes (T. Bloxton, unpublished data; S. Desimone, personal observation). Abandonment of a nest area following timber management depends on the proximity, timing, and extent of the habitat removal. Habitat assessment models and change detection (e.g., McGrath 1997, Desimone 1997) can evaluate the effects of management on site suitability. However, these processes sometimes lead to an overestimation of suitable habitat if the assumptions of the model are not explicitly addressed (McGrath 1997). A landscape-scale habitat model is currently being developed for predicting nesting habitat for goshawks in Washington (S. Finn, personal communication).

Falconry

The impact of removing wild goshawks for falconry is thought to be negligible (Squires and Reynolds 1997). Of the various hawk species captured, Kenward (1997) estimated that 50-93% are eventually lost or released back into the wild. In Washington, falconry permit holders reported 64 northern goshawks taken from the wild between 1990 and 2002; one immature escaped and one adult died in captivity between 1998 and 2002 (WDFW, unpublished data). As the data are relatively sparse for Washington birds, the removal of northern goshawks from the wild for falconry should continue to be closely monitored.

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KEY POINTS

Habitat Requirements

- Home ranges for breeding goshawks can be split into three functional divisions: the nest area or areas, post-fledgling family area (PFA), and foraging area.
- Nest areas are composed of one or several forest stands that contain active or alternate nest structures that are usually occupied by goshawks between March and September.
- Nest areas are typically located in mature or old coniferous forest with a high density of large trees. Additionally, nest areas primarily are composed of stands with a closed canopy and multiple canopy layers.
- Nests are often found in Douglas-fir in western Washington and in Douglas-fir, ponderosa pine, western larch, lodgepole pine, and grand fir east of the Cascades.
- Nest areas typically have a higher basal area than that of surrounding forest east of the Cascade crest.
- Plucking posts are usually found within 100 m (328 ft) of active nests.
- Goshawks apparently prefer to nest close to water and at low topographic positions.
- All nests and alternate nests of a pair form a cluster that generally does not overlap with clusters of neighboring territories.
- The PFA is an area of concentrated use by adult females and developing juvenile goshawks.
- PFAs are typically comprised of complex forest structure and typically contain mature and old forest
- Foraging areas are where goshawks secure prey and it defines their home range during the breeding season. Goshawks forage in a variety of forest types.
- Goshawks are considered opportunistic foragers, as exhibited by the wide range of prey taken.

- Goshawks are believed to be non-migratory

Management Recommendations

- Protect at least three nest areas and three alternate nest areas per home range. Each nest area should be at least 12 ha (30 ac) in size, and selected nest areas should be structurally similar to known nest areas.
- Minimize human disturbance in active nest areas between March 1st – September 30th.
- Retain an average canopy closure of 70-80% and maintain forest in late stages of forest development.
- Limit all overstory or regeneration harvest and increase harvest rotation length in nest area clusters.
- Delineate and center areas to managed as PFAs on active and alternate nests. PFAs should be approximately 170 ha (420 ac) and include as much old and mature forest as possible.
- Manage PFAs for $\geq 70\%$ canopy closure in western Washington and for moist forests east of the Cascade crest. Drier forests east of the Cascade crest should have $\geq 60\%$ canopy closure.
- Avoid removing late-seral forest in PFAs, and retain snags and downed logs.
- Retain at least 60% of foraging habitat in mid-aged (20%), mature (20%), and old (20%) forest successional classes.
- Large diameter snags and logs should be retained in goshawk foraging areas.
- Retain at least 5 large (≥ 46 cm dbh [18 in], ≥ 9.1 m [30 ft] in height) snags/ha (2 large snags/ac), and at least 7 large (≥ 30 cm [12 in] diameter, ≥ 2 m [7 ft] in length) downed logs/ha (3/ac) in foraging areas comprised of ponderosa pine forest in eastern Washington. At least 7 large snags/ha (3/ac) with at least 12 large downed logs/ha (5/ac) should be retained in interior-fir forests.
- Conservation of goshawk habitat should be managed on a landscape-scale and multiple spatial scales (e.g., watershed, forest-wide, territory, etc.)
- Forest management should consider increasing timber harvest rotations (e.g., 70-120 years in western Washington lowlands and Olympic peninsula) because intensively managed forest appear to negatively impact goshawks.
- Thin young (30-35 years) conifer stands to a density of 345-445 trees/ha (140-180/ac) to promote the development of nesting habitat in western Washington. If allowed to mature beyond 50-70 years, this practice should result in preferred forest conditions.
- Closely monitor the impact of the removal of northern goshawks from the wild for falconry purposes.

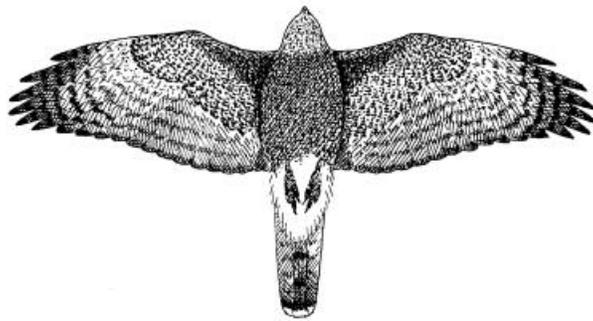


Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; <http://royalbcmuseum.bc.ca/>

Ferruginous Hawk

Buteo regalis

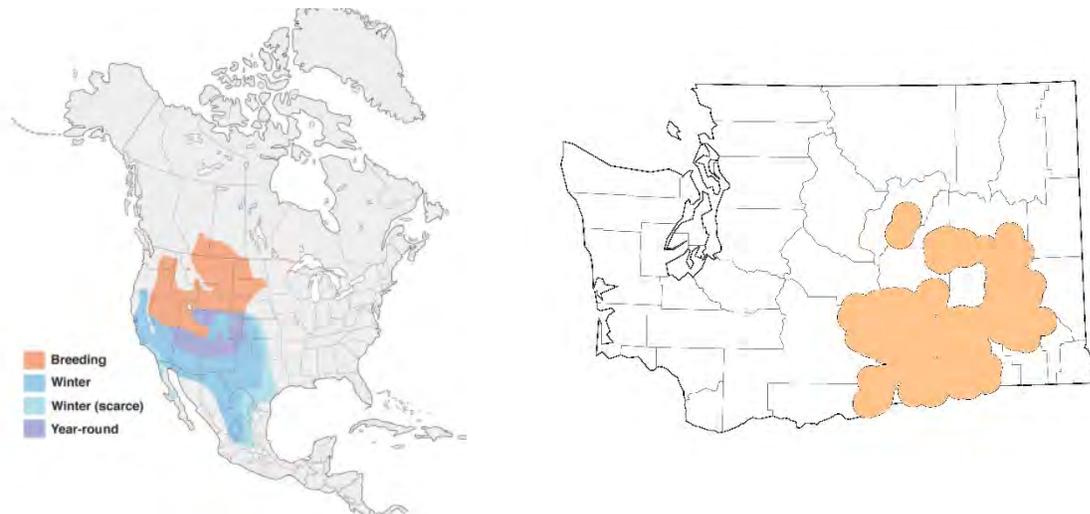
Last updated: 2024

Written by James W. Watson and Jeffrey M. Azerrad

General range and regional distribution

The ferruginous hawk (*Buteo regalis*) occupies western North America from Canada through central Mexico (Ng et al. 2020). Washington is at the western limit of the species' breeding range, which extends eastward to extreme southwestern Manitoba, and south to northern Texas (Figure 1). This species' historic breeding distribution has remained unchanged, except for a contraction of their range in Alberta, Saskatchewan, and Manitoba in the 1900s caused by agricultural conversion and aspen (*Populus spp.*) invasion (Ng et al. 2020).

Figure 1. Distribution of ferruginous hawks in North America



Left map from allaboutbirds.org and Washington map from WDSM Data System, WDFW.

Throughout their range, most (98%) adult ferruginous hawks migrate from breeding territories after nesting (Watson et al. 2018a). Juvenile hawks migrate a few weeks after fledging (Watson et al. 2019). Migration begins in late summer for regional breeding populations, except those in Canadian grasslands, with hawks migrating eastward and northward to the northern grasslands and Great Plains (Watson et al. 2018a). Hawks migrate again in fall to winter ranges. Hawks from Washington winter in central to southern California, and other populations winter eastward through the southern grasslands (Figure 1).

Because most ferruginous hawks that nest in Washington are migratory, management recommendations in this document are directed to the land-use impacts affecting breeding populations. However, many of the same threats and management recommendations presented here are also relevant to Washington's hawks on their non-breeding ranges in other regions.

Rationale

Range-wide population estimates of ferruginous hawks in the early 1990s were between 2,921 and 5,665 nesting pairs (Olendorff 1993). Trend analysis of Breeding Bird Surveys indicates several states and regions have experienced downward trends since 1993 (Sauer et al. 2019). In the United States, the species was petitioned for federal listing under the Endangered Species Act in 1983 and 1991 (USFWS 1992). No federal listing resulted from either of these petitions. The species was federally listed in Canada as threatened in 1980, downlisted to special concern in 1995, and relisted to threatened in 2008 (COSEWIC 2008). In Alberta, a breeding stronghold of the species range-wide, the species was designated as endangered in 2006. The ferruginous hawk in 2005 was designated as a Species of Greatest Conservation Need in 17 U.S. states and is a listed species in several states (Ng et al. 2020). In Washington it was listed as threatened in 1983. Due to continued declines it was reclassified as endangered in Washington in 2021 (Hayes and Watson 2021).

Resource requirements

The ferruginous hawk is an open-country raptor that inhabits grasslands, shrubsteppe, and deserts of North America (Ng et al. 2020). These habitats provide the critical resources that ferruginous hawks require for successful nesting: medium-sized mammalian prey, low substrate suitable for nest placement, and space that isolates it from disturbance. Their [breeding habitat](#) in Washington most often occurs in shrubsteppe and juniper savanna. These areas are especially important as ferruginous hawk habitat when occupied by native mammalian prey and when there are basalt rock outcrops or isolated trees, primarily juniper, to provide suitable substrate for supporting nests (Bowles and Decker 1931, Bechard et al. 1990, WDFW 1996). Degradation or conversion of shrubsteppe and grassland often results in reduction or removal of the critical resources required for ferruginous hawk nesting. Recent attempts at habitat restoration for ferruginous hawks in southeast Washington through the Conservation Reserve Program have been effective in re-establishing hawks in degraded habitats.

Prey

Ferruginous hawks are dietary specialists that thrive on mammalian prey (Olendorff 1993), including ground squirrels (*Urocitellus* spp.) and jackrabbits (*Lepus* spp.), often supplemented by pocket gophers (Figure 2). Ferruginous hawk nesting populations and breeding performance fluctuate in synchrony with populations of these prey. Hawks can lay more eggs per nesting attempt when their prey populations are high (Ng et al. 2020). As many as six young can fledge from a nest in a year when prey populations are productive (Clarke and Houston 2008).

Figure 2. Washington ground squirrel



Washington ground squirrels like this one are preferred by ferruginous hawks as prey. Photo by Rich Finger.

Ferruginous hawk diets in Washington are diverse compared to elsewhere in their range. This is likely a consequence of declines in their preferred prey of ground squirrels and jackrabbits in Washington. Jackrabbits now contribute less in terms of prey frequency, which is a major dietary shift noted since the 1920s. More recently, a greater proportion of their diets have consisted of insects (51%) and mammals (49%). This shift in diet was based on the findings of a study of 67 nests between 1992 to 1995 in Washington (Richardson et al. 2001). In that study, Mormon crickets (*Anabrus simplex*) were the main insect prey (92% of insects in their diet), and northern pocket gophers (*Thomomys talpoides*) were the main mammalian prey (72% of mammals in their diet). A negligible portion of their total diet consisted of ground squirrels (1%) and jackrabbits (<1%; Richardson et al. 2001). Other studies in Washington have reported diets consisting of pocket gophers, Columbia Plateau pocket mice (*Perognathus parvus*), reptiles, and even gulls (Fitzner et al. 1977, Mazaika and Cadwell 1994, Leary et al. 1996). These dietary shifts are not without consequences as they can reduce nestling survival and can lead to declining raptor populations (Preston et al. 2017, Heath et al. 2021).

Nests

Ferruginous hawks build their nests on natural and artificial objects that are often short structures, or they build their nests on the ground (Ng et al. 2020). In Washington, ferruginous hawks construct nests away from human activity, in contrast to Swainson's (*Buteo swainsoni*) or red-tailed hawks (*Buteo jamaicensis*; Bechard et al. 1990). In some places, artificial structures have improved suitability as ferruginous hawk nest structures and reduce access to hawks by ground-based predators (Neal et al. 2010, Wallace et al. 2015). A range-wide summary of nest substrate in the 1970s and 1980s found that 49% of nests were in trees (Figure 3), 21% on cliffs, 12% on utility structures, 10% on dirt outcrops, and only 6% on the ground (Olendorff 1993).

Figure 3. Ferruginous hawk nest



Ferruginous hawk nest in crook of a lone tree in grassland habitat. Photo by Jim Watson.

Ferruginous hawks in Washington have been observed nesting primarily on cliffs (62%), trees (34%), and artificial substrates (4%; Bechard et al. 1990). In recent years, nest platforms installed in southeast Washington have been successfully used by nesting ferruginous hawks (M. Vekasy, unpublished data). Early research in southeastern Washington found nests constructed with greasewood branches (*Sarcobatus vermiculatus*; Bowles and Decker 1931). Later research found nests constructed mainly of sagebrush (*Artemisia* spp.) and rabbitbrush sticks of at least 5 centimeters (2 inches) in diameter and lined with bunchgrass and peeled sagebrush bark (Fitzner et al. 1977).

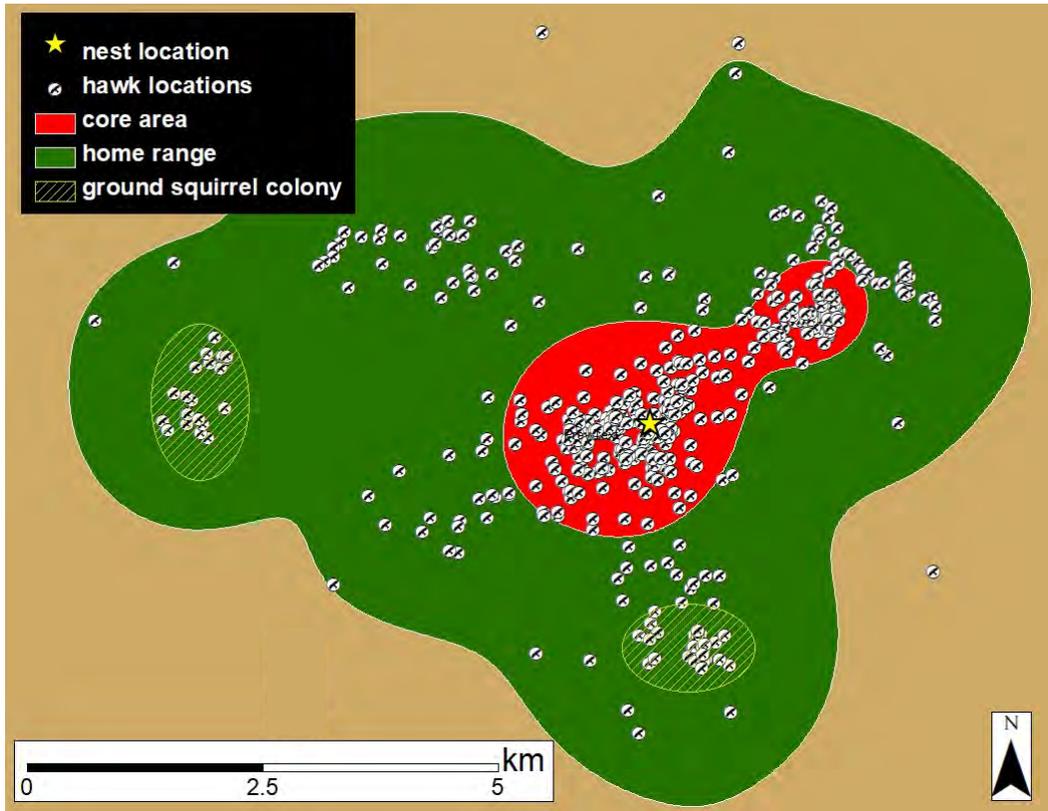
Ferruginous hawk nests and nest substrate may be lost to natural and human-caused disturbances. This can include fire, inclement weather, and abrasion from cattle rubbing (Houston 1982, Datta 2016, Parayko 2021). The resulting loss of nests can reduce ferruginous hawk nesting opportunities and increase competition for nest substrates with other raptors, as well as with common ravens (*Corvus corax*) and great-horned owls (*Bubo virginianus*).

Space

Breeding [home ranges](#) of raptors encompass the area within which all resources for successful nesting occur (Figure 4; Newton 1979). Home ranges of nesting ferruginous hawks are most often in arid, open landscapes that typically have low levels of human activity. Due to their dietary specialization, the location and size of breeding home ranges of ferruginous hawk are affected by the distribution and abundance of preferred prey (Leary 1996, Watson 2020). The distribution of elevated nest substrates and perches also influence characteristics of breeding home ranges of ferruginous hawk (Wiggins et al. 2014, Watson 2020, Watson et al. 2023). The [core areas](#) of breeding home ranges encompass the most

intense areas of use (Figure 4; Wilson et al. 2010). Core areas typically include nests and key foraging habitats (Watson 2020, Watson et al. 2023).

Figure 4. Stylized ferruginous hawk home range and core area.



A study of seven hawks tracked with ground-based telemetry in Washington found that their breeding home ranges (95% minimum convex polygons) were 10 times larger (78.6 kilometers²) than those in other regions (Leary 1996). Large home ranges were attributed to distant irrigated agricultural fields (i.e., >15 kilometers [km] from nests) where hawks foraged. These fields were harvested several times a year and thus had low canopy cover that likely enhanced the foraging opportunities for hawks.

More recent use of precise satellite telemetry found even larger ferruginous hawk home ranges in southern Washington and north-central Oregon (Watson et al. 2023). This study of 17 hawks monitored for an average of 100 days and 1588 fixes revealed an average breeding home range size (95% isopleths, Brownian Bridge Model) of 378 km². Core areas (50% isopleths, Brownian Bridge Model) averaged 39.8 km². The comparatively large home ranges found in this study were attributed to the scattered distribution of prey in this region. These relatively large home ranges are an indicator of overall low prey abundance. Ferruginous hawks must in turn travel farther from their nests in search of prey, which ultimately increases the size of their home range.

Adult ferruginous hawks in the Pacific Northwest occupy their home ranges between 27 December and 17 October (Table 1; Watson et al. 2018a). The December arrival date is due to the small percentage of adult male hawks (6%) that return to winter on their breeding ranges after late-summer migration. Most hawks arrive in early March. Although earlier studies suggest ferruginous hawks moved nomadically during prey declines (Schmutz and Hungle 1989, Woffinden and Murphy 1989), more recent evidence based on satellite telemetry (Watson and Keren 2019) found that ferruginous hawks have a high fidelity to their breeding home ranges throughout their breeding distribution, with most birds returning to the same ranges year after year. In this study using satellite telemetry, 83% of hawks returned to the same breeding range. Fledgling ferruginous hawks typically migrate before, and independently from, adults (Watson et al. 2019).

Table 1. Chronology of ferruginous hawk nesting in the Pacific Northwest*

Behavior	Date		
	Begin	Average	End
Arrival of adults on home ranges	27 December	2 March	22 March
Incubation initiated	1 April	13 April	30 April
First eggs hatch	3 May	15 May	31 May
First young fledge	11 June	24 June	11 July
Late summer departure of adults from ranges	5 June	21 July	17 October

* Derived from 20 radio-monitored adults studied for 33 combined years, J. Watson, unpublished data.

Limiting factors

Human-caused or natural changes in ferruginous hawk habitat may reduce breeding rates and productivity when these changes impact the prey, nest substrates, and space that hawks require for nesting. A population viability analysis concluded the most important factors affecting ferruginous hawk population trends were adult survival and their ability to produce offspring (Collins and Reynolds 2005). Adult mortality from anthropogenic sources like wind power is likely additive (Dwyer et al. 2018, Diffendorfer et al. 2021), effectively meaning there is no surplus of adults to replace those lost to cumulative sources. Disturbance of nesting hawks may alter their behavior and potentially impact their reproductive success, health, and survival of young. Disturbance of nesting raptors may result in nest desertion; injury to eggs and young by startled adults; loss of eggs or death of young from exposure; premature fledging of young; or avian and mammalian predation (Rosenfield et al. 2007). Disturbances may not only reduce ferruginous hawk productivity but can cause hawks to desert their territories (White and Thurow 1985).

Development

Direct mortality and disturbance of hawks from development, including that for residential, recreational, and industrial purposes (e.g., renewable energy, surface mining, and road construction), may limit breeding population sizes. These disturbances associated with development can disrupt natural behaviors in ways that may be subtle (e.g., flushing; Keely and Bechard 2011, Nordell et al. 2017) or less obvious (e.g., displacement). These behavioral changes can ultimately reduce reproduction and population sizes (Kolar and Bechard 2016). Development can indirectly impact hawks that may avoid or completely abandon a developed area due to the associated disturbances (Dwyer et al. 2018). Hawks

that continue nesting near development may be adversely impacted by construction (e.g., machinery) and post construction (e.g., pedestrians) disturbances. Development may also directly eliminate prey and nesting habitat.

Mortality

Several factors cause direct, accidental mortality of ferruginous hawks. Mortality is often the result of vehicle collisions. Other sources of mortality include power line electrocutions (Harness and Wilson 2001, APLIC 2006) and collisions with wind turbines (Smallwood and Thelander 2008). Recreational development and road construction that increase off-road vehicle access can increase disturbances and mortality, including the illegal shooting of ferruginous hawks. Shooting was historically the highest cause of mortality (15.8%) for ferruginous hawks banded and recovered between 1916 and 1992 (Gossett 1993). Programs to control or eliminate populations of burrowing mammals through shooting or poisoning may result in lead toxicosis or sub-lethal hemorrhage of hawks that consume affected mammal carcasses (Chesser 1979, Knopper et al. 2006, Vyas et al. 2012, Murray 2017).

Prey and prey availability

Disturbances affecting ferruginous hawk prey can indirectly impact nesting hawks (Coates et al. 2014, Wiggins et al. 2014). Habitat disturbances that alter shrubsteppe and grasslands favored by native prey species can then indirectly affect nesting hawks. This can include adverse influences on prey resulting from the conversion of grasslands and shrubsteppe to agriculture as well as invasions by exotic annuals caused by overgrazing or altered fire regimes (Fleischner 1994, Vander Haegen et al. 2000, Knick et al. 2003, Wick et al. 2016, Heath et al. 2021). Because ferruginous hawks cannot hunt in dense forests, encroachment of aspen or juniper into grasslands and shrublands may inhibit their nesting (Woffinden and Murphy 1983, Bartuszevige et al. 2012, Kennedy et al. 2014).

Cultivation and grazing

Effects of cultivation on ferruginous hawk nesting have been studied extensively in grassland habitats in Alberta where ground squirrels were the primary prey (Schmutz 1999). In that study, hawk densities were greatest on random survey plots where $\leq 10\%$ of the land was in cultivation. Hawk densities declined in areas where cultivated lands exceeded 30% (Schmutz 1999). Overgrazing and overstocking cattle in pastures can also affect ferruginous hawks by damaging and trampling nest trees (Houston 1982).

Management recommendations

Because of the *endangered* status of ferruginous hawks, the Washington Department of Fish and Wildlife (WDFW) recommends land-use managers protect all areas associated with their breeding and nesting habitat. A status of *endangered* means that the species is “seriously threatened with extinction throughout all or a significant portion of its range within the state” (see [WAC 220-610-110](#)). For this reason, WDFW recommends broad protective measures with respect to (a) the extent of the area that should be protected, and (b) the degree to which areas are protected (e.g., strong emphasis on avoidance of harm). We recommend protecting unoccupied nesting territories because ferruginous

hawks have been observed re-occupying territories after an absence of at least 20 years (Romin and Muck 2002; M. Vekasy, pers. comm.; J. Fidorra, pers. comm.). We recommend strictly avoiding places that provide key breeding and foraging opportunities because this is the lowest-risk option for this seriously at-risk species. Recovery of the species will ultimately require restoration of currently degraded habitat (WDFW 1996).

Proposals to develop in areas associated with ferruginous hawk breeding should be assessed for impacts on nesting habitat. This can be accomplished by devising a plan to avoid (strongly preferred) or minimize and provide compensatory mitigation for unavoidable impacts to important nesting habitat resources. The following steps are provided to help assess the potential impacts of a proposed development to ferruginous hawks and to avoid, minimize, and provide compensatory mitigation to offset all unavoidable impacts.

Identification of ferruginous hawk breeding habitat

Ferruginous hawk nests are the focal point of breeding. From 1978 to 2020, WDFW identified and mapped 672 ferruginous hawk nest locations on 287 home ranges (WDFW Wildlife Survey Management Database). Nest locations were used to identify areas associated with ferruginous hawk breeding habitat. Occupancy and productivity surveys at historical ferruginous hawk territories and searches to document new territories are ongoing and conducted statewide by WDFW every five years.

Areas “associated with” ferruginous hawk breeding habitat are lands that provide the ecosystem services of space and prey needed for ferruginous hawks to successfully reproduce (“breeding habitat”). Breeding habitat consists of natural vegetation or agricultural cover types listed in Table 2 provided the land is either (a) within 10 km of a ferruginous hawk [nest site](#) that has been identified at any time since September 1, 1991¹, or (b) within 20 km of a nest site that has been used by ferruginous hawks within the past five years (Figure 5).

¹ Since September 1, 1991, the Growth Management Act has required that local jurisdictions designate and protect critical areas. The GMA requires that local governments provide for no net loss of ecosystem functions and values for fish and wildlife habitat conservation areas (See WAC 365-196-830(4)). Our recommendations use the same no net loss standard and date.

Table 2. Natural vegetation and agricultural cover types associated with ferruginous hawk breeding habitat.

Natural vegetation types ¹
Columbia Plateau Scabland Shrubland
Inter-Mountain Basins Big Sagebrush Shrubland
Columbia Plateau Steppe and Grassland
Inter-Mountain Basins Big Sagebrush Steppe
Inter-Mountain Basins Semi-Desert Shrub-Steppe
Columbia Basin Foothill and Canyon Dry Grassland
Columbia Basin Palouse Prairie
Inter-Mountain Basins Active and Stabilized Dune
Inter-Mountain Basins Cliff and Canyon
Agricultural cover types ²
Pasture
Other ³

The 10-km distance approximates the radius of a circular breeding home range of a ferruginous hawk (378 km²) in the Columbia Basin (Watson et al. 2023). This distance is doubled to define the 10-20 km zone for suitable habitat, which also approximates the maximum nearest-neighbor distance for nesting ferruginous hawks (i.e., 7.2 km) in studies reviewed by Olendorff (1993). Because of their tendency to reoccupy a site, a “nest site” does not require a nest or even nesting material at the time a land-use proposal is in review. The presence of a nest site only requires a recent or historically reliable documentation of a nest, such as those recorded in WDFW’s Priority Habitats and Species (PHS) data or observed nesting ferruginous hawks that have not yet been recorded⁴.

Breeding ferruginous hawks may nest in agricultural lands, including pastures, and hunt along edges of irrigated fields. Guidance for managing agricultural practices in cover types “associated with” ferruginous hawk breeding habitat is found in the *Guidance for Agriculture and Rangelands* section of this publication.

Local governments should flag development proposals whenever the activity is within an area associated with ferruginous hawk breeding habitat (Figure 5). This step is carried out by overlaying the location of the proposed activity with WDFW’s PHS data. The PHS data shows the locations of areas associated with ferruginous hawk breeding habitat. The appropriate management strategies to avoid, minimize, and provide compensatory mitigation to offset all unavoidable impacts will depend on the proximity of a given development proposal to the nearest ferruginous hawk nest site (Table 3)⁵.

¹ Vegetation types associated with ferruginous hawk breeding areas according to the Washington State Wildlife Action Plan (WDFW 2015).

² Below are the two primary “crop group” where breeding ferruginous hawks may nest or hunt. Source: Washington Department of Agriculture Crop Database

³ “Other” is a crop group that includes fallow irrigated cropland edges, which has value to breeding ferruginous hawks.

⁴ Report locations of any nesting ferruginous hawks if they are not already in our PHS data to the [local district wildlife biologist](#).

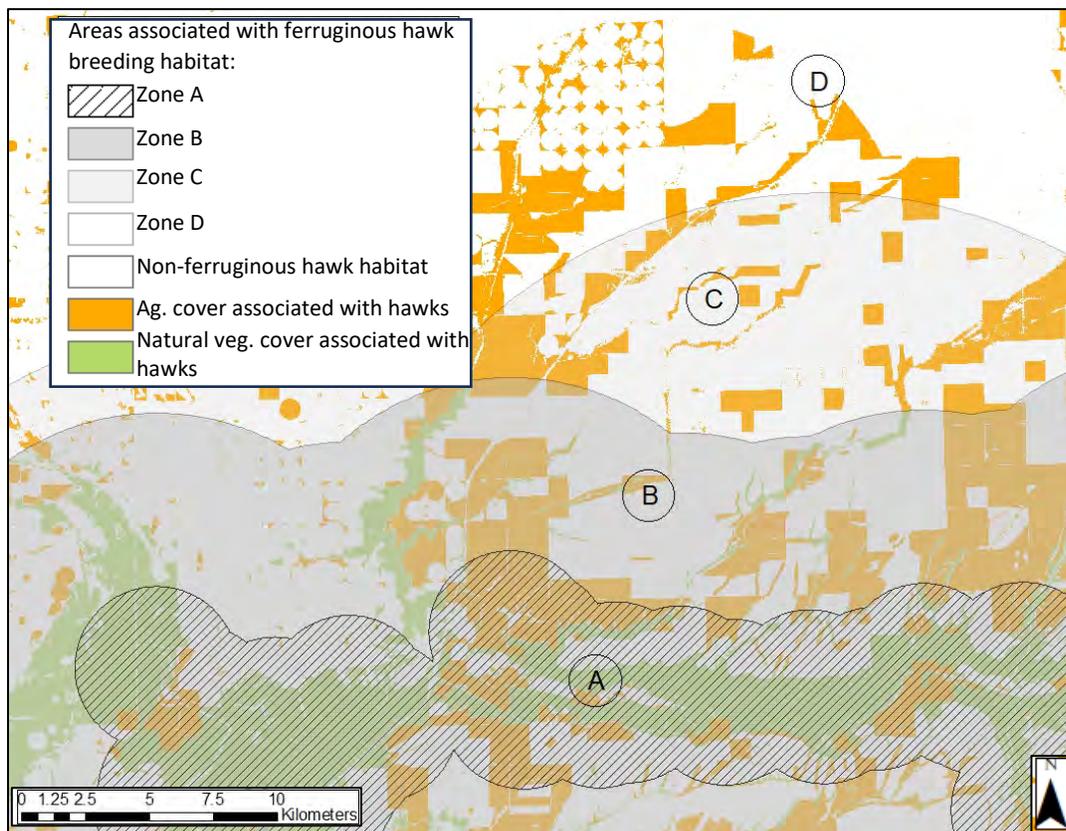
⁵ Disclosing the specific location of ferruginous hawk nest sites is restricted under the state’s Public Records Act (RCW 42.56.430(2)) and WDFW policy. However, WDFW allows local governments to disclose to a landowner that their proposal is within a core area (Zone A), home range (Zone B), or outer priority management zone (Zone C) for a ferruginous hawk.

Strategies for management will also depend on the ecosystem functions provided by the site (e.g., breeding, foraging) as well as the nature of the disturbance.

Site assessment

WDFW recommends local governments take strong measures to strictly avoid any disturbance within **Zone A** (Table 3). A *survey assessment* should be required when any proposal to develop or otherwise cause a disturbance in lands in Zone A cannot be completely avoided. A survey assessment should also be required in **Zone B** when the project or disturbance cannot be avoided. The protocol for conducting a survey assessment is described in Appendix 1. The survey assessment is necessary for gathering information to develop a Habitat Management Plan.

Figure 5. Ferruginous hawk management zones



Ferruginous hawk management zones A to D (see Table 3) and cover types associated with breeding habitat (see Table 2). The outer edge of Zone B represents a 10 km buffer around nests where no nesting has been documented in the last five years. The outer edge of Zone C represents a 20 km buffer around nests used by ferruginous hawks in the past five years. A land use proposal anywhere in Zone A should be flagged for a site assessment for potential mitigation. Only land use proposals that fall within a green or orange area in zones B and C should be flagged for a site assessment for potential mitigation. No site assessment or mitigation is needed for any land use proposals set entirely within Zone D. The most current version of this ferruginous hawk data is available in WDFW's Priority Habitats and Species Database. Table 3 outlines the type of mitigation recommended for land use proposals in each of these management zones.

We recommend a *rapid assessment* whenever a land-use activity is proposed in **Zone C**. The protocol for conducting a rapid assessment is in Appendix 2. The rapid assessment does not require collecting any detailed measurements. Rather, it is a brief survey of the site to determine if further action is necessary. If the rapid assessment demonstrates a need for further action, then proceed with a more detailed survey assessment. No action is required for ferruginous hawks when the proposed activity is in **Zone D**.

Table 3. Management zones within the areas “associated with” ferruginous hawk breeding habitat.

Zone	Nearest nest (km)	Area	Survey and management strategies for land use proposals
A	<3.2 km (Core area)	All lands within 3.2 km of a ferruginous hawk nest site. Prevent hawk mortality, avoid nesting disturbance, and avoid habitat alteration in this zone including protection of nest support structures and foraging habitat.	Survey Assessment - Require Habitat Management Plan <ul style="list-style-type: none"> ✓ Avoidance strongly recommended in this zone. ✓ Minimization measures require no-net-loss of function. ✓ Compensatory mitigation strongly discouraged.
B	3.2 to 10 km (Home range)	Lands between 3.2 to 10 km of a ferruginous hawk nest site when lands are composed of the natural vegetation and agricultural cover types listed in Table 2.	Survey Assessment - Require Habitat Management Plan <ul style="list-style-type: none"> ✓ If possible, avoid disturbances in areas associated with ferruginous hawk. If strict avoidance is not possible, minimize disturbance, and provide compensatory mitigation for unavoidable disturbance. ✓ Take extraordinary measures to strictly avoid disturbance of any ground squirrel colony.
C	10 to 20 km	Lands between 10 to 20 km of a nest site used by ferruginous hawks in the past five years <u>and</u> when these lands are composed of vegetation types listed in Table 2.	Rapid Assessment – Require Survey Assessment – Dependent on rapid assessment results. Habitat Management Plan – Prepare habitat management plan if a ferruginous hawk nest or ground squirrel colony is observed during rapid or survey assessment.
D	>20 km	All lands where the closest ferruginous hawk nest site is >20 km away.	No action necessary

Mitigation

The Growth Management Act (GMA) uses the same definition for “mitigation” as the State Environmental Policy Act ([RCW 43.21C](#)). Local government’s use of this framework is required for many development proposals (see [RCW 43.21C.240](#)). The GMA defines “mitigation” and describes the prescribed order of steps (i.e., mitigation sequence) to implement in order to reduce the impacts of activities on critical areas in [WAC 360-196-210\(23\)](#). It is imperative that mitigation be followed in the prescribed order. Specific to projects that affect ferruginous hawks, here are strategies to consider when applying the standard mitigation sequence:

Avoid the impact altogether by not taking a certain action or parts of an action. Especially in Zone A, avoidance must be pursued to the maximum extent possible for this endangered species. Strong measures to avoid disturbance should also be taken for Zone B. All options to avoid harm or disturbance should receive genuine and serious consideration. Minimization should be sought only after all options to avoid impacts have been exhausted and deemed not feasible. Parcels almost entirely comprised of higher-value breeding habitat or where options to minimize impacts are limited should be strong candidates for taking a strategy of avoiding impacts.

Minimize (includes rectifying and reducing over time) impacts by reducing the degree or magnitude of the effects exerted on the site’s ecosystem functions for ferruginous hawks (e.g., breeding, foraging).

Common strategies to minimize impacts include:

- Reducing a project’s footprint and intensity (e.g., the smallest possible building envelope, precluding otherwise acceptable uses such as off-road vehicle use, burying electric lines).
- Siting a project further away from areas of high ecosystem function for breeding ferruginous hawks (e.g., nests, ground squirrel colonies).
- Creating or restoring habitat and breeding ecosystem functions.
- Using low impact development practices.
- Timing actions to avoid breeding periods.

Although actions to minimize can reduce a significant amount of a project’s potential to disturb ferruginous hawk breeding habitat, minimization will still result in some degree of unavoidable losses of ecosystem function. These losses must then be offset to achieve GMA’s No Net Loss (NNL) standard. However, given the species’ endangered status, ferruginous hawk recovery will likely require increasing the total amount of habitat statewide (i.e., net-ecological-gain) to successfully reverse population decline.

Offsetting unavoidable disturbances should focus on improving nest productivity and occupancy as well as richness and density of available prey species within the home range. Actions to both minimize and offset unavoidable disturbances should be guided by a Habitat Management Plan, which should take advantage of site-specific opportunities to benefit the species. This should include setting aside and permanently protecting areas of higher value habitat for breeding ferruginous hawks. Although it is preferable to offset harm to ferruginous hawks through on-site measures, when on-site measures fall short of achieving NNL, then additional measures to mitigate must be taken off-site.

Often there will be more opportunities to minimize negative impacts on ferruginous hawk on-site when the parcel being developed is either relatively large or when it consists of varying levels of ecosystem function. This is because larger parcels with more varied habitat can often have a combination of lesser quality areas where development can be sited while also containing areas that are of higher value for breeding ferruginous hawks that should be set aside and permanently protected. Parcels almost entirely comprised of higher value breeding habitat or where options to minimize impacts are limited should be strong candidates for taking a strategy of avoiding impacts.

Compensate unavoidable development-related impacts that cannot be adequately offset with actions on-site by replacing or providing substitute resources or environments. Compensating through off-site mitigation occurs at a location (“receiving site”) that has been secured for the express purpose of recouping lost habitat functions on-site (“sending site”). It provides a substitute for the habitat functions that have been lost or degraded by the land use activity. Receiving sites must provide an ecological “lift”. Mitigation ratios reflect the level of risk from the loss of a given species’ habitat, with greater mitigation ratios reserved for more vulnerable species.

Off-site compensatory mitigation guidance:

- If not adjacent, the receiving site should be as close as possible to the sending site – within 10 km if possible to remain in the same home range.
- Sending and receiving sites should undergo a survey assessment to quantify the amount of ecosystem function harm at the sending site and “lift” at the receiving site.
- Receiving site should be of equal or greater habitat and ecosystem quality than that of the sending site as determined through survey assessments of both sites.
- At a minimum, a receiving site should be three times the area of the sending site (3:1 mitigation ratio).
- When the sending and receiving sites are greater than 10 km apart, the mitigation ratio should be at least 5:1.
- A receiving site should be well connected to other areas of natural or semi-natural habitat with few or no artificial impervious surfaces.
- Receiving sites adjacent to other conserved properties are preferred.
- A receiving site should not require long-term maintenance to sustain ferruginous hawk breeding habitat functions.
- Known historical ferruginous hawk nesting sites or sites with a documented prey base should be prioritized as receiving sites.
- A receiving site should be permanently protected (e.g., with an enforceable conservation easement that precludes harm but not restoration activities) prior to harm occurring at the sending site.
- Permit approval and occupancy should be conditioned upon successful completion of all off-site mitigation requirements (e.g., Habitat Management Plan completion, land purchase, conservation easement execution, completion of receiving site restoration activities). A performance bond should guarantee performance of actions not yet taken.

Fee-in-lieu programs are sometimes arranged for off-site mitigation. Whenever fee-in-lieu is used to mitigate losses of ferruginous hawk breeding habitat, the result of any such arrangement will need to meet the mitigation standards (e.g., mitigation ratios) described in this section.

Local governments and landowners should consult with WDFW's area habitat and district wildlife biologists or another neutral qualified expert for technical assistance with off-site mitigation.

Habitat management plan

Local governments should require a Habitat Management Plan (HMP) that identifies and quantifies the ecosystem functions for ferruginous hawks provided by the site. It also will need to describe the actions that will be taken to avoid and minimize harm. The HMP should describe and quantify unavoidable impacts and how those impacts will be offset on-site or, if necessary, off-site to achieve NNL. Attributes that can be used in the HMP to quantify and evaluate ecosystem function include nest productivity and occupancy as well as the species richness and density of available prey species within the project site. These measures will preferably need to be evaluated beyond the project site (e.g., on adjacent parcels and throughout the home range).

A three-part template for developing the HMP is provided in Appendix 3:

- **Part 1** gathers basic information about the applicant, their representatives, the site, and the proposed project.
- **Part 2** provides a description and map of the site features of significant value to ferruginous hawks. This information provided in Part 2 will be informed by the results of a survey assessment.
- **Part 3** provides a detailed explanation of the on-site and off-site actions. It includes a detailed description and quantification of ecosystem losses and gains and necessary future monitoring.

Appendix 4 provides standard actions that may be included as mitigation in the HMP. These activities, which address the loss of ferruginous hawk breeding habitat function, are categorized by development and disturbance types. The HMP should also describe any restrictions on the time of year when various activities should not take place. Any activities associated with site preparation or development should generally be avoided during the [breeding season](#), which occurs in Washington between April 1 (earliest time of incubation) through September 5 (when most adults have departed).

The HMP should include a certification by a qualified biologist that the HMP will result in NNL and should be reviewed by an unbiased qualified expert prior to its approval and implementation. A WDFW area habitat and district wildlife biologist or some other neutral qualified expert should provide such a review.

Additional guidance

Guidance for community and long-range planning

Local governments play an important role in helping conserve ferruginous hawks and their breeding habitat. The following recommendations are intended to help local governments review, develop, and implement regulatory tools and incentives to protect ecosystem functions necessary to support ferruginous hawks.

Critical Areas Ordinance:

- Designate as Fish and Wildlife Habitat Conservation Areas in critical areas ordinances (CAO) all areas associated with ferruginous hawk breeding habitat.
- Incorporate by reference in CAO the current PHS map and require use of PHS maps showing ferruginous hawk breeding habitat. The PHS program publishes maps for this purpose that are considered Best Available Science ([RCW 36.70A.172](#)). Use these maps to flag projects and proposals (see the *Identification of Ferruginous Hawk Breeding Habitat* section above).
- Require that a qualified expert conducts a site assessment to determine if a proposed project is in ferruginous hawk breeding habitat after a project or proposal has been flagged (see *Site Assessment* section above).
- Require that a qualified expert prepare the HMP to inform mitigation actions to achieve NNL, while also requiring review of the HMP by a WDFW area habitat or district wildlife biologist or some other neutral qualified expert.
- Require that the permit approval be conditioned on the successful implementation of protections specified in the HMP.
- Evaluate success at achieving the NNL at the full jurisdictional scale. Local WDFW district wildlife biologists can assist with this, for example through the information they gather during on-going surveys of nesting ferruginous hawks statewide. These surveys will be done at 5-year intervals to measure productivity and occupancy (WDFW 1996). Review and amend local GMA protections for ferruginous hawks if NNL is not being achieved.

Long-range planning and zoning:

- Carefully consider the potential impacts of rezoning sites with ferruginous hawk breeding habitat to more intensive land use designations. We recommend avoiding the expansion of Urban Growth Areas or creating more intense land use designations in areas associated with ferruginous hawk breeding habitat. Such changes in land use designations create greater expectations for development that then may be difficult to mitigate.
- To curb conversions of agricultural lands to higher intensity uses, apply zoning policies, such as zoning for long-term agricultural significance.
- In places where land use designations are already set at levels likely to result in impacts, other tools should be made available to landowners to minimize potential impacts to ferruginous hawk breeding habitat such as:
 - Cluster development with the possibility of a slight bonus density as an incentive for setting aside areas in proposed parcels where there is breeding habitat.
 - Create a transfer of development rights (TDR) program that allows landowners to sell their development rights to other less sensitive areas. Many counties in Washington, mainly Puget Sound counties, have their own TDR programs.

Other conservation programs:

- Consider developing the following land conservation incentive programs:
 - A Public Benefit Rating Systems program to provide property tax breaks to landowners who enroll lands with ferruginous hawk breeding habitat.

- A conservation futures program that uses funds levied to acquire ferruginous hawk breeding habitat, and particularly habitat in Zone A that is at high risk of development.

Other considerations:

Develop a process to ensure that all departments involved in permitting any part of a project proposal (e.g., building, clearing, grading, utilities) on a site flagged for ferruginous hawk breeding habitat coordinate and are aware of any related conditions or regulations in the local CAO.

Guidance for agriculture and rangelands

Grazing and other types of agriculture are the most prevalent land uses within the range of ferruginous hawks. Unlike more intensive land uses such as energy development, rangeland and other agricultural uses can coexist with important ecosystem functions to support ferruginous hawk foraging, nesting, and breeding while also supporting the state's agricultural economy. Conservation of these lands can provide a valuable contribution to ferruginous hawk recovery. Common uses of these lands include livestock grazing, cultivating irrigated crops, and dryland agriculture, which together create a mosaic of seminatural and cultivated lands within the range of ferruginous hawk. Several federal and state programs fund voluntary and incentive-based conservation practices on these types of lands to support species' recovery. This section provides guidance on the use of these types of programs to conserve this species on rangeland and other agricultural lands.

Voluntary stewardship guidelines presented here focus on protecting and restoring shrubsteppe and grassland habitats to support ferruginous hawk recovery. Rangelands used for livestock grazing are often composed of native shrubs and grasses. These features can provide important nesting and foraging habitat for ferruginous hawks. To protect and restore important habitat, conservation tools should be applied to limit the conversion of agricultural and rangelands to more intensive uses. Converting rangelands to cultivated croplands and other more intensive uses may impact the species' long-term survival by fragmenting the natural landscape. To curb conversions of agricultural lands to higher intensity uses, we recommend the application of zoning policies, such as zoning for long-term agricultural significance, and by using conservation easements to permanently protect lands for their agricultural and conservation values.

At the state level, counties enrolled in the Voluntary Stewardship Program (VSP) are eligible for state funding to protect and enhance environmentally sensitive areas, referred to as critical areas, on agricultural lands. The ferruginous hawk, which is listed as a Priority Species by WDFW, is considered a focal species for recovery under VSP. Counties enrolled in VSP receive funding to work with agricultural producers to voluntarily implement best management practices (BMPs) on agricultural lands to protect and enhance critical areas. Within the ferruginous hawk's geographic range, WDFW recommends using BMPs to support the species recovery (see the *Restoration / grazing and agriculture* section in Appendix 4). These BMPs can be implemented through a variety of federal, state, and local programs to support voluntary conservation outcomes.

Conservation Districts (CD), local governments, private landowners, and other entities can use voluntary and incentive-based conservation tools to improve recovery outcomes for ferruginous hawks. CD staff are particularly skilled at helping agricultural producers get financial support and technical assistance. Farm plans are a resource tool developed jointly between a landowner and a CD to identify voluntary actions landowners can take to improve farm productivity and protect natural resources. Conservation

Districts and local entities can also help producers apply for federal and state cost-share programs to implement voluntary actions identified in their farm plans.

To restore valuable habitat, federal and state programs fund conservation actions on private lands. The federal Farm Bill offers several conservation programs that agricultural landowners can use to receive financial support. This includes the [Ferruginous Hawk State Acres for Wildlife Enhancement Program](#), which provides targeted funding to restore habitat conditions for the species. Agricultural landowners in eligible counties in Washington can apply for this program. Other applicable federal programs that are not specifically designed for ferruginous hawk but can help to buffer nesting habitat from human disturbances include the Conservation Reserve Enhancement Program, Environmental Quality Incentives Program, and Conservation Stewardship Program.

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Glossary

Breeding Habitat – Habitat used by a mated pair of birds during the breeding season.

Breeding Season – Synonym for nesting season, the period of courtship through dispersal of young.

Core Area – Portion of the home range of a breeding pair of birds that is used most intensively during the breeding season and typically encompasses nests and frequented foraging areas.

Home Range – Area used by a breeding pair of birds that provides the elements for nesting including used and unused nests, prey, and isolation from disturbance.

Nest Site – Historical or current location of a nest.



Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; <http://www.royalbcmuseum.bc.ca/>

Golden Eagle

Aquila chrysaetos

Last updated: 2003

Written by Jim Watson and Morie Whalen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Golden eagles are distributed throughout much of the northern hemisphere (Kochert et al. 2002). In Washington, golden eagles nest throughout much of the state, but are most common in the north-central highlands transitional area between montane and shrub-steppe habitats (see Figure 1). Scattered nest sites are found in more arid portions of eastern Washington and west of the Cascades where the species is uncommon (Larrison and Sonnenberg 1968). The migratory status of nesting golden eagles in Washington has not been studied; observations of golden eagles along the upper Columbia River suggest they remain at nest sites throughout the winter (Knight et al. 1979).

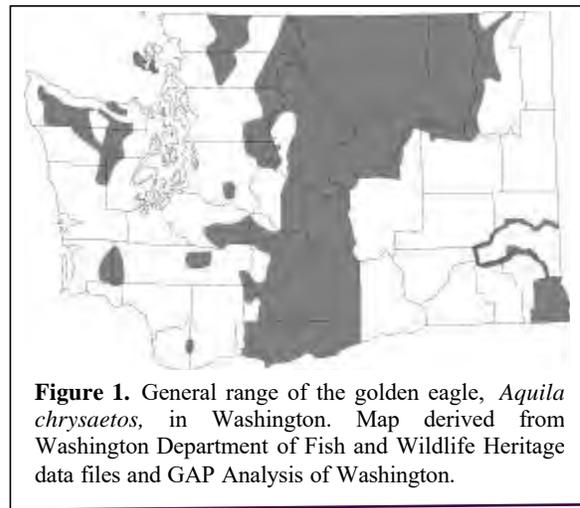


Figure 1. General range of the golden eagle, *Aquila chrysaetos*, in Washington. Map derived from Washington Department of Fish and Wildlife Heritage data files and GAP Analysis of Washington.

RATIONALE

The golden eagle is a State Candidate species. This species is vulnerable to population declines due to habitat loss and disturbance, loss of foraging areas, and through direct human-caused mortality (Franson et al. 1995, Kochert et al. 2002).

HABITAT REQUIREMENTS

Golden eagles are commonly associated with open, arid plateaus deeply cut by streams and canyons, western shrub-steppe and grassland communities and transition zones between shrub, grassland and forested habitat (De Smet 1987, Marzluff et al. 1997). Nests generally are located on cliffs and are occasionally located in trees (Anderson and Bruce 1980, Menkens and Anderson 1987, Kochert et al 2002). Golden eagles use the same territory annually but may use alternate nests in different years. This species uses an average of 2-3 alternate nests (range: 1-14 alternate nests) (Snow 1973). Individual eagles mature and may establish territories and breed during their fifth summer but are capable of breeding earlier in life (Kochert et al. 2002).

Although they are more common east of the Cascades, golden eagles are sometimes found in mature and old-growth forests near the edges of clearcuts in western Washington (Anderson and Bruce 1980). Golden eagle nesting was observed in the San Juan Island archipelago (<10 pairs) during the 1970s and 1980s (Washington State Wildlife Heritage Database). Bruce et al. (1982) found that golden eagle tree nests in western Washington were generally

smaller than bald eagle nests, were placed at or below canopy height, and were located no more than 500 m (1,600 ft) from large clearcuts (<10 years old) or open fields. In another study, bald eagle nests were located at or above the canopy on the interior of a stand and were closer to water than golden eagle nests (Anderson and Bruce 1980).

Shrub-steppe and native grassland communities provide important foraging habitat for the golden eagle (Marzluff et al. 1997, Kochert et al. 2002). Small to medium-sized mammals such as hares (*Lepus* spp.), ground squirrels (*Citellus* spp.), marmots (*Marmota* spp.), mountain beaver (*Aplodontia rufa*) and birds (e.g., pheasant, grouse) are important prey for golden eagles (McGahan 1967, Olendorff 1976, Bruce et al. 1982, Steenhof and Kochert 1988, Marzluff et al. 1997). Based on a survey of prey remains at 74 nests in eastern Washington, yellow-bellied marmots were the most important prey of nesting golden eagles, whereas carrion was regularly consumed in fall and winter (Marr and Knight 1983). Golden eagles nesting on large cliffs in the Columbia Basin commonly capture rock doves (*Columba livia*) that roost on canyon walls (J. Watson, personal observation). Jackrabbits and ground squirrels were historically more abundant in the Northwest (Richardson et al. 2001, Yensen and Sherman 2003) and likely were a more significant source of prey for the golden eagle. Extensive poisoning of ground squirrels in the 1980s, and possibly other factors (S. Zender, personal communication), significantly reduced Townsend's (*Citellus townsendi*) and Washington ground squirrel (*Citellus washingtoni*) populations in Washington (Washington State Wildlife Heritage Database) to the degree that they are being reviewed for status listing. Several researchers (Bates and Moretti 1994, Steenhof et al. 1997, McIntyre 2002) have found increased productivity in golden eagles in years with a higher abundance of hare. McIntyre (2002) and Steenhof et al. (1997) found that golden eagle reproduction was related to prey abundance, with more pairs producing eggs and increased numbers of young fledged when prey numbers were higher. Some eagles conserve energy by suspending their breeding activity when food supplies decrease (Steenhof et al. 1997, McIntyre 2002).

Densities of golden eagles in the western states range from one pair per 34 km² to 251 km² (13-96 mi²) (Phillips et al. 1984). In Wyoming, prime golden eagle habitat as defined by high population densities consisted of a mixture of cliffs and trees suitable for nesting and open habitat with abundant and diverse prey (Phillips et al. 1984). Home range size, size of core areas, and travel distances can vary dramatically based on habitat composition, potential prey abundance and individual preferences (Marzluff et al. 1997).

LIMITING FACTORS

Golden eagle populations appear to be limited by habitat availability and disturbance, adequate prey populations (e.g., large rodents, rabbits and hares), and the availability of undisturbed nest sites (Olendorff and Stoddard 1974, Beecham and Kochert 1975, Kochert and Steenhof 2002). Direct mortality is increased by poisoning from lead and other contaminants, power line electrocutions, collision with wind turbines, and shooting (Phillips 1986, Harlow and Bloom 1989, Craig et al. 1990, Wingfield 1991, Leptich 1994, Avian Power Line Interaction Committee 1996, Hunt et al. 1997, Hoover 2002). Breeding success is limited by reduced habitat availability and decreased prey populations resulting from habitat conversion (Murphy 1977).

MANAGEMENT RECOMMENDATIONS

Factors affecting golden eagle habitat and populations have not been extensively studied in Washington, but studies have been conducted throughout western North America, and the following reflect the findings of these studies. These recommendations generally apply to conditions east of the Cascade Range because very few North American studies have been conducted in high rainfall zones.

In general, golden eagle habitat should be managed to improve native vegetation and maintain native prey populations (e.g., jackrabbits, ground squirrels) (Andersen 1991). Management of grassland habitats can influence prey density, diversity and availability (Andersen 1991). In general, certain prey species decrease with reduced herbaceous cover and foliage height diversity (Kochert 1989). Prey such as jackrabbits and ground squirrels, are believed to be moderately tolerant to grazing but they disappear where habitat is overgrazed (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community). Severely damaged native grassland can be restored by removing livestock, using controlled burning or chaining to

remove trees and invasive shrubs, and reseeded with native grasses (Kochert 1989). However, fire management should be conducted only after developing a professional fire management plan (see Washington State University Cooperative Extension Service in Appendix A), especially in low rainfall zones, where exotic vegetation (e.g., Cheatgrass [*bromus tectorum*]) often becomes dominant (Knick and Rotenberry 1995).

Burning and other techniques that reduce shrub stand density should be avoided in healthy shrub-steppe communities, such as those dominated by sagebrush, in order to maintain existing prey populations (Kochert et al. 1999, Kochert et al. 2002).

Few studies have documented the effects of habitat fragmentation on raptors. However, in several states, raptors survived only on large habitat patches (Robinson 1991). In arid regions, golden eagles require large expanses of undisturbed shrub habitat (Marzluff et al. 1997). Therefore, it is recommended that shrub stands be preserved within 3 km (1.9 mi) of golden eagle nests (Kochert et al. 1999). This distance accounted for 95% of eagle movements measured during the breeding season in western Idaho (Marzluff et al. 1997). Large-scale conversion of eagle foraging habitat should be avoided because it reduces prey abundance and availability. This is particularly important where prey are concentrated, such as at ground squirrel colonies. Many types of development that remove vegetation from localized areas, including oil, gas, and geothermal exploitation; power line, pipeline and road construction; and the development of campgrounds and other facilities may result in loss of habitat for certain prey species (Suter and Jones 1981).

Although empirical evidence is limited, recreation and other human activities near nests appear to cause breeding failure (Kochert et al. 2002). Rock climbing as well as development activities on or near cliffs containing nests should be avoided (De Smet 1987). Avoiding these activities is especially important during the nesting period of 15 February to 15 July (Beebe 1974; R. Friesz, personal communication). The establishment of buffer zones surrounding nests, wide enough to include 90-95% of flushing distances, is generally an accepted technique to reduce disturbance to nesting raptors (Olendorff and Stoddart 1974, Suter and Jones 1981, Mersmann and Fraser 1990). Buffer widths may be adjusted on a case by case basis (with the assistance of a professional wildlife biologist), depending on factors that may influence a pair's response to a particular disturbance, such as influence of terrain on the "line of sight" distance, security of the nest, history of disturbance, and elevation of the disturbance relative to the nest (Suter and Jones 1981; K. Steenhof, personal communication).

Holmes et al. (1993) found that wintering golden eagles are more likely to flush when approached by a human on foot than by a vehicle. They suggested that a buffer zone of 300 m (980 ft) would prevent flushing by 90% of eagles.

Golden eagles often have wing spans that are greater than the distances between conductive materials on power poles, which increases their probability of electrocution (Harness and Wilson 2001). Power lines and poles in any nesting or feeding area should be constructed so birds cannot make simultaneous contact between any two items of conductive equipment. Once an electrocution problem is identified on any existing structures, utility managers should ensure these are quickly retrofitted or modified to eliminate bird loss (Avian Power Line Interaction Committee 1996, Harness and Wilson 2001). Because multiple-phase transformers are believed to be associated with a disproportionate number of eagle electrocutions (Harness and Wilson 2001), the construction of this form of transformer should be avoided.

Rabbits and ground squirrels are important prey for golden eagles and have been targeted in control efforts. Rodent control should not occur within eagle foraging areas because it reduces the prey base (Eaton 1976, Phillips 1986, Young 1989). Shooting and rodenticides should be replaced by wildlife repellents for use in agricultural damage control. Two very effective jackrabbit/hare repellents available are trinitrobenzene-aniline (TNB-A), and zinc tetramethyl thiuram disulfide (TMTD) (Besser and Welch 1959). Another effective jackrabbit/hare repellent for use in orchards consists of a rosin and ethyl alcohol mixture (Cardinell 1958).

Because ground squirrels are an important prey of golden eagles (Kochert et al. 2002), spray application of pesticides near squirrel colonies should be avoided. If pesticides are to be sprayed, an additional buffer area should be used to prevent drift into the protected area. Droplet size, volume of compound and meteorological conditions should be factored into the buffer width (Kingsbury 1975, Brown 1978, Payne et al. 1988). Payne et al. (1988) describes a method for estimating buffer zone widths for pesticide application. In addition, pesticide use should be avoided during the ground squirrel breeding season, from early March to late May, and during the critical foraging time before estivation (dormancy period), mid-August through September (Carlson et al. 1980).

Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to raptors and mammals, and their use in areas inhabited by golden eagles should be avoided (McEwen et al. 1972; Balcom 1983; Grue et al. 1983, 1986; Smith 1987; Hooper et al. 1989). If insecticides must be used, synthetic pyrethroid compounds may be an alternative. For example, permethrin is low in toxicity to raptors and mammals and bio-degrades rapidly (Grue et al. 1983, Smith and Stratton 1986). Repellents can be used with pesticides to deter golden eagle prey species from treated areas (Blus et al. 1989). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

From collection and clinical analysis of dead or dying golden eagles, toxic lead poisoning has been recently identified as a potential source of adult golden eagle mortality in eastern Washington (J. Watson, personal observation). Craig et al. (1990) and Craig and Craig (1995) found elevated levels of lead in golden eagles in southern Idaho and believed this may be a more serious problem than previously thought. The source of contamination is under investigation. If bullet fragments and lead shot prove to be the source of contamination, hunter removal of carcasses and gut piles from the field, or conversion to the now widely available and ballistically comparable non-toxic ammunition (e.g., tungsten-alloy shot, solid copper bullets) might substantially reduce lead exposure (G. Hunt, personal communication).

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KEY POINTS

Habitat Requirements

- Commonly associated with open, arid plateaus deeply cut by streams and canyons, western shrub-steppe and grassland communities and transition zones between shrub, grassland and forested habitat. Nests usually located on cliffs and trees.
- Use the same territory annually, but have an average of 2-3 alternative nests used in different years.
- Although yellow-bellied marmots are the most important prey of nesting golden eagles, jackrabbits and ground squirrels were probably the most significant historical prey for eagles in the Northwest.
- Carrion is important prey during the fall and winter.
- Home range size, size of core areas, and travel distances can vary dramatically based on habitat composition, potential prey abundance, and individual preferences.

Management Recommendations

- Manage golden eagle habitat to improve native vegetation and maintain native prey populations
- Restore severely damaged grassland (e.g., non-shrub) habitat with controlled burning or chaining of trees and invasive shrubs, followed by reseeding with native grasses.
- Preserve shrub-dominated habitat (i.e., sagebrush) within 3 km (1.9 mi) of golden eagle nests and avoid practices that remove shrub cover (i.e., chaining or burning).
- Avoid new development and human activities near nest sites (especially between 15 February and 15 July).
- Designate spatial buffer areas to protect nests and juvenile eagles.
- Construct or modify power lines and poles so birds cannot make simultaneous contact between any two items of conductive equipment and avoid construction of multiple-phase transformers.
- Avoid rodent control within eagle foraging areas.
- Avoid using organochlorine, organophosphate, and carbamate insecticides in eagle habitat and prey concentration areas.

Bald Eagle

IMPORTANT MESSAGE

May 2011

The Washington Fish and Wildlife Commission amended the bald eagle protection rules (WAC 232-12-292), removing the requirement that landowners develop bald eagle management plans. This decision was mainly the result of the species' recovery and its downlisting to Sensitive status in Washington state. If at any point the bald eagle is listed as an endangered or threatened species (federally or by Washington state), the requirement to develop a management plan will be restored.

The Department removed the bald eagle chapter from this publication because it was specifically written to provide guidance on developing bald eagle management plans. Now that the state no longer requires a plan, the responsibility for bald eagle management has shifted from the Washington Department of Fish and Wildlife to the U.S. Fish and Wildlife Service (USFWS).

For information about federal requirements and guidelines, please go to the USFWS Pacific Region's bald eagle website at <http://www.fws.gov/pacific/eagle/>.



Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; <http://www.royalbcmuseum.bc.ca/>

Prairie Falcon

Falco mexicanus

Last updated: 1999

Written by David W. Hays and Frederick C. Dobler

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The breeding range of the prairie falcon extends southward from central British Columbia through much of the western United States (Snow 1974), and reaches as far south as San Luis Potosi in northern Mexico (Lanning and Hitchcock 1991).

Prairie falcons winter throughout their breeding range, as far south as central Mexico and as far east as the Mississippi River (American Ornithologists' Union 1957).

In Washington, prairie falcons have been known to breed in all central and eastern counties except Pend Oreille County (see Figure 1; Parker 1972). Prairie falcons winter throughout their breeding range in Washington, but the largest wintering populations are found in the central Columbia Basin (Grant, Adams, Franklin, Walla Walla, and Benton counties). Reports of prairie falcons wintering in western Washington have also been reported (Decker and Bowles 1930, F. Dobler, unpublished data).

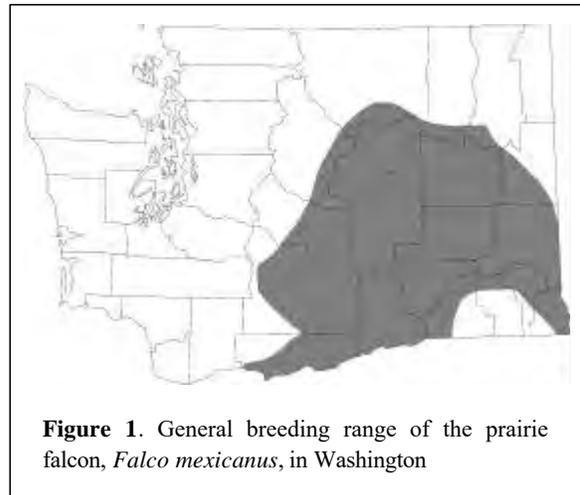


Figure 1. General breeding range of the prairie falcon, *Falco mexicanus*, in Washington

RATIONALE

Prairie falcons are of recreational importance in Washington, and are vulnerable to habitat loss and degradation. Prairie falcons nest on cliffs, and depend on steppe and shrub-steppe habitats that support abundant prey. There is a limited number of suitable cliffs in Washington, and steppe and shrub-steppe ecosystems in this state are rapidly being converted to agriculture. Human habitation close to cliffs limits their use by prairie falcons, as do agricultural practices that reduce available prey.

HABITAT REQUIREMENTS

Prairie falcons inhabit the arid environments of eastern Washington and nest on cliffs usually associated with native steppe and shrub-steppe habitat (Denton 1975). Often this habitat is intermixed with agricultural lands (Denton 1975). Typically, the landscape is treeless, but its edges include shrub-land that may contain a few conifers. Prairie falcon habitat in Washington does not differ markedly from other areas described in the literature (Fowler 1931, Skinner 1938, Enderson 1964, Denton 1975).

Prairie falcons use a wide variety of cliffs. Along the Columbia, Snake, and Yakima rivers, they commonly nest on basalt cliffs up to 122 m (400 ft) tall. They also use scant escarpments raised only 6 m (20 ft) above sloping canyon walls. In North Dakota, Allen (1987) found prairie falcons using cliffs ranging from 3-35 m (10-115 ft) tall, with a mean of 11 m (36 ft), and 5-500 m (16-1,649 ft) in length, with a mean of 103 m (338 ft). In Mexico, Lanning and Hitchcock (1991) found the range of cliff heights used by prairie falcons to be between 25 m and 130 m (92-427 ft) tall, with a mean of 65 m (213 ft). Runde and Anderson (1986), summarized data from 8 studies on prairie falcons, and reported a combined cliff height range of 2-154 m (6.5-505 ft), with a mean of 29 m (95 ft). They also summarized the aspect of the cliff lines, and reported that although prairie falcons may use cliffs facing any aspect, they tend to use cliffs with a southerly aspect.

Nest sites are often on a sheltered ledge or in a pothole in the cliff. Runde and Anderson (1986) found that 97% of their sites in Wyoming had overhead protection. Other studies (Enderson 1964, Leedy 1972, Platt 1974, Ogden and Hornocker 1977) generally found this same trend. Use of abandoned stick nests built by other raptors (particularly golden eagle [*Aquila chrysaetos*] or raven [*Corvus corvus*]) is well documented (Decker and Bowles 1930, Bent 1938, Williams 1942, Webster 1944, Enderson 1964, Brown and Amadon 1968, Hickman 1971). Use of artificial nests by prairie falcons has been documented in North Dakota, but long-term successful nesting was limited (Mayer and Licht 1995).

In Oregon, Denton (1975) found that most nest sites were located at elevations between 60 and 2530 m (200-8300 ft), in habitats typified by undulating topography and moderately xeric vegetation. This was comprised of juniper (*Juniperus* spp.), big sagebrush (*Artemisia tridentata*), and bunchgrass (*Agropyron spicatum* and *Festuca idahoensis*) associations, which were sometimes degraded where cheatgrass (*Bromus tectorum*) replaced native grasses. He also reported that of 63 nest sites, 76% were within 400 m (0.25 mi) of a water source, 32% bordered agricultural land, 62% were within 800 m (0.5 mi) of a road, but only 15% were within 800 m (0.5 mi) of human habitation.

Foraging territories surround prairie falcon nest sites, and studies have reported a wide variety of home range sizes during the breeding season. In Idaho, home range size varied between 26-142 km² (10-55 mi²) (U. S. Bureau of Land Management 1979), in Southern California between 31-78 km² (12-30 mi²) (Harmata et al. 1978), and in Northern California between 34-389 km² (13-150 mi²) (Haak 1982). Squires et al. (1993) found that prairie falcons typically foraged within 10 km (6 mi) of nest sites during the breeding season, and that habitats closer to nesting sites were preferred. Males had the larger home ranges and traveled greater distances from their nests while hunting than did females.

Prairie falcons forage on a variety of prey, including birds and small mammals. Prey abundance largely determines diet composition. Some studies have found that prairie falcons foraged primarily on mammalian prey (Ogden and Hornocker 1977), whereas others found that avian prey predominated (Marti and Braun 1975, Becker 1979, Boyce 1985). In Wyoming, thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) were found in 91% of pellets analyzed, western meadowlark (*Sturnella neglecta*) in 56%, and horned lark (*Eremophila alpestris*) in 23% (Squires et al. 1989). In Idaho, Townsend's ground squirrels (*S. townsendii*) were prey items in at least 98% of the aeries, with western meadowlark and horned lark present in 13% and 22%, respectively (Ogden and Hornocker 1977). Steenhof and Kochert (1988) found ground squirrels to be the primary prey during the breeding season in Idaho's Snake River Birds of Prey Natural Area.

Less is known about prairie falcon food habits during winter, though small mammals and birds continue to play a major role. Horned larks are the main food for prairie falcons in winter wheat areas (Snow 1974, Beauvais and Enderson 1992) and in the Snake River Birds of Prey Natural Area (Prokop 1995). Wintering prairie falcons have

also been observed hunting microtine rodents in harvested hay fields and chasing upland game birds and rock doves (Beauvais and Enderson 1992). The home range size in winter is less than what is reported for the nesting season, ranging between 12-68 km² (4.6-26 mi²) (Beauvais and Enderson 1992). Prokop (1995) reported that home range size did not vary between sexes in winter.

LIMITING FACTORS

In Washington, prairie falcons are limited by the availability of cliffs suitable for nesting that are adjacent to steppe and shrub-steppe habitats (Denton 1975). Prey abundance within their home ranges also limits prairie falcons. Ground squirrels, western meadowlarks (*Sturnella neglecta*), and horned larks (*Eremophila alpestris*) are important prey (Marti and Braun 1975, Ogden and Hornocker 1977, Becker 1979, Boyce 1985). Human habitation near nesting cliffs limits prairie falcon use, as do agricultural practices that reduce available prey (Denton 1975). In winter, the availability of avian prey, particularly horned larks, is important to the survival of resident prairie falcons (Snow 1974).

MANAGEMENT RECOMMENDATIONS

Homes and other sources of human activity should be placed no closer than 805m (2640 ft) from prairie falcon nest sites (Denton 1975). Prairie falcons commonly occur where human habitation is absent. As difficult as it may be to protect existing nest sites, creating new sites suitable for continued, long-term use may be even more difficult (Mayer and Licht 1995).

Native steppe and shrub-steppe habitats should be maintained near prairie falcon nesting sites to ensure falcon survival and nesting success. These habitats are important for maintaining populations of the prairie falcons' prey. Studies of shrub-steppe in Washington indicate that the western meadowlark and the horned lark are the most common shrub-steppe birds (Dobler 1996). They are also the 2 most common bird species in prairie falcon diets (Squires et al. 1989). In addition, *Spermophilus* ground squirrels are commonly associated with native steppe and shrub-steppe habitats, and they also make up a significant portion of the prairie falcon's diet (Ogden and Hornocker 1977, Steenhof and Kochert 1988).

Widespread rodent control should not occur within prairie falcon foraging areas, because ground squirrels are common prey items, and foraging prairie falcons may depend on food located a great distance from the nest (Haak 1982). The foraging area is approximated by using the dimensions of the home range, which can be as large as 389 km² (150 mi) (Haak 1982). If rodenticides or other chemical treatments are planned for areas where prairie falcons exist, refer to Appendix A for contacts that can assist in assessing chemical treatments and their alternatives.

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KEY POINTS

Habitat Requirements

- Prairie falcons inhabit the arid environments of eastern Washington, nesting on cliffs in arid steppe and shrub-steppe habitat.
- Prairie falcons use a wide variety of cliffs, from those made of basalt that are 122 m (400 ft) tall to scant escarpments raised only 6 m (20 ft) above sloping canyon walls.

- Nest sites are often on a sheltered ledge or in a pothole in the cliff, and prairie falcons often use abandoned stick nests built by other raptors.
- Most nest sites are located over 800 m (.5 mi) from human habitation.
- Most nests occur within one-quarter mile of water.
- Prairie falcon nest sites are located within foraging territories. Breeding home range can be as large as 389 km² (150 mi²).
- Prairie falcons forage on a variety prey common to shrub-steppe environments. Ground squirrels (*Spermophilus* spp.), western meadowlarks and horned larks are primary prey items during the breeding season.

Management Recommendations

- Human habitation limits the use of nesting cliffs and should not occur within 800 m (0.5 mi) of known nests.
- Steppe and shrub-steppe habitats should be maintained within the range of prairie falcons to provide a sufficient prey base.
- Widespread control of ground squirrels and other rodents should be limited to areas outside of prairie falcon foraging areas. If rodenticides or other chemical treatments are being considered in areas with prairie falcons, refer to Appendix A for contacts useful when assessing chemical treatments and their alternatives.

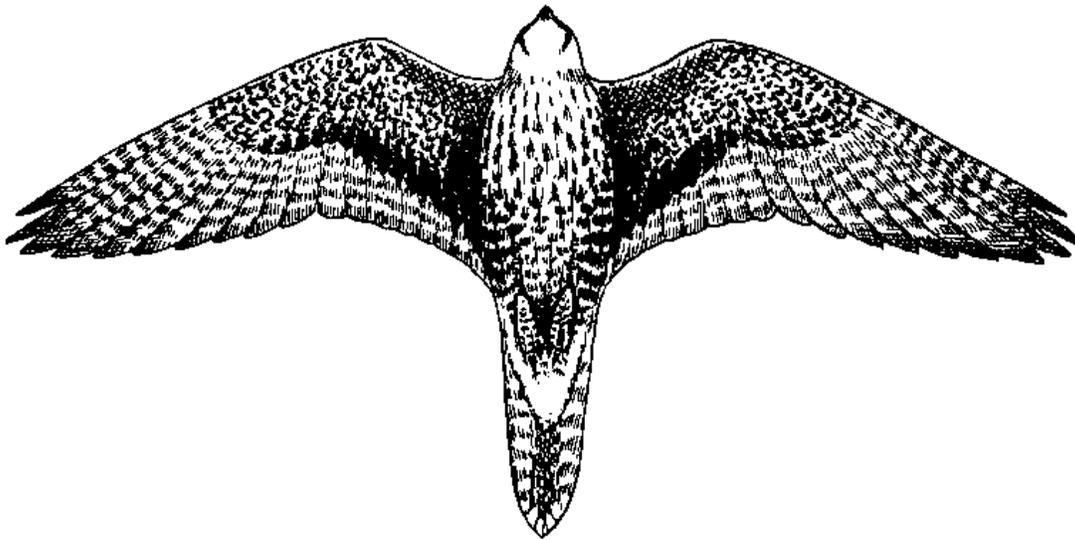


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Peregrine Falcon removed from Priority Habitat and Species list in 2016



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Peregrine Falcon

Falco peregrinus

Last updated: 1999

Written by David W. Hays and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Peregrine falcons occur nearly worldwide. In Washington, nesting may occur in all but the driest parts of the state (see Figure 1). Naturally occurring breeding sites are verified along the outer coast, in the San Juan Islands, and in the Columbia Gorge. Young birds have been introduced in unoccupied historical habitat in Skamania, Lewis, Spokane, Asotin, and Yakima counties.

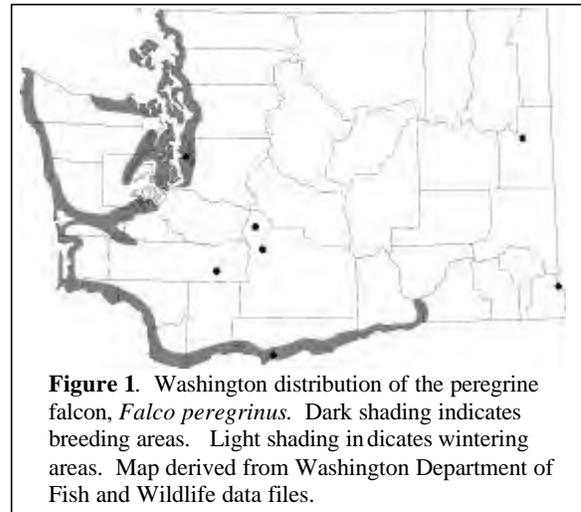


Figure 1. Washington distribution of the peregrine falcon, *Falco peregrinus*. Dark shading indicates breeding areas. Light shading indicates wintering areas. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

The peregrine falcon is a State Endangered¹ species. Peregrine falcon populations have increased in Washington since chlorinated hydrocarbon pesticides were banned in the United States, and through the success of reintroduction programs. Their numbers and distribution are still limited however, due primarily to the lingering effects of pesticides and the lack of suitable nesting sites. Nest sites need to be in close proximity to adequate food sources and free from human disturbance.

HABITAT REQUIREMENTS

Peregrine falcons usually nest on cliffs, typically 45 m (150 ft) or more in height. They will also nest on off-shore islands and ledges on vegetated slopes. Eggs are laid and young are reared in small caves or on ledges. Nest sites are generally near water. The birds are sensitive to disturbance during all phases of the nesting season (1 March through 30 June) (Pacific Coast American Peregrine Falcon Recovery Team 1982, Towry 1987). Disturbance can cause desertion of eggs or young, and later in the breeding season can cause older nestlings to fledge prematurely.

Peregrines feed on a variety of smaller birds that are usually captured on-the-wing. Hunting territories may extend to a radius of 19-24 km (12-15 mi) from nest sites (Towry 1987).

¹ On April 12, 2002, the Washington Fish and Wildlife Commission downlisted the species from endangered to sensitive

Peregrine Falcon removed from Priority Habitat and Species list in 2016

In winter and fall, peregrines spend much of their time foraging in areas with large shorebird or waterfowl concentrations, especially in coastal areas (Dekker 1995). At least 3 western Washington areas support significant numbers of winter resident peregrines annually: the Samish Flats, Grays Harbor, and the Sequim area (Dobler 1989).

LIMITING FACTORS

Peregrine falcon populations declined worldwide as a result of sublethal doses of chlorinated hydrocarbon pesticides, especially DDT and dieldrin. Chemical contamination of the prey base resulted in reduced eggshell thickness, and consequently poor hatching success and survival of young peregrines (Snow 1972). Although these chemicals are now banned in the United States, eggshell thinning and other effects of pesticide contamination are still seen in some peregrine pairs (Peakall and Kiff 1988). Contamination probably results from consuming prey species that winter in countries that continue to use DDT and other organochlorine pesticides, from persistent pesticide residue remaining at the breeding grounds, or from current, illegal use of these chemicals in the United States (Henny et al. 1982, Stone and Okoniewski 1988).

Additionally, peregrines may be limited in some parts of their range by availability of nesting sites in proximity to an adequate food source.

MANAGEMENT RECOMMENDATIONS

Breeding peregrine falcons are most likely to be disturbed by activities taking place above their nest (eyrie) (Herbert and Herbert 1969, Ellis 1982). Ellis (1982) recommended buffer zones of "no human activity" around peregrine falcon breeding sites in Arizona that ranged from 0.8 km to 4.8 km (0.5-3.0 mi), with wider buffer zones recommended for activities above the breeding cliff. These buffer distances were based on incidental observations of peregrine responses to various disturbances. In Washington, buffer zones of 4.8 km (3.0 mi) may not be necessary. However, human access along the cliff rim should be restricted within 0.8 km (0.5 mi) of the nest from March through the end of June (F. Dobler, personal communication). Human activities on the face of, or immediately below, nest cliffs should be restricted from 0.4-0.8 km (0.25-0.5 mi) of the nest during this time (F. Dobler, personal communication). Where falcon nests are already established in proximity to humans there is no need to eliminate trails, picnic grounds, or other facilities except where the birds are evidently disturbed by the human activities. However, further facilities should not be established within 0.4-0.8 km (0.25-0.5 mi) of the eyries (Ellis 1982). Cliff tops above the eyrie should remain undeveloped.

Ellis (1982) suggested that logging be curtailed within 1.6 km (1 mi) of occupied peregrine eyries in Arizona. In Washington, forest practices are reviewed by the Department of Fish and Wildlife when occurring within 0.4 km (0.25 mi) of an eyrie during any season, and within 0.8 km (0.5 mi) of an occupied eyrie during the breeding season (Washington Administrative Code 222-16-080, 1,f).

Eyries occurring within non-forested lands, and those eyries not subjected to forest practices or forest practice rules, should be similarly considered through the development of a site specific peregrine management plan when activities near nests are considered. Male peregrines require perches within sight of the eyrie. Preserve all major perches around the nest and on ridges or plateaus above the nest by retaining all snags and large trees (F. Dobler, personal communication).

Aircraft should not approach closer than 500 m (1,640 ft) above a nest (Fyfe and Olendorff 1976). Closer approaches may cause peregrines to attack planes or may cause a frantic departure from the nest. Falcons startled from the eyrie have been known to damage eggs or nestlings (Nelson 1970).

Powerlines and other wires may be serious hazards to peregrine falcons. Wherever possible, powerlines should be routed away from eyries (Olsen and Olsen 1980).

Applications of pesticides that could potentially affect passerine birds should be avoided around occupied peregrine eyries during the breeding season. Some chemicals such as organochlorines, organophosphates, strychnine, and

Peregrine Falcon removed from Priority Habitat and Species list in 2016

carbofuran can impact birds by causing toxicosis or death, or by contaminating their tissues. Other pesticides may be less toxic to birds, but will increase mortality of young passerines by directly reducing their food supply, thus indirectly reducing the prey available to peregrines (Driver 1991). Reduced or contaminated food sources will negatively affect peregrine falcons. Appendix A provides useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

Wetlands, especially intertidal mudflats, estuaries, and coastal marshes, are key feeding areas in winter. Wetlands used regularly by peregrine falcons at any time of the year should receive strict protection from filling, development, or other excessive disturbances that could alter prey abundance. Do not apply pesticides to areas where winter prey species congregate. Lead shot should not be used in waterfowl areas where peregrine falcons feed. Peregrines can tolerate human presence at wintering sites if they are not harassed and if abundant prey remains.

Maintain all large trees and snags in areas where peregrine falcons feed in winter. These perches are important for roosting and for hunting at terrestrial sites. Snags and debris located on mud flats should also be left for winter perching and roosting.

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Peregrine Falcon removed from Priority Habitat and Species list in 2016

PERSONAL COMMUNICATIONS

Frederick C. Dobler, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

KEY POINTS

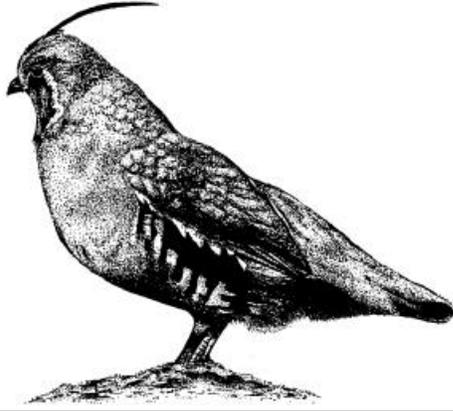
Habitat Requirements

- Peregrine falcons nest in cliffs that are 45 m (150 ft) or more in height.
- Peregrines feed on a variety of smaller birds.
- Hunting territories may extend to a radius of 24 km (15 mi) from nest sites.
- These falcons winter along coastal areas with large shorebird or waterfowl concentrations.

Management Recommendations

- Avoid disturbance during the breeding season (March through June); restrict access to cliff rims where nests are built within 0.8 km (0.5 mi) and within 0.4 km (0.25 mi) of cliff faces.
- Avoid forest practices within 0.8 km (0.5 mi) of eyrie cliffs during the breeding season. If logging does occur, retain all trees on top of the cliff ridge.
- Develop site management plans for Eyries when considering land uses outside of forested environments or for non-forest practice activities.
- Preserve all major perches around nests by retaining all snags and large trees.
- Aircraft should not approach closer than 500 m (1,500 ft) above a nest.
- Route powerlines away from eyries.
- Avoid applying pesticides that affect birds near eyries. Refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.
- Avoid applying pesticides to areas where winter prey species congregate.
- Do not use lead shot in peregrine winter feeding areas.
- Maintain large trees and snags as perches in winter peregrine feeding localities.





Mountain Quail

Oreortyx pictus

Last updated: 1999

Written by David A. Ware, Michelle Tirhi, and Becky Herbig

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The mountain quail ranges from southwestern British Columbia, through Washington and central Idaho south to the mountainous regions of California, Nevada, and Baja California (American Ornithologists' Union 1983).

Mountain quail have been introduced into Alabama, British Columbia, Colorado, Hawaii, Idaho, Montana, Nebraska, Nevada, and Oregon (Heekin 1991). Mountain quail also have been introduced into Washington; however, along the Columbia and Snake rivers there are scattered populations that may be extensions of Oregon flocks (see Figure 1).

The healthiest populations of mountain quail in western Washington appear in Kitsap County (B. Tweit, personal communication). Localized populations also persist in logged areas of Grays Harbor, Thurston, and Mason counties (G. Shirato, personal communication). Incidental sightings have been reported on Fort Lewis, Pierce County (J. Stevenson, personal communication) and in Cowlitz, Jefferson, King, Lewis, Pacific, Pierce, Snohomish, Asotin, Columbia, Garfield, Kittitas, and Klickitat counties (Brennan 1989; Kessler 1990; B. Tweit, personal communication; G. Shirato, personal communication). Scattered sightings have also been reported along the southern portion of Hood Canal and in Skamania County (Hunn and Mattocks 1980), as well as in western Yakima County (L. Stream, personal communication). Many of the localized sightings are thought to be the result of captive flocks being released by hobbyists.

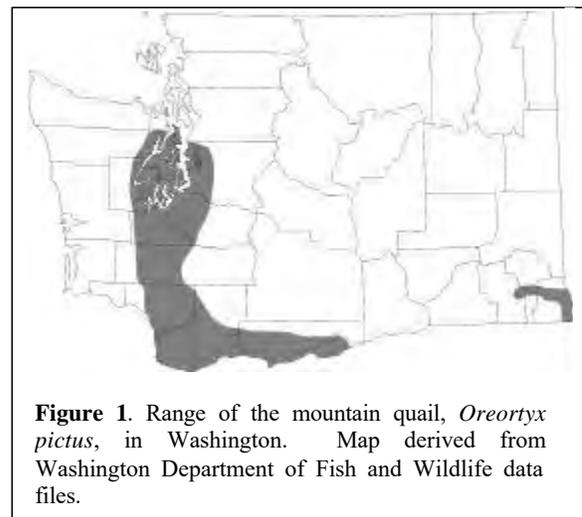


Figure 1. Range of the mountain quail, *Oreortyx pictus*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

Mountain quail are uncommon game birds that are at the edge of their range in Washington. Eastern Washington populations are thought to have declined in recent years largely from declining habitat quality. Because of their secretive nature and reliance on brushy habitats that are usually associated with riparian zones, they are not capable of extensive movements away from suitable patches of habitat. Once these habitats are degraded or removed, mountain quail become isolated from other habitat that may be available.

HABITAT REQUIREMENTS

Mountain quail are associated with mixed evergreen-deciduous forests, regenerating clearcuts, forest and meadow edges, chaparral slopes, shrub-steppe, and mixed forest/shrub areas, characteristically in overgrown brushy areas (Johnsgard 1973, American Ornithologists' Union 1983, Brennan 1989, Crawford 1989, Kessler 1990). Tall, dense cover is a requirement for the majority of activities throughout the year (Johnsgard 1973, Gutiérrez 1975) and mountain quail are seldom found far from this cover (Brennan 1993).

In western Washington, mountain quail may be found at sea level in areas cleared for development that contain stands of Scotch broom (*Cytisus scoparius*) and madrone (*Arbutus* spp.) (G. Shirato, personal communication). In arid regions, such as in southeastern Washington, typical habitat consists of deciduous shrub thickets below talus and cliffs, and alder (*Alnus* spp.) thickets along streams (Yocom and Harris 1953, Brennan et al. 1987). In such arid settings, free-flowing water is essential (Ormiston 1966, Leopold 1972, Gutierrez 1975) and mountain quail are often found in close proximity to both water and escape cover (Brennan et al. 1987). Mountain quail commonly inhabit slopes of 20-60% (Miller 1950, Gutiérrez 1980) and have been observed using slopes of 60-110% (P. Heekin, personal communication).

Nesting

In spring, mountain quail seek brush, hardwood, and conifer communities for nesting (R. Gutiérrez, personal communication). Johnsgard (1973) and Kessler (1990) characterized nesting cover as large shrubs and young trees in dense clusters. Nests are typically well concealed and situated beneath roots, brush, grass clumps, bank edges, or at the base of a dead shrub in patches of live shrubs (P. Heekin, personal communication). Miller (1950) reported a mean vegetational height of 0.5 m (1.6 ft) at nest sites. Nests may also be found next to rocks or logs. Some birds nest in their winter range and others move to higher ground, such as forest or farmland edges (Ormiston 1966). In Idaho, nests were located between 713 m and 1,426 m (2,340-4,680 ft) on slopes 60-110% (P. Heekin, personal communication). Nests were situated in relatively open stands of conifer/mountain shrub cover having a fairly dense understory.

Brood Rearing

In mid-summer, mountain quail broods move to the cool, moist bottoms of draws and canyons (Ormiston 1966). Such movements may be related to the availability of preferred foods within the daily cruising range of water (Ormiston 1966, Gutiérrez 1975). In Idaho, broods 2 to 3 weeks old were located in relatively open cover, often on or near game trails (P. Heekin, personal communication).

Winter

In late fall, mountain quail often migrate to lower elevation winter range (Bent 1963, Johnsgard 1973). They winter in brushy thickets, canyons, and along the borders of farms and woodlands (Yocom and Harris 1953) where mixed trees, shrubs, and herbs exist (Kessler 1990). Mountain quail remain below the snow-line, moving up or down in elevation depending on weather conditions (Ormiston 1966). In Idaho, the mean straight-line distance moved from nest site to winter range was 648 m (2,126 ft) (P. Heekin, personal communication).

Loafing and Roosting Cover

Loafing and roosting cover consists of dense vegetation approximately 2-3 m (5-6 ft) in height (Miller 1950). Mountain quail in west-central Idaho have been observed night roosting in hawthorn (*Crataegus* spp.) trees 3-4 m (10-13 ft) above ground level and loafing at the base of dead shrubs (P. Heekin, personal communication).

Escape Cover

Escape cover is typically 1.5-2 m (5-6.5 ft) high with fairly dense growth (Miller 1950). Where this cover type is not available, quail use slopes of 36% or more to escape (Johnsgard 1973). Trees, such as ponderosa pine (*Pinus ponderosa*), firs (*Abies* spp.), and oaks (*Quercus* spp.) may also be important.

Food

Mountain quail feed primarily on vegetable matter (Ormiston 1966, Rue 1973 in Heekin 1991); animal matter typically comprises <5% of the diet (J. Crawford, personal communication). Food species for mountain quail include lotus (*Lotus* spp.), smooth sumac (*Rhus glabra*), hackberry (*Celtis* spp.), serviceberry (*Amelanchier* spp.), grape (*Vitis* spp.), gooseberry (*Ribes* spp.), elderberry (*Sambucus* spp.), snowberry (*Symphoricarpos* spp.), manzanitas (*Arctostaphylos* spp.), nightshade (*Solanum* spp.), chickweed (*Stellaria* spp.), blue-eyed Mary (*Collinsia* spp.), hawthorn (*Crataegus* spp.), sweet clover (*Trifolium* spp.), thistle (*Cirsium* spp.), ragweed (*Ambrosia* spp.), teasel (*Dipsacus* spp.), scotchbroom, fringecup (*Lithophragma* spp.), composite seeds (*Madia* spp.), poison oak (*Rhus diversiloba*), geranium (*Geranium* spp.), and lupine (*Lupinus* spp.) (Yocom and Harris 1953, Ormiston 1966, Kessler 1990). Mast (tree seed) is eaten in abundance and includes the seeds of pines, Douglas fir (*Pseudotsuga menziesii*), and black locust (*Robinia pseudoacacia*). Acorns, legumes, tubers, roots, and weed seeds may also be consumed. Ormiston (1966) observed seeds of grasses, hawthorn, pines, sweet clover, thistles, ragweed, and teasel in the fall diet in Idaho. The winter diet is comprised of seeds of large annuals and perennials and fruits of woody species such as hawthorn, acorn meats, pine seeds, and greens (Ormiston 1966, Johnsgard 1973).

LIMITING FACTORS

An inadequate food supply caused by habitat loss throughout mountain quail range is considered a major limiting factor (Miller 1950; R. Gutiérrez, personal communication). The loss of winter habitat from dams and water impoundments, residential development, intensive agriculture, and the deterioration of wintering and breeding grounds as a result of overgrazing also limits mountain quail (Brennan 1990, P. Heekin, personal communication). Timber harvest does not appear to limit mountain quail if the cut site is allowed natural regrowth and invasion by brush species (R. Gutiérrez, personal communication). Excessive timber harvest [>200-400 ha (500-1,000 ac)] may negatively impact mountain quail (Leopold 1977; R. Gutiérrez, pers. comm.); however, this has not been proven (R. Gutiérrez, personal communication).

Water has been reported as a limiting factor (Rahm 1938, Ormiston 1966, Gutiérrez 1975, Miller and Stebbins 1964 in Gutiérrez 1975) and may be a problem in southeastern Washington (Kessler 1990). An increased water supply due to greater rainfall has resulted in higher breeding success in arid regions (Gutiérrez 1975, 1980; Brennan et al. 1987). The loss of riparian habitat in arid portions of mountain quail range is a serious threat to their stability (R. Gutiérrez, personal communication).

MANAGEMENT RECOMMENDATIONS

Habitat preservation is the key to mountain quail management in Washington (Kessler 1990). In eastern Washington, mountain quail persist in relatively isolated populations interconnected by corridors of riparian brush communities. These corridors serve as avenues for dispersal and movement between breeding and wintering habitat, as well as provide food and cover in close proximity to water sources (Brennan 1993). Removal of riparian brush communities should be avoided within the range of the mountain quail. The burning of decadent shrub fields should be avoided unless performed as a mosaic burn (P. Heekin, personal communication).

Herbicides that destroy brushy habitat should be avoided where management for mountain quail is a priority. Landowners are encouraged to use integrated pest management that targets specific pests or noxious weeds, pest population thresholds to determine when to use pesticides or herbicides, and crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). Appendix A provides useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

The interspersed cover [covering 20-50% of the ground area (Miller 1950)] should be given major consideration. Ideal habitat consists of a variety of plants at various heights (Miller 1950). The creation of edges between cover types is of lesser importance in habitat management (Miller 1950, Gutiérrez 1975). Management should protect and/or provide a variety of micro-habitats within the mountain quail range including mixed evergreen-deciduous forests, openings, forest and meadow edges, chaparral slopes, shrub-steppe, and mixed forest-shrub areas. Tall, dense cover in close proximity to water should receive priority in management consideration.

Clearcutting extremely large blocks of coniferous and deciduous forests [>200 ha (500 ac)] should be avoided where mountain quail are known to exist. Land managers should be encouraged to replant logged areas with a variety of tree species or allow natural regeneration of sites (J. Crawford, personal communication; R. Gutiérrez, personal communication). Small harvested areas; selective harvest which maintains several mature, standing trees; harvest which retains slash and/or slash piles; and harvested sites which are not subject to broadcast burning have been beneficial to mountain quail in west-central Idaho (P. Heekin, personal communication). Every effort should be made to protect or provide water sources within mountain quail range, especially along riparian corridors. Livestock use of riparian corridors should be avoided as heavy grazing by sheep and cattle may be detrimental to mountain quail habitat (Gutiérrez 1975). Where water is lacking, watering devices should be installed (Miller 1950). Water devices should be placed in or near heavy cover to reduce predation (P. Heekin, personal communication).

Public education programs targeting habitat removal and water diversion issues associated with residential development are desirable where mountain quail management is priority (P. Heekin, personal communication). Furthermore, mountain quail are often attracted to and concentrate at bird feeders during the winter months. The concentration of birds at these sites increases the threat of predation by both natural and introduced predators. People that maintain bird feeders should be discouraged from placing feeders in open areas which are highly visible to predators (P. Heekin, personal communication).

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KEY POINTS

Habitat Requirements

- Mountain quail are associated with mixed evergreen-deciduous forests; regenerating clearcuts, selective cuts, and seed-tree cuts; forest and meadow edges; chaparral slopes; shrub-steppe; and mixed forest/shrub areas.
- Mountain quail require tall, dense cover over 20-50% of the area.
- A source of free-flowing water such as that found in riparian zones is critical to mountain quail occupying arid regions.
- Mountain quail nest in brush, shrubs, hardwood, and conifer communities.
- Loafing and roosting cover consists of dense vegetation approximately 2-3 m (5-6 ft) in height.
- Mountain quail winter in brushy thickets, along canyons, and about farms and woodland borders.
- Mountain quail feed on fruits, mast, acorns, legumes, tubers, roots, and seeds of grasses, weeds, flowering plants, and insects.

Management Recommendations

- Tall, dense cover (covering 20-50% of the ground area) in close proximity to water sources should be retained in areas where mountain quail management is a priority.
- Protect riparian brush communities within the range of the mountain quail.
- Encourage the use of integrated pest management within the mountain quail primary management zone. Refer to Appendix A for contacts useful when assessing pesticides, herbicides, and their alternatives.
- The burning of decadent shrub fields should be avoided unless performed as a mosaic burn.
- Public education should be encouraged where managing for mountain quail is a priority, and should target habitat removal and water diversion issues associated with residential development. The avoidance of placing bird feeders in open areas highly visible to predators should also be addressed.
- Minimize livestock use of riparian habitat.
- Protect or provide a variety of micro-habitats.
- Avoid clearcutting large areas of coniferous and deciduous forests (>500 ac).
- Encourage the planting of multiple tree and shrub species and/or allowing natural regeneration in areas subject to timber harvest.
- Install watering devices where water is lacking in or near dense cover.



Chukar

Alectoris chukar

Last revised: 1999

Written by David A. Ware and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Chukars are native to Asia, the Middle East, and southern Europe. They have been introduced into rocky, arid, mountainous areas from southern British Columbia south to Baja California and east to western Colorado (Udvardy 1977, Dunn et al. 1987). In southern Alberta, Arizona, New Mexico, and South Dakota only remnant populations exist (Johnsgard 1973).

In Washington, chukars are mainly found along deep river canyons in the arid regions east of the Cascade Mountains. The primary management zone includes portions of the middle and upper Columbia River and its tributaries, the Banks Lake area, the lower Yakima River and its tributaries, and the eastern portion of the Snake River (see Figure 1).

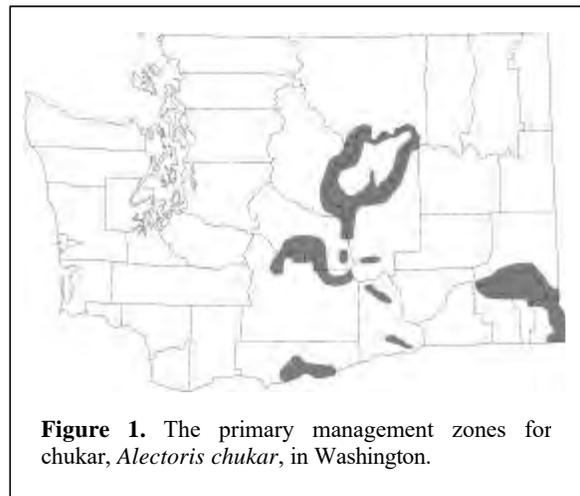


Figure 1. The primary management zones for chukar, *Alectoris chukar*, in Washington.

RATIONALE

The chukar, a recreationally important game bird, is one of the most popular upland game species in Washington. From 1991 to 1995, an average of 8,000 hunters a year reported pursuing chukars in Washington. Habitat is limited by the availability of talus or rocky slopes.

HABITAT REQUIREMENTS

Chukars flourish in mesic (moist) and semi-arid portions of shrub-steppe habitat characterized by steep, rocky, dry slopes (Galbreath and Moreland 1953, Christensen 1954, Molini 1976, Oelklaus 1976, Carmi-Winkler et al. 1987). The habitat is described as dense to open, with non-spiny shrubs, perennial and annual grasses, and forbs (Molini 1976). Galbreath and Moreland (1953) and Molini (1976) identified the optimum range as 50% sagebrush

(*Artemisia* spp.)-cheatgrass (*Bromus tectorum*)-bunchgrass (*Agropyron* spp.); 45% talus slope, rock outcrops, cliffs, and bluffs; 5% brushy creek bottoms and swales; and steep slopes (up to 40).

In Washington, chukar habitat consists of talus areas containing brome-grasses, bunchgrasses, and sagebrush at elevations of 175-1,220 m (575-4,000 ft) (Moreland 1950). Oelklaus (1976) found Douglas hackberry (*Celtis douglasii*) communities, smooth sumac (*Rhus glabra*) stands, and poison ivy (*Toxicodendron* spp.) clones along rivers and riparian corridors used extensively by chukars throughout the Snake and Columbia river canyons. Chukars are apparently not agricultural inhabitants and typically exist in areas unoccupied by other upland birds (Moreland 1950). Big sagebrush (*Artemisia tridentata*) is the predominant shrub and cheatgrass brome the predominant grass throughout the chukar range (Galbreath and Moreland 1953, Molini 1976). However, a variety of native and non-native shrubs and grasses are used.

Nesting

Most chukar nests are located under low-growing scabland sagebrush, 90-120 m (300-400 ft) above creek bottoms in heavy sagebrush areas mixed with bunch- and brome-grasses (Galbreath and Moreland 1953). Hens may also seek more gentle terrain in which to nest (Alkon 1983).

Roosting, Loafing, and Dusting Sites

Chukars typically roost and loaf on the ground beneath sagebrush, under rock outcrops, or in open rocky areas (Christensen 1970). Chukars often roost on peninsulas. Rock outcrops, Douglas hackberry, and smooth sumac communities may be used for loafing (Oelklaus 1976) depending on availability. Dusting is very important and occurs alongside trails and roads, or near water sites (Christensen 1970).

Food

Chukars feed primarily on exotic grasses and the seeds of weedy forbs (Galbreath and Moreland 1953, Bohl 1957, Christensen 1970, Kam et al. 1987). Cheatgrass (both seeds and leaves) is the most important yearly food item for chukars throughout their range (Galbreath and Moreland 1953, Harper et al. 1958, Christensen 1970). In Washington, cheatgrass and wheat comprise the main diet of the chukar year-round (Galbreath and Moreland 1953). When chukars are in close proximity to agricultural fields, they may feed on available grains, seeds, and green shoots (Sandfort 1954, Christensen 1970). Insects are an important source of food during the summer and early fall (W. Molini, personal communication).

Water

The summer range of the chukar depends upon the distribution and availability of water (Galbreath and Moreland 1953, Christensen 1970). Oelklaus (1976) consistently found chukars concentrated around rivers and tributaries in Idaho. Oelklaus (1976) also found chukars moving away from tributaries that dried up in the summer and fall to those that remained. In eastern Washington, chukars have been observed feeding on ripe fruits of hawthorne (*Crataegus* spp.), common chokecherry (*Prunus virginiana*), and serviceberry (*Amelanchier* spp.) in July and August in part to fulfill their water needs (Galbreath and Moreland 1953).

LIMITING FACTORS

Grasses, particularly cheatgrass, and water are the 2 components necessary for chukar survival (Oelklaus 1976). Severe winters may limit local populations and have been known to adversely effect chukar populations in Nevada, Idaho (Christensen 1970), and Washington (Galbreath and Moreland 1953). Low precipitation, especially droughts, are deleterious to these birds (Christensen 1958).

MANAGEMENT RECOMMENDATIONS

Of primary importance in maintaining good chukar production is the availability of green grasses, especially cheatgrass (Christensen 1958). Chukars rely on sagebrush stands within semi-arid sagebrush grasslands (Galbreath and Moreland 1953). Reduction of sagebrush within primary chukar management zones should be avoided. Management practices that significantly impact insect populations will likely decrease chukar numbers and should be avoided (W. Molini, personal communication).

The summer range of the chukar depends on the availability of water. Therefore, water improvement and development can be used to expand their distribution and possibly increase the chukar population (Christensen 1970). The protection and improvement of existing water supplies should receive priority in chukar habitat management (Christensen 1970). This would include reconstructing livestock watering troughs and other watering developments to insure a permanent water supply for chukars and other wildlife. Providing escape ramps and supplemental bird drinking basins to stock water tanks used by livestock would also benefit chukars. Gallinaceous guzzlers [1,300 L (350 gal)] placed within 45 m (148 ft) of steep, rocky escape cover or near the bottom of draws, gullies, and/or ravines provide the most benefits to chukars (W. Molini, personal communication). Chukars require some form of protective cover around water sources. Therefore, plant shrub cover around watering devices (Galbreath and Moreland 1953).

Douglas hackberry communities, sumac stands, and poison ivy clones along rivers and riparian corridors throughout the range of the chukar should be retained (Oelklaus 1976). Landowners and land managers are encouraged to use integrated pest management that targets specific pests or noxious weeds, uses pest population thresholds to determine when to use pesticides or herbicides, and utilizes crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on integrated pest management, refer to Appendix A, for contacts to help assess the use of pesticides, herbicides, and their alternatives.

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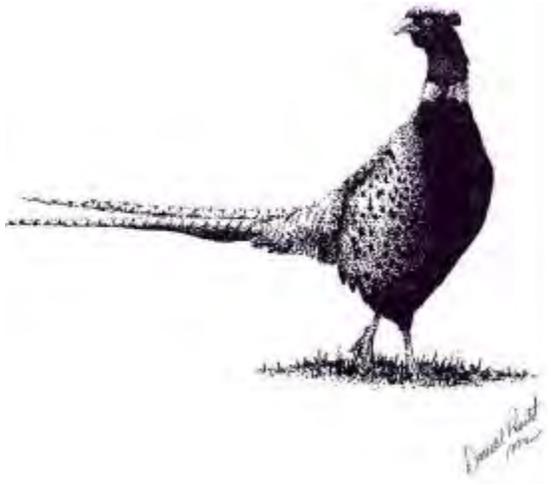
KEY POINTS

Habitat Requirements

- Chukars inhabit dense to open portions of shrubland associated with perennial and annual grasses and forbs.
- Optimum range is 50% sagebrush-cheatgrass-bunchgrasses; 45% talus slope, rock outcrops, cliffs, and bluffs; 5% brushy creek bottoms and swales; and steep slopes (up to 40).
- Big sagebrush and cheatgrass predominate throughout the chuckar's range.
- Chukars nest under low-growing scabland sagebrush, 90-120 m (300-400 ft) above creek bottoms in heavy sagebrush areas mixed with bunch- and brome-grasses.
- Chukars roost and loaf on the ground beneath sagebrush or under rock outcrops, in Douglas hackberry and in smooth sumac communities.
- Chukars dust alongside trails and roads or near water sites.
- Chukars feed mostly on cheatgrass as well as grains, seeds, and green shoots when available.

Management Recommendations

- Protect sagebrush in semi-arid sagebrush grasslands used by chukars.
- Management practices which significantly impact insect populations will likely decrease chukar numbers and should be avoided.
- Protect and/or improve existing water supplies throughout chukar range.
- Provide escape ramps and supplemental bird drinking basins to stock water tanks used by livestock.
- Gallinaceous guzzlers [1,300 L (350 gal)] placed within 45 m (148 ft) of steep, rocky escape cover or near the bottom of draws, gullies, and/or ravines provides the most benefits to chukars.
- Plant shrub cover around watering devices.
- Retain Douglas hackberry communities, sumac stands, and poison ivy clones along rivers and riparian corridors.
- Encourage the use of integrated pest management within the chukar primary management zone. For more information on integrated pest management, refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.



Ring-necked Pheasant

Phasianus colchicus

Last updated: 1999

Written by David A. Ware and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The ring-necked pheasant is native to Asia and has been extensively introduced throughout North America. Ring-necked pheasants range from central Canada through the northern United States and southward into New Mexico, Texas, Louisiana, and Mississippi (Dumke et al. 1984, Dahlgren 1988, Droege and Sauer 1990).

Ring-necked pheasants are found in most agricultural areas throughout Washington. However, they are only considered a priority species within the primary management zone delineated by Washington Department of Fish and Wildlife's Game Division (see Figure 1).

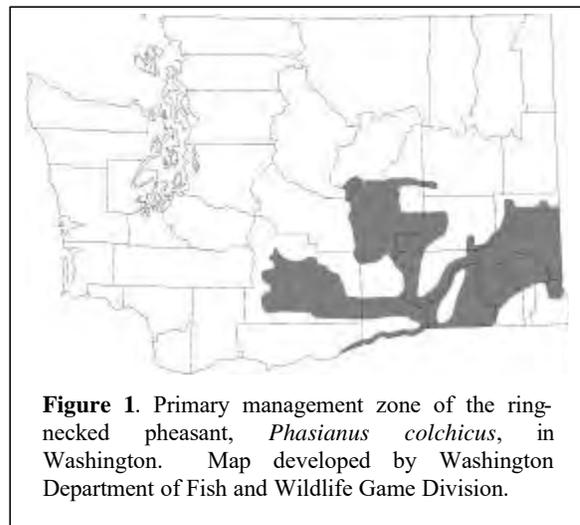


Figure 1. Primary management zone of the ring-necked pheasant, *Phasianus colchicus*, in Washington. Map developed by Washington Department of Fish and Wildlife Game Division.

RATIONALE

The ring-necked pheasant, a recreationally important game species, is the most popular upland game bird in Washington. Ring-necked pheasants are currently the focus of a major habitat restoration program. Pheasants are dependent on agricultural habitats and they thrive in non-crop vegetation around cultivated crops. As shrub-steppe habitats were converted to agriculture, pheasant populations grew. However, with today's improved farming technology and management practices, pheasants have undergone a tremendous decline as indicated by harvest surveys (Washington Department of Fish and Wildlife 1996). This has resulted in significant declines in hunter numbers and associated recreation. There were over 110,000 pheasant hunters in 1981. In 1995, that number declined to 29,000. Pheasant harvest declined from over 500,000 to 70,000 birds from 1981 to 1995.

HABITAT REQUIREMENTS

Ring-necked pheasants require permanent retention-type cover to sustain populations and use a variety of agricultural cover types. In Washington, prime cover occurs near irrigated farmlands containing cattail patches (*Typha* spp.) mixed with willow (*Salix* spp.) (Blatt 1975, Foster et al. 1984). Riparian/shrub tree bottoms in dryland wheat areas of eastern Washington that are not grazed by livestock also provide excellent habitat. Thickets and shrubs provide shelter and shade; woody plants and thorny shrubs provide escape cover; wetland areas and weedy patches provide roost and loaf sites; and cattail, willow, and bulrush sloughs (*Scirpus* spp.) provide escape and

thermal cover during winter. Fence rows, roadside ditches, and field edges with adequate vegetation provide travel corridors. In Britain, pheasants have been observed roosting in trees and in ditches in areas void of trees (D. Hill, personal communication).

Where adequate habitat exists, pheasants may spend their entire life in an area approximately 256 ha (640 ac) in size. Prime ring-necked pheasant habitat contains approximately 25-50% uncultivated land and 50-75% cultivated land (having 20-75% small grain crops and/or 30-40% field corn crops) (Warner et al 1984).

Roadsides, canals, and drainage banks have good potential for pheasants and other upland wildlife (Joselyn and Tate 1972, Snyder 1974, Varland 1985, Warner et al. 1987). The use of such linear cover depends on the proximity to other prime breeding habitats (Warner and Joselyn 1986), the density and height of cover (Wieggers 1959, Hoffman 1973, Warner et al. 1987), and the width of linear cover (Linder et al. 1960, Gates and Hale 1975).

Nesting and Brood Rearing

Undisturbed cover provides the best nesting and brood rearing habitat. Areas containing new vegetation are preferred; where this is lacking, residual vegetation is used. Alfalfa, wheat, and grass hayfields are often selected as nest sites (Galbreath and Ball 1969; Snyder 1982, 1984). This choice of nesting habitat is the most precarious due to harvest and cultivation. Pastures, woodlots, orchards, row crops, wetlands, and untilled sites adjacent to cropland are also used for nesting (Gates 1970; J. Tabor, personal communication). Ring-necked pheasants typically nest in the tallest [15 cm (6 in) residual cover and 25 cm (10 in) for current growth] herbaceous vegetation available (Washington Department of Wildlife 1987). In Britain, Hill (personal communication) has observed pheasants nesting under area of bramble (*Rubus* spp.) intertwined with grasses that provides both open ground cover and overhead concealment. Nest predation actually increased when nests were situated in clumps of obvious vegetation (D. Hill, personal communication). In Wisconsin, undisturbed grasslands or hayfields with adequate residual cover and wetlands provide key nesting and brood-rearing habitat (Gatti 1983).

Roadsides could provide important nesting areas if managed properly (Trautman 1982, Warner and Joselyn 1986, Hill and Robertson 1988). Warner et al. (1987) commonly found pheasants nesting on roadsides when prime nesting habitat was unavailable. Haensly et al. (1987) cautioned that strip cover, such as that found at roadsides, may also have a higher rate of predation in comparison to more extensive habitats used for nesting.

Brood-rearing habitat includes shrubs, tree rows, grain fields (corn or sorghum), and cool-season grasses (Nelson et al. 1990), which provide both dense hiding cover and adequate food supplies. Optimal brood-rearing habitat contains a high proportion of broad-leaved plants which are a key source of insects and seeds. Optimal brood-rearing habitat also provides overhead concealment from predators and open space at ground level for ease of movement of chicks. Broods typically range over large areas and various vegetative communities in search of food during the first 2 weeks of life (D. Hill, personal communication). Often areas containing the highest densities of preferred foods are avoided, such as weed fields (D. Hill, personal communication).

Roosting

Roosting takes place in grasslands and stubble fields except during severe winter weather when low, herbaceous vegetation (Labisky 1956, Robertson 1958), cattails, and marshy vegetation are preferred (Olsen 1977). In Washington's Columbia Basin, wet meadows containing rush (*Juncus* spp.) are used throughout the year as roosting sites (J. Tabor, personal communication).

Loafing

Loafing areas contain minimal ground cover but dense overhead concealment, such as bushy vegetation, ragweed (*Ambrosia* spp.), or summercypress (*Kochia* spp.). These areas usually provide dusting sites, sunlight, or shade depending upon the needs of the pheasant (Ginn 1962).

Winter

Ideal winter habitat provides food and woody plants for cover (Hill and Robertson 1988). In South Dakota, wetlands lacking snow accumulation are ideal wintering sites (A. Leif, personal communication). In Washington, pheasants mainly winter in dense willow stands and cattail patches on sites 2-6 ha (5-15 ac) in size which are within 1 km (0.6 mi) of cultivated crops (Blatt 1975, Foster et al. 1984). In Great Britain, the highest density of wintering pheasants are located in small woodlots with convoluted boundaries which maximizes the edge:area ratio with surrounding tilled land (D. Hill, personal communication). Multi-row shelterbelts, windbreaks, fencerows, and shrub-type cover which is not grazed by livestock also provide good winter cover.

Food

Ring-necked pheasants feed primarily on cultivated grains, including corn, wheat, barley, peas, and oats (Trautman 1952, DeSimone 1975, Hill and Robertson 1988). Beans, rice, and sorghum are eaten in smaller quantities. Weed and grass seeds are also important food items, especially when waste grain is unavailable (Hiatt 1947, Trautman 1952, Olsen 1977, Wise 1986). In winter, wild fruits are consumed and may include the fruits of chokecherry (*Aronia* spp.), wild rose (*Rosa* spp.), snowberry (*Symphoricarpos* spp.), hawthorn (*Crataegus* spp.), and serviceberry (*Amelanchier* spp.). Insects and gastropods are eaten in small quantities by adults. Insects are consumed in larger quantities by hens during the breeding season and by chicks and juveniles (Loughrey and Stinson 1955; Korschgen 1964; Olsen 1977; A. Leif, personal communication). Species eaten include grasshoppers, snails, beetles, ants, cutworms, crickets, plant bugs, and sawfly larvae. During egg laying, hens consume large amounts of snail shells and high calcium grit to help in egg shell production (Wise 1986).

LIMITING FACTORS

Loss of permanent nesting and winter cover on irrigated lands is the primary factor limiting the ring-necked pheasant (Kimball et al. 1956 in Allen 1956, Washington Department of Game 1957, MacMullan 1961, Blatt 1975, Burger 1988, Hart 1990). Specific problems include the loss of cattail and willow stands, woody plants, windbreaks, and brushy fencerows (Warner et al. 1984). Pesticides have been shown to lower chick production (Labisky and Lutz 1967, Borg et al. 1969 in Potts 1986) and chick viability, (Rudd and Genelly 1956) as well as degenerate the nervous system.

MANAGEMENT RECOMMENDATIONS

Irrigated farmlands within the Columbia Basin Project, the Yakima Valley, and riparian areas in south Whitman, northern Garfield, Columbia, and Walla Walla counties should be considered high priority areas for ring-necked pheasants. Optimal feeding and wintering areas are 1 km (0.6 mi) (Hart 1990) to 1.2 km (0.75 mi) apart (Blatt 1975). Hill (personal communication) recommends maintaining many small plots of woodland with a maximum distance of 500-750 m (1,600-2,500 ft) between woodlots and permanent winter cover. On public lands, legumes and/or native grasses should be planted as nesting cover and shrubs and woody plants as winter cover. Multi-species food plots should be established near permanent cover. At the landscape level, habitat management for pheasants should include a mosaic of different crops and residual cover interspersed with plots of permanent cover (D. Hill, personal communication).

Fence rows, waterways, cattail and willow patches, thickets, shrubs, and other woody plants on irrigated private farmlands should be protected and enhanced. Farmers should be encouraged to delay alfalfa cutting 1 week or longer to increase nesting success (Hartman and Fisher 1984) and/or grow winter wheat, seed alfalfa, or grass seed crops. Strips of standing corn should be left in fields for winter food. Undisturbed grasslands and hayfields containing residual cover should be preserved (Gatti 1983). Where these components are lacking, the provision of large, square-shaped fields 4-32 ha (10-80 ac) in close proximity [3 km (2 mi)] to winter cover would enhance pheasant nesting and brood-rearing (Gatti 1983). Private landowners may also be encouraged to retire lands of marginal grazing or crop value, especially lands with moderate to high erosion risks (Gatti 1983).

Livestock grazing should be restricted or excluded on isolated tracts throughout pheasant range, in riparian areas, in woody cover, and on prime wintering, nesting, and roosting grounds (Wechsler 1986; Hart 1990; J. Tabor, personal communication). Fences should be constructed around ponds to exclude cattle and increase nesting cover.

In areas of low precipitation, protect or plant dense stands of warm- and cool-season grasses and legumes for nesting (Warner and Joselyn 1986). If weed control on these areas is necessary, mow between 1 August and 1 September (late summer) to allow hens to bring off a brood and allow vegetation to regrow prior to winter dormancy (Hoffman 1973, Wechsler 1986, Hart 1990).

Pesticide spraying should be avoided within prime pheasant habitat (Hoffman 1973). Where spraying is unavoidable, use a spot spraying technique versus blanket spraying (Wechsler 1986). Incorporate 6 m (20 ft) strips around the perimeter of cereal grain fields which would not receive chemical treatment (Potts 1986; A. Leif, personal communication). Landowners are encouraged to use integrated pest management that targets specific pests or noxious weeds, pest population thresholds to determine when to use pesticides or herbicides, and crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991; L. Peterson, personal communication). See Appendix A for useful contacts for assistance when assessing pesticides, herbicides, and their alternatives.

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KEY POINTS

Habitat Requirements

- Irrigated farmlands containing cattail patches mixed with willow and ungrazed riparian/shrub tree habitat in dryland wheat areas provide suitable retention cover for ring-necked pheasants.
- Ring-necked pheasant habitat contains approximately 25-50% idle land and 50-75% cultivated land (having 20-75% small grain crops and/or 30-40% field corn crops).
- Pheasants nest in undisturbed cover (May-July) found in alfalfa and wheat fields, grass hayfields, pastures, woodlots, orchards, row crops, wetlands, roadsides, and untilled areas adjacent to cropland.
- Nests are placed in tall, dense herbaceous vegetation [minimum 15 cm (6 in) residual cover and 25 cm (10 in) current growth].
- Brood rearing habitat includes shrubs, tree rows, grain fields (corn or sorghum), and cool-season grasses with an abundance of broad-leaved plants and insects for chicks.
- Pheasants roost in grasslands, stubble fields, cattails, marshy vegetation, and wet meadows containing rush.
- Preferred loafing areas contain minimal ground cover and dense overhead concealment.
- Pheasants winter in dense willow stands and cattail patches 2-6 ha (5-15 ac) in size and 1 km (0.6 mi) from cultivated crops. Multi-row shelterbelts, windbreaks, fencerows, ungrazed shrub-type cover, and wetland vegetation also provides key wintering habitat.
- Pheasants feed primarily on cultivated grains, including corn, wheat, barley, peas and oats, weed and grass seeds, wild fruits, and insects.

Management Recommendations

- Optimal feeding and wintering areas are 1-1.2 km (0.6-0.75 mi) apart, preferably 500-750 m (1,600-2,500 ft).
- Plant legumes and/or native grasses as nesting cover and shrubs and woody plants as winter cover.
- Establish multi-species food plots (>2 acres in blocks) near permanent cover.
- Manage strip cover (roadsides, canals, and drainage banks) in areas of medium to high precipitation [\geq 25 cm (10 in)]. Maintain or plant dense stands of warm- and cool-season grasses and legumes in areas of low precipitation. If weed control is necessary, mow between 1 August and 1 September.
- Discourage the removal and annual burning of fence rows, waterways, cattail and willow patches, thickets, shrubs, and other woody plants on irrigated private farmlands.
- Encourage farmers to delay alfalfa cutting to increase nesting time and/or grow other less hazardous crops.
- Leave scattered, standing grain in fields for winter food.
- At the landscape level, habitat management for pheasants should include a mosaic of different crops and residual cover, interspersed with tracts of permanent cover.
- Livestock grazing should be restricted and/or excluded on isolated tracts, woody cover, riparian areas, and on wintering grounds. Restrict livestock by placing fences around ponds.
- Avoid the use of pesticides within prime pheasant habitat where possible. Refer to Appendix A when assessing pesticides, herbicides, and their alternatives.
- Use spot spraying (verses blanket spraying) where spraying pesticides is unavoidable and establish a 6 m (20 ft) conservation headland (buffer) around the perimeter of cereal fields.
- Encourage the use of integrated pest management within the ring-necked pheasant primary management zone.



Blue Grouse

Dendragapus obscurus

Last updated: 1998

Written by David A. Ware

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Blue grouse are found throughout western North America, including the offshore islands of British Columbia, Canada. Their range extends from the southern portions of Alaska and the Yukon, south along the Pacific Coast to northern California. The range continues east, encompassing the Cascade and Sierra Nevada mountains of the Pacific Northwest and California, and the northern and central Rocky Mountains from Canada to Arizona (Aldrich 1963, Johnsgard 1973).

In Washington, blue grouse are found in mountainous areas wherever open coniferous forests are present (see Figure 1; Soil Conservation Service 1969). They are closely associated with true fir (*Abies* spp.) and Douglas fir (*Pseudotsuga menziesii*) forests (Johnsgard 1973). Hunter survey results from the 1995 season indicated that blue grouse were harvested from all counties except Adams, Benton, Franklin, Grant, Island, San Juan, and Whitman (Washington Department of Fish and Wildlife 1996).

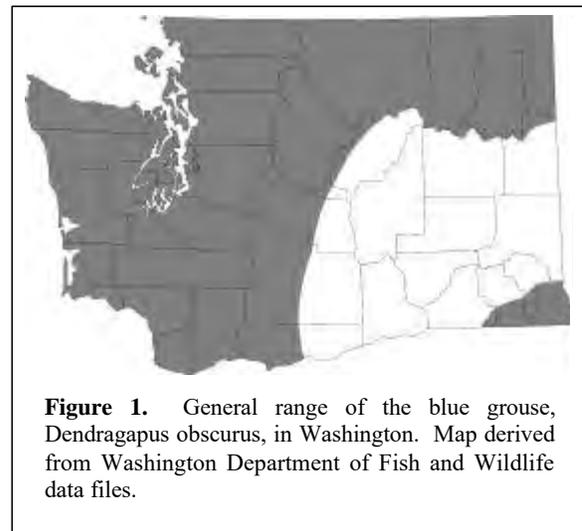


Figure 1. General range of the blue grouse, *Dendragapus obscurus*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

The blue grouse is a recreationally important species that is vulnerable to habitat loss or degradation.

HABITAT REQUIREMENTS

Blue grouse breed in open foothills and are closely associated with streams, springs, and meadows. Much of the food they require comes from the succulent vegetation that grows in these areas. During spring and summer blue grouse use stream bottoms and areas with gentle slopes (Washington Department of Game 1961). In the fall they migrate to higher elevations where they spend the winter feeding on fir needles (Soil Conservation Service 1969). Large fir trees are a food source for wintering blue grouse and are required for roost sites. Blue grouse exhibit strong site fidelity to their wintering areas (Cade 1984).

Diet

True fir and Douglas fir needles constitute 60% of blue grouse diet west of the Cascade Mountains (Beer 1943). In other areas they are often supplemented with larch (*Larix* spp.) and pine (*Pinus* spp.) needles (Boag 1963). Important forbs and grasses in drier climates include balsamorhiza (*Balsamorhiza* spp.), buckwheat (*Eriogonum* spp.), dwarf mistletoe (*Phoradendron* spp.), dandelion (*Taraxacum* spp.), false dandelion (*Agoseris* spp.), strawberry (*Fragaria* spp.), clover (*Trifolium* spp.), sedge (*Carex* spp.), daisy or fleabane (*Erigeron* spp.), knotweed (*Polygonum* spp.), manzanita or bearberry (*Arctostaphylos* spp.), huckleberry (*Vaccinium* spp.), pussy toes (*Antennaria* spp.), elderberry fruit (*Sambucus* spp.), hawksbeard (*Crepis* spp.), dock (*Rumex* spp.), starwort (*Stellaria* spp.), and lupine (*Lupinus* spp.) (Beer 1943, Boag 1963). A study on Vancouver Island indicated that 90% of adult blue grouse diets consisted of bracken fern (*Pteridium aquilinum*), willow (*Salix* spp.), Oregon grape (*Berberis* spp.), blackberry (*Rubus* spp.), huckleberry, salal (*Gaultheria* spp.), and cat's ear (*Hypochaeris* spp.) (Johnsgard 1973). Insects are also an important food source, especially for young chicks during their first 10 days of life (Beer 1943).

Breeding Areas

Conifer thickets, their edges, and adjacent clearings are characteristic of high quality breeding habitat for blue grouse. Selective logging and small clearcuts have the potential to produce good blue grouse habitat by creating uneven aged timber stands with numerous 20-60 year-old thickets (Martinka 1972). Nests are usually located near logs or under low tree branches in open timber (Johnsgard 1973). Smith (1990) found that in Idaho, nesting occurs in brushy areas and that sites with tall sagebrush were preferred.

Mussehl (1962) stated that broods use areas with high plant density and diversity and high canopy coverage. Bare ground should be less than 11%, and the average effective height of grass and forbs should be 20 cm (8 in). Grass and forb cover in areas of highest use range from 53-85%. The forb component of high use areas is 11-41%. Typically, broods feed within 90 m (295 ft) of brush/tree cover. As the broods get older, they switch to riparian areas and shrubby vegetation (Mussehl 1962).

LIMITING FACTORS

Reforestation practices that include high density replanting, herbicide application, and fertilization result in rapid tree canopy closure which reduces blue grouse use (Bendell and Elliott 1967, Zwickel and Bendell 1985). In drier areas, intense grazing of open lowland forests reduces the quality and availability of breeding habitat (Mussehl 1962, Seaburg 1966, Zwickel 1972).

MANAGEMENT RECOMMENDATIONS

Streams, springs, and wet meadows should be safeguarded from potential damage due to livestock grazing and logging operations. Lush vegetation, shrubs, and deciduous trees associated with such areas should be retained for blue grouse brooding and feeding habitat. Grazing should be managed for maximum forb production. The grazing intensity should be light enough to allow grass/forb vegetation to reach a standing height of 20 cm (8 in) (Mussehl 1962, Seaburg 1966). Preferred brooding areas for blue grouse include grass and forb communities that are up to 30 cm (12 in) high. Moderate grazing from May through August or grazing deferred until after 1 August, preserves nesting, brooding, and feeding cover (Soil Conservation Service 1969). Heavy grazing on lower slopes can be deleterious to blue grouse habitat (Johnsgard 1973).

Reforestation activities should address the needs of blue grouse. Succession is naturally rapid, but it is accelerated by dense plantings of Douglas fir. Allowing the tops of hills and low-productivity sites to remain unplanted would be beneficial to blue grouse as breeding areas (Johnsgard 1973, Zwickel and Bendell 1985). Forbs should always be included in seed mixes when reseeding forest land and range where blue grouse occur (Seaburg 1966). Mussehl

(1962) showed that blue grouse preferred sites composed of at least 11% forbs. Openings in densely forested areas such as Vancouver Island, Canada, are important to blue grouse. Logging activity and fire in the low to mid-elevations can open up the forest canopy which may improve breeding habitat.

Cade (1984) recommended using clearcuts smaller than 250 m (820 ft) across and leaving at least 40 trees/ha (16 trees/ac) that have a minimum 24 cm (9 in) diameter on wintering areas. Selective cuts or long rotations greater than 60 years are also better for wintering blue grouse than clearcuts (Cade and Hoffman 1990). Winter roost areas should be retained, including mature, mistletoe-laden Douglas fir thickets near ridges (R. McKeel, personal communication; M. Quinn, personal communication).

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KEY POINTS

Habitat Requirements

- Blue grouse use open, low- to mid- elevation forests for breeding areas. They can be found in close association with streams, springs, and meadows.
- Forest openings <250 m (820 ft) best allow for blue grouse movement across them.
- Areas where vegetation is comprised of 11-40% broadleaf plants (forbs) are preferred.
- Rangeland with vegetation averaging 20 cm (8 in) tall provides brood rearing habitat from May through August.
- Broods use areas with high plant density and diversity and high canopy coverage.
- Insects are an important food source for very young chicks (<10 days old).
- Needles from true fir (*Abies* spp.) and Douglas fir (*Pseudotsuga menziesii*) are an important food source.
- Blue grouse winter in true fir and Douglas fir forests at higher elevations.

Management Recommendations

- Streams, springs, and wet meadows should be safeguarded from potential damage due to livestock grazing and logging operations. Lush vegetation, shrubs, and deciduous trees associated with such areas should be retained for blue grouse brooding and feeding habitat.
- Grazing should be light so that an effective height of 20 cm (8 in) for grasses and forbs is maintained from May through August, or grazing should be postponed until after 1 August.
- Timber harvest in areas known to contain wintering or breeding blue grouse should be restricted to selective cutting or clearcuts smaller than 250 m (820 ft).
- At least 40 trees/ha (16/ac) with diameters >24 cm (9 in) should be left standing when timber harvest occurs in areas inhabited by blue grouse.
- Revegetation efforts should aim for a high percentage of forbs and a variety of trees rather than single plantings that include 1 or 2 species.
- Known winter roosts should be retained, including mature Douglas fir thickets near ridges.



Sharp-tailed Grouse

Tympanuchus phasianellus

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GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sharp-tailed grouse (*Tympanuchus phasianellus*) were originally found throughout substantial portions of central and western North America, including a large portion of Canada and Alaska (Hays et al. 1998). Although there are 6 subspecies of sharp-tailed grouse in North America, only the Columbian subspecies (*T. p. columbianus*) is found in Washington. Columbian sharp-tailed grouse were originally distributed in shrub-steppe, steppe, and meadow-steppe habitats from southern British Columbia, through northeastern California, Utah, Colorado, Wyoming and western Montana (Yocom 1952, Jewett et al. 1953, Aldrich and Duvall 1955, Aldrich 1963, Daubenmire 1970).

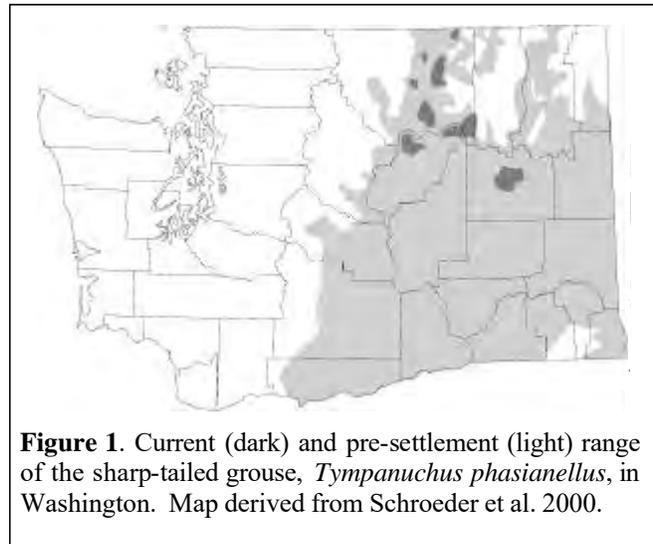


Figure 1. Current (dark) and pre-settlement (light) range of the sharp-tailed grouse, *Tympanuchus phasianellus*, in Washington. Map derived from Schroeder et al. 2000.

The current range of sharp-tailed grouse in Washington is restricted to eight small, isolated populations in the north-central portion of the state (see Figure 1; Washington Department of Fish and Wildlife 1995, Hays et al. 1998, Schroeder et al. 2000). The largest of these remaining populations is near the Swanson Lakes Wildlife Area in Lincoln County, Nespelem in Okanogan County, and the Tunk-Siwash valleys in the Okanogan River valley (Schroeder et al. 2000). Sporadic sightings outside these primary distribution areas have been reported in Lincoln, Douglas, Okanogan and Asotin counties (Schroeder et al. 2000). Sharp-tailed grouse management areas are currently being designated by the Department of Fish and Wildlife that include portions of Okanogan, Lincoln, Douglas, Chelan and Grant counties (Stinson, in preparation; see also Washington Department of Fish and Wildlife 1995).

RATIONALE

The Columbian sharp-tailed grouse was petitioned for federal listing as a threatened or endangered species under the Endangered Species Act, but the petition was rejected by the U.S. Fish and Wildlife Service after it was determined that populations in southeastern Idaho, north-central Utah, and northwestern Colorado were relatively robust (Warren 2000). Although the sharp-tailed grouse is classified as a game species in Washington, hunting was suspended in 1988 (Washington Department of Fish and Wildlife 1995); the grouse is currently listed as a state-threatened species (Hays et al. 1998). The distribution of sharp-tailed grouse in Washington has severely decreased

since pre-settlement times due to the conversion of native habitat to cropland and to the degradation and fragmentation of remaining shrub- and grass-dominated habitats (Schroeder et al. 2000). Approximately 76% of Washington's sharp-tailed grouse habitat has been lost to conversion since the late 1800s (Schroeder et al. 2000). Protection and enhancement of remaining habitats is critical to the long-term management and survival of this species in Washington (Washington Department of Fish and Wildlife 1995).

HABITAT REQUIREMENTS

General Vegetation

Sharp-tailed grouse depend on grass-dominated habitats intermixed with patches of deciduous trees and shrubs for food and cover throughout the year (Connelly et al. 1998). In Washington, sharp-tailed grouse were historically associated with shrub-steppe, steppe, and meadow-steppe (hereafter referred to collectively as shrub-steppe), riparian, and mountain shrub habitats (Daubenmire 1970, Zeigler 1979, Giesen and Connelly 1993, Schroeder et al. 2000). Sharp-tailed grouse habitat is characterized by a high diversity and quantity of shrubs including common chokecherry (*Prunus virginiana*), bittercherry (*Prunus emarginata*), water birch (*Betula occidentalis*), serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos* spp.), hawthorn (*Crataegus* spp.), wild rose (*Rosa* spp.), aspen (*Populus tremuloides*), big sagebrush (*Artemisia tridentata*), three-tipped sagebrush (*Artemisia tripartita*), and antelope bitterbrush (*Purshia tridentata*) (Washington Department of Fish and Wildlife 1995). Herbaceous vegetation often includes bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* spp.), yellow salsify (*Tragopogon dubius*), milkvetch (*Astragalus* spp.), and yarrow (*Achillea* spp.) (Jones 1966, Zeigler 1979, Oedekoven 1985, Marks and Marks 1988, Meints 1991, Washington Department of Fish and Wildlife 1995).

Breeding Display Grounds (leks)

During spring, males congregate on display sites (leks) to breed with females (Connelly et al. 1998). Leks are typically located on knolls and ridges with relatively sparse vegetation (Hart et al. 1952, Rogers 1969, Oedekoven 1985). Leks are typically surrounded by nesting habitat, often outward from the lek to a distance of about 2 km (1.2 mi) (Marks and Marks 1988, Giesen and Connelly 1993). There is no evidence that lek habitat is limiting, especially because males have been observed displaying on a variety of sites that comprise a range of plant conditions (e.g., croplands, roads, native rangelands grazed by livestock) (Hays et al. 1998).

Nesting and Brood Rearing

Sharp-tailed grouse are ground nesters, preferring relatively dense cover provided by clumps of shrubs, grasses and/or forbs (Ammann 1963, Hillman and Jackson 1973, Meints et al. 1992). Residual grasses and forbs from the previous year's growth are particularly important for concealment and protection of nests and broods (Hart et al. 1952, Parker 1970, Zeigler 1979, Oedekoven 1985, Meints et al. 1992, Giesen and Connelly 1993, Hays et al. 1998). In research studies, visual obstruction readings (VOR; i.e., quantitative measure of vertical plant cover) were found to be greater at nest sites than at random sites (Kobriger 1980, Marks and Marks 1987, Meints 1991, McDonald 1998).

In Washington, McDonald (1998) found that litter cover, bare ground, and visual obstruction differed between nest and random sites within 5 meters of nests. Litter cover and visual obstruction were significantly greater at nest sites, while bare ground was significantly less at nest sites. McDonald (1998) found VOR readings of 24 cm (9.5 in) within 5 m (20 ft) of all nests, and successful nest sites had higher VOR readings than unsuccessful nests (28 cm vs. 23 cm). In addition, litter cover at successful nest sites was greater than 80 percent.

Fields enrolled in agricultural set-aside programs (e.g., federal Conservation Reserve Program [CRP]) are often used by nesting grouse (Sirotiak et al. 1991, McDonald 1998, Schroeder et al. 2000). After eggs hatch, hens with broods move to areas where succulent vegetation and insects can be found (Hamerstrom 1963, Bernhoft 1967, Sisson 1970,

Gregg 1987, Marks and Marks 1987, Klott and Lindzey 1990). In late summer, riparian areas and mountain-shrub communities are preferred (Giesen 1987).

Winter

Throughout winter, patches of deciduous trees and shrubs in upland and riparian areas provide food and protective cover (Zeigler 1979, Oedekoven 1985, Marks and Marks 1988, Meints 1991, Giesen and Connelly 1993). Although sharp-tailed grouse will feed on cultivated grain crops in Washington, deciduous shrubs and trees (e.g., water birch) appear to be critical when snow conditions are such that access to wheat is restricted (Zeigler 1979).

Food

Food items consumed by sharp-tailed grouse in spring and summer include wild sunflower (*Helianthus* spp.), common chokecherry, sagebrush, serviceberry, salsify, dandelion (*Taraxacum* spp.), bluegrass (*Poa* spp.), and brome (*Bromus* spp.) (Marshall and Jensen 1937, Hart et al. 1952, Jones 1966, Parker 1970). Although juvenile and adult grouse consume insects, chicks consume the greatest quantity of insects during the first few weeks of life (Parker 1970). The fruits, seeds, and buds of deciduous trees and shrubs (e.g., chokecherry, serviceberry, snowberry, wild rose, hawthorn, aspen, and water birch) and wheat and corn where available, are consumed throughout the winter (Marshall and Jensen 1937, Buss and Dziedzic 1955, Marks and Marks 1988, Giesen and Connelly 1993).

LIMITING FACTORS

The conversion of native shrub-steppe habitat to cropland over most of the pre-settlement range of sharp-tailed grouse is the primary cause of long-term population declines (Buss and Dziedzic 1955, Hays et al. 1998, Schroeder et al. 2000). Grassland habitat has decreased from 25% of the eastern Washington landscape to 1%, while shrub-steppe has decreased from 44% to 16% (McDonald and Reese 1998). Remaining areas of suitable habitat are relatively small and highly fragmented. Within the currently occupied range of sharp-tailed grouse, the degradation, removal and fragmentation of winter habitat appears to be the most significant limiting factor (Hays et al. 1998). Specific management concerns include grazing, removal of native shrubs and trees in riparian and mountain shrub communities, urban development, orchard development, fire, and permanent flooding of historic wintering habitat by dams along the Columbia River system (Oedekoven 1985, Giesen 1987, Marks and Marks 1987, Washington Department of Fish and Wildlife 1995, Connelly et al. 1998, Schroeder et al. 2000).

MANAGEMENT RECOMMENDATIONS

Conversion of Shrub-Steppe

Most of the remaining shrub-steppe habitats are characterized by relatively shallow soil; hence, they are usually undesirable for crop production (Dobler et al. 1996, Jacobson and Snyder 2000, Vander Haegen et al. 2001). Nevertheless, additional conversion of shrub-steppe habitat for development and/or crop production within sharp-tailed grouse management areas should be discouraged (Washington Department of Fish and Wildlife 1995). The retention of remaining shrub-steppe in Douglas, Lincoln and Okanogan counties is especially important (Washington Department of Fish and Wildlife 1995).

Vegetation Removal

Vegetation removal should be discouraged within 2 km (1.2 mi) of active or potential lek sites, especially during the breeding season (Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). In some cases, limited sagebrush treatment that improves the productivity and diversity of desirable grasses, forbs, and shrubs, with careful pre-treatment assessment and post-treatment management, might be considered (Washington Department of

Fish and Wildlife 1995). Deciduous shrubs and trees in sharp-tailed grouse habitat should be retained (Giesen and Connelly 1993). In addition, manipulation of vegetation that reduces or disturbs riparian habitats should not occur within 100 m (328 ft) of streams, including dry and intermittent streams (Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). Vegetative cover should be maintained at a visual obstruction reading of 24 cm (9.5 in) within nesting habitat (McDonald 1998).

Fire

Controlled burning should not be considered for any type of sharp-tailed grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high (Washington Department of Fish and Wildlife 1995). Any fire plan should carefully consider the potential spread of weeds and exotic annuals, loss of sagebrush, response of existing vegetation to different fire intensities and seasons, and the conditions of adjacent lands (Washington Department of Fish and Wildlife 1995). Fire can be used to improve grassland habitat and control invasion by conifer species (Giesen and Connelly 1993, Hays et al. 1998). Livestock control following planned burns and wildfires is essential to permit the establishment of native shrubs and herbaceous vegetation (Brown 2000). Because the availability of critical wintering habitat is likely the most significant limiting influence on sharp-tailed grouse (Washington Department of Fish and Wildlife 1995), any burning conducted in wintering habitat should be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season.

Grazing and Browsing

Large herbivores (wild and domestic) can significantly influence and alter plant community composition and structure to varying degrees among different ecosystems (Daubenmire 1940, Augustine and McNaughton 1998, Opperman and Merenlender 2000). The forbs and bunchgrasses native to shrub-steppe in Washington are most likely not adapted to severe grazing because large grazing animals were presumably not present in large numbers for several thousand years prior to the introduction of domestic livestock (Mack and Thompson 1982, Lyman and Wolvertson 2002).

Over-grazing (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community) is often detrimental to sharp-tailed grouse habitat (Yocom 1952, Sisson 1970, Zeigler 1979, Klott and Lindzey 1990, Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). Management for sharp-tailed grouse habitat should be conducted to establish a relatively lush composition of perennial bunchgrasses and forbs (McDonald 1998), and grazing management should maintain habitat in good to excellent ecological condition as defined by the Natural Resources Conservation Services technical guidelines (Ulliman et al. 1998). In shrub-steppe habitats, it is difficult to provide acceptable levels of visual obstruction in nesting and brood-rearing habitats with more than light grazing (Sisson 1976, McDonald 1998). Consequently, light grazing: $\leq 25\%$ removal of annual herbaceous growth; [Holechek et al. 1999, Galt et al. 2000]) or no grazing may be necessary for habitat improvement (McDonald 1998). It is especially important that these levels of grazing not be exceeded in areas where habitat restoration is the objective (Galt et al. 2000), during drought years (Holechek et al. 2003), and/or following fires (Brown 2000).

Light grazing combined with rest rotation on a yearly basis may be compatible with sharp-tailed grouse management (Giesen and Connelly 1993). No grazing may be necessary where the habitat has been previously degraded and habitat restoration is the goal (Kirsch et al. 1973, McDonald 1998). Cattle can also harm nests through trampling (McDonald 1998). McDonald (1998) recommends deferring grazing until July (after the nesting season) in sharp-tailed grouse habitat in Washington. Livestock use of riparian areas should be managed or eliminated to minimize the loss of associated shrubs and trees (Giesen and Connelly 1993, Paulson 1996). Grazing is discouraged in areas where encroachment by noxious weeds is a problem. If necessary, wildlife resource agencies may consider means of reducing the impacts of wild ungulates on grouse habitat that might include the alteration of supplemental feeding programs, adjustments to hunting regulations, and temporary fencing.

Biological soil crusts are a common feature of many shrub-steppe plant communities, particularly in the lowest precipitation zones (Belnap et al. 2001). Biological crusts are comprised of lichens, mosses, cyanobacteria, green algae, microfungi, and other bacteria that might indirectly benefit grouse through aiding nitrogen fixation of plants, increasing the nutrient value of plants, increasing native plant germination rates, and by inhibiting the expansion of exotic species including cheatgrass (Belnap et al. 2001; J. Belnap, personal communication). These organisms form a living soil crust that is easily damaged by grazing (Daubenmire 1940, Mack and Thompson 1982, Belnap et al. 2001). Belnap et al. (2001) describes grazing practices that can help reduce damage to biological soil crusts. Although most soil crust studies were conducted in more arid environments, precipitation levels in some of these studies rival the drier areas of eastern Washington. Research is needed to fully understand the ecological function, impacts of disturbance, and the means to reduce impacts to biological crusts in eastern Washington's shrub-steppe.

Chemical Treatments

Herbicides and insecticides may negatively affect sharp-tailed grouse habitat by removing forbs and deciduous shrubs used for cover and by eliminating insects used for food (Oedekoven 1985, Hays et al. 1998). Land managers should be encouraged to use integrated pest management that targets specific pests or noxious weeds, to use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on alternatives such as integrated pest management, contact the county Washington State University Cooperative Extension Service or the USDA Natural Resource Conservation Service. Additional contacts are found in Appendix A.

Human Disturbance

All mechanical, physical and audible disturbances should be avoided during the breeding season (March through June) within 2 km (1.2 mi) of active lek sites (Giesen and Connelly 1993). Wind turbines should not be located in habitat known to be occupied by sharp-tailed grouse because this species avoids vertical structures and is sensitive to habitat fragmentation (U.S. Fish and Wildlife Service 2003). In known grouse habitat, avoid placing turbines within 8 km (5 mi) of known leks (U.S. Fish and Wildlife Service 2003). Viewing and censusing sharp-tailed grouse leks should be conducted in a way that minimizes disturbance of birds. If public interest in viewing leks is high, agencies should consider providing and supervising viewing opportunities, perhaps with specific viewing blinds. If public use appears to be impacting breeding behavior, closures and/or timing restrictions may be necessary on public lands.

Predation

Predator management should include the use of facilities that minimize perching by raptors (e.g., perch guards; Bureau of Land Management et al. 2000), removal of artificial nest sites for predators such as the common raven (*Corvus corax*), and control of dumps and/or livestock feeding stations that may concentrate and/or enhance predator populations (Washington Department of Fish and Wildlife 1995). Raptor-proofing techniques might include placing power-lines underground, covering horizontal surfaces (e.g., ledges) and other structures with steeply angled slanting boards or sheets metal, or placing low-voltage, electrically charged wires over perching structures. Because sharp-tailed grouse rely on grass and shrub cover for concealment from predators, activities that reduce tall residual grass and shrubs, especially in nesting areas, should be avoided (Giesen and Connelly 1993). In general, management that retains or produces good quality grouse habitat should be used as the most cost-effective tool for minimizing the negative effects of predation (Schroeder and Baydack 2001).

Conservation and Restoration

Research has shown that sharp-tailed grouse depend on deciduous trees/shrubs for winter food and that the lack of winter habitat may be a limiting factor in some areas (Marks and Marks 1988, Giesen and Connelly 1993, Schroeder et al. 2000). Therefore, planting appropriate vegetation in suitable sites (e.g., along streams, draws, or springs), preferably within 6.5 km (4 mi) of actual or potential breeding habitat (Meints et al. 1992) should occur in areas marked for conservation or restoration. These considerations should be included in the guidelines for future agricultural set-aside and/or conservation programs (such as CRP). Recommended deciduous shrub and tree species include water birch, aspen, chokecherry, hawthorn, snowberry and serviceberry (Washington Department of Fish and Wildlife 1995). Management practices to rejuvenate or increase mountain shrub communities within breeding complexes should be restricted to $\leq 25\%$ of this cover type annually. Shrub-steppe restoration and enhancement in areas where this native habitat has been removed (e.g., croplands) or degraded may benefit sharp-tailed grouse (Washington Department of Fish and Wildlife 1995). Restoration would include seeding with a combination of native shrubs, perennial forbs and bunchgrasses. Land management should also include the control of noxious weeds that compete with native vegetation.

Agricultural set-aside programs (such as the Conservation Reserve Program, Grassland Reserve Program) in sharp-tailed grouse areas should be supported (Washington Department of Fish and Wildlife 1995). The set aside programs should be structured to promote growth of a diversity of perennial bunchgrasses and forbs, annual retention of residual cover, and restoration of deciduous shrubs (Hays et al. 1998, Boisvert 2002). The use of species of limited habitat value like smooth brome (*Bromopsis inermis*) and intermediate/pubescent wheatgrass (*Thinopyrum intermedium*) should be discouraged (Boisvert 2002, A. Sands personal communication).

Local and regional government programs should be reviewed to ensure they address long-term conservation of sharp-tailed grouse populations and habitat. Specifically, critical areas protection that falls under Washington's Growth Management Act are intended to protect State Threatened, Endangered and Sensitive species and can be an effective conservation tool. Local development regulations could require mitigation standards and provide incentives to reduce impacts from projects that potentially affect sharp-tailed grouse habitat. Many resource agencies, including Washington Department of Fish and Wildlife, have staff that can provide assistance in critical areas planning.

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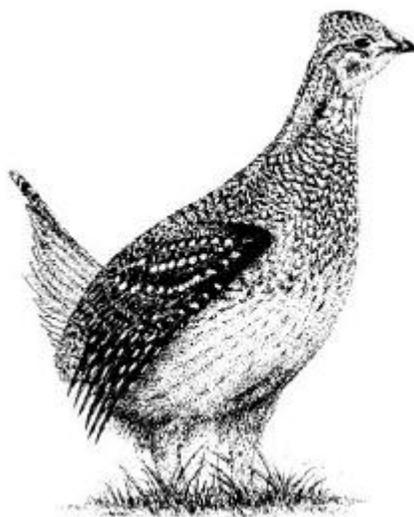
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KEY POINTS

Habitat Requirements

- Sharp-tailed grouse occupy a variety of habitats in eastern Washington, including steppe, meadow-steppe, shrub-steppe, riparian, and mountain shrub.
- Buds, seeds, and fruits of chokecherry, serviceberry, snowberry, wild rose, hawthorn, aspen, and water birch are important winter food species for sharp-tailed grouse.
- Residual perennial bunchgrasses and forbs are the preferred nesting habitat of sharp-tailed grouse. Residual herbaceous growth from the previous growing season is a necessary component of sharp-tailed grouse nesting habitat.
- Sharp-tailed grouse depend on grass-dominated habitats intermixed with patches of deciduous trees and shrubs for food and cover throughout the year.

Management Recommendations

- Vegetation manipulation should be avoided (herbicide application, burning, mechanical treatment) for reasons other than sharp-tailed grouse habitat improvement within 2 km (1.2 mi) of active or potential lek sites, within 100 m (328 ft) of streams, or within winter habitat.
- Conversion of shrub-steppe habitat should be avoided within sharp-tailed grouse management areas.
- Vegetative cover should be maintained at a visual obstruction reading of 24 cm (9.5 in) within nesting habitat.
- Controlled burning should be avoided within any type of sharp-tailed grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high.
- Grazing management that improves and/or maintains habitat in good to excellent condition should be supported.
- Light grazing levels ($\leq 25\%$ removal of annual herbaceous growth) or cessation of grazing to improve habitat conditions should be maintained.
- Grazing should be managed or eliminated within riparian areas to minimize the loss of associated shrubs and trees.
- Herbicide and insecticide use should be discouraged where sharp-tailed grouse occur, and encourage the use of integrated pest management.
- All physical and audible disturbances should be avoided from March through June within 2 km (1.2 mi) of active lek sites.
- Native shrubs and perennial native forbs and bunchgrasses should be reseeded to restore sharp-tailed grouse habitat.
- Land managers should control noxious weeds and prevent noxious weed encroachment in suitable sharp-tailed grouse habitat.
- The use of agricultural set aside programs (e.g., Conservation Reserve Program, Grassland Reserve Program) should be supported in sharp-tailed grouse areas dominated by cropland.



Greater Sage-Grouse

Centrocercus urophasianus

Last updated: 2003

Written by Michael A. Schroeder, Derek Stinson and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Greater sage-grouse (*Centrocercus urophasianus*) are closely tied to the distribution of big sagebrush (*Artemisia tridentata*) throughout much of their range (Schroeder et al. 1999). Prior to settlement by people of European descent, sage-grouse were distributed from southern British Columbia, Alberta, and Saskatchewan to eastern California, northern Arizona, and western portions of Oklahoma, Kansas, Nebraska, South Dakota and North Dakota. The core of the distribution was in Washington, Oregon, Nevada, Idaho, Utah, Colorado, Wyoming and Montana. The newly described Gunnison sage-grouse (*Centrocercus minimus*) was found primarily in northwestern New Mexico, southeastern Utah, and southwestern Colorado (Young et al. 2000).

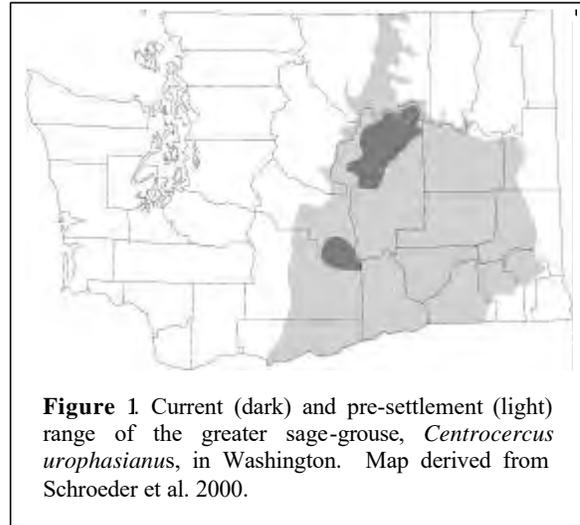


Figure 1. Current (dark) and pre-settlement (light) range of the greater sage-grouse, *Centrocercus urophasianus*, in Washington. Map derived from Schroeder et al. 2000.

Sage-grouse historically occurred throughout the shrub-steppe and meadow-steppe (hereafter referred to collectively as shrub-steppe) communities of eastern Washington (Yocom 1956, Schroeder et al. 2000). They were observed in abundance in 1805 by members of the Lewis and Clark expedition near the confluence of the Columbia and Snake Rivers (Zwickel and Schroeder 2003). Currently, the state has two relatively isolated breeding populations; one in Douglas-Grant Counties (. 650 grouse), and one in Kittitas-Yakima Counties (. 350 grouse) (see Figure 1; M. Schroeder, personal observation). Sporadic sightings outside the primary distribution have been reported in Benton, Yakima, Kittitas, Grant, Lincoln and Okanogan Counties. Sage-grouse management areas are currently being mapped and include portions of Yakima, Kittitas, Benton, Grant, Douglas, Lincoln and Okanogan Counties (Stinson, in preparation; see also Washington Department of Fish and Wildlife 1995).

RATIONALE

Greater sage-grouse in the state of Washington became a candidate for federal listing as threatened under the Endangered Species Act after a recent petition for listing precipitated a status review (Warren 2001). Although the sage-grouse is classified as a game species in Washington, hunting was terminated in 1988 (Washington Department of Fish and Wildlife 1995); they currently are listed as a state-threatened species (Hays et al. 1998). The distribution of sage-grouse in Washington has been dramatically reduced since pre-settlement times due to the conversion of shrub-steppe to cropland, and the degradation and fragmentation of the remaining habitat (Schroeder et al. 2000). Conserving, restoring and enhancing remaining habitat is critical to the survival of this species (Washington Department of Fish and Wildlife 1995).

HABITAT REQUIREMENTS

General Vegetation

Sage-grouse depend on sagebrush (*Artemisia* spp.), primarily big sagebrush, for food and cover throughout the year in Washington (Schroeder et al. 1999). Other important cover species include threetip sagebrush (*Artemisia tripartita*), stiff sagebrush (*Artemisia rigida*), rabbitbrush (*Chrysothamnus* spp.), bitterbrush (*Purshia tridentata*) and gray horsebrush (*Tetradymia canescens*) (Washington Department of Fish and Wildlife 1995). Common grasses and forbs include Sandberg bluegrass (*Poa sandbergii*), bluebunch wheatgrass (*Pseudoroegneria spicata*), needle-and-thread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), Idaho fescue (*Festuca idahoensis*), prickly lettuce (*Lactuca serriola*), yellow salsify (*Tragopogon dubius*), milkvetch (*Astragalus* spp.), and microseris (*Microseris* spp.). Relatively dense shrub cover is important during winter and, and a combination of shrub, grass, and forb cover is important during the nesting season (Connelly et al. 2000).

Breeding Display Grounds (leks)

During spring, males congregate on display sites (leks) to breed with females (Schroeder et al. 1999). Leks are typically located in open areas near relatively dense stands of sagebrush (> 20% canopy coverage) used for food and escape cover (Dalke et al. 1963, Autenrieth 1981, Emmons and Braun 1984, Roberson 1984, Klebenow 1985). In north-central Washington, most documented leks are in wheatfields (M. Schroeder, personal observation). Sage-grouse leks are often located near nesting areas (Wallestad and Pyrah 1974, Berry and Eng 1985, Connelly et al. 1988, Gibson 1996). The typical distance between nests and the nearest leks ranges from 1.3 to 3.4 km (0.8 to 2.1 mi) (Wallestad and Pyrah 1974, Petersen 1980, Autenrieth 1981, Wakkinen et al. 1992, Fischer et al. 1993). In the fragmented shrub-steppe of eastern Washington, the nest-lek distance averages 5.1 km (3.2 mi) (Schroeder 1994). Typical characteristics of productive habitat are 15-25% sagebrush coverage in both arid and mesic (moist) sites; $\geq 15\%$ perennial grass/forb cover on arid site; $\geq 25\%$ perennial grass/forb cover on mesic sites (Connelly et al. 2000). Grass/forb cover tends to be higher in Washington (Schroeder 1994, Sveum et al. 1998a).

Nesting and Brood Rearing

Sage-grouse commonly nest in habitat containing sagebrush approximately 30-80 cm (12-31 in) in height, and relatively tall (>20 cm [8 in]), dense (> 40% grass and forb cover) herbaceous cover (Gray 1967, Wallestad and Pyrah 1974, Crawford and DeLong 1993, Gregg et al. 1994, Schroeder 1995, Sveum 1995, Connelly et al. 2000, Livingston and Nyland 2002). Although sage-grouse prefer to nest under sagebrush, they will nest under other plant species (Klebenow 1969, Wallstad and Pyrah 1974, Connelly et al. 1991). Nest success is directly related to higher horizontal and vertical cover at the nest site (Wallestad and Pyrah 1974, Gregg 1991, Connelly et al. 2000). In Washington, sage-grouse select nest sites that contain thicker and taller vegetation as opposed to other regions (Schroeder 1994, Sveum et al. 1998a). At the Yakima Training Center, Livingston and Nyland (2002) found that at the site level, females usually selected shrubs that provided overhead nest concealment and were surrounded by heavy bunchgrass cover >18 cm (7 in) in height.

Broods prefer open sagebrush-dominated habitats with an abundance of insects and succulent forbs (Klebenow 1969, Peterson 1970, Wallestad 1975, Klott and Lindzey 1990, Drut et al. 1994, Sveum et al. 1998b). As plants mature and dry, hens move their broods to habitats with green vegetation such as wet meadows, irrigated farmland or areas at higher elevations (Oakleaf 1971, Connelly et al. 1988, Klott and Lindzey 1990, Fischer et al. 1996, Connelly et al. 2000). Brood habitats in Washington also include areas enrolled in the federal Conservation Reserve Program (Conservation Reserve Program unpublished data).

Winter

Sagebrush provides escape cover and a majority of the dietary requirements for sage-grouse in winter (Connelly et al. 2000). They prefer sagebrush ≥ 25 cm (10 in) high above the ground or snow, with 10-30% canopy coverage (Eng and Schladweiler 1972, Wallestad and Schladweiler 1974, Wallestad 1975, Autenrieth 1981, Connelly et al. 2000). Good wintering areas are found at a variety of elevations, and include windswept ridges and sagebrush flats (Eng and Schladweiler 1972, Wallestad and Schladweiler 1974, Wallestad 1975, Autenrieth 1981). Winter habitat selection is often dependent on snow-depth (Hays et al. 1998). During winter, Robertson (1991) reported that migratory sage-grouse in southeastern Idaho made average daily movements of 752 m (2467 ft) and occupied an area >140 km² (54 mi²). Wallestad (1975) reported that winter home range size varied between 11 and 31 km² (4-12 mi²) in Montana.

Food

Sagebrush is a crucial component of the sage-grouse diet year-round, particularly during late autumn, winter and early spring (Remington 1983, Remington and Braun 1985, Welch et al. 1988, 1991; Myers 1992). Forbs are important food items for sage-grouse during spring, summer and early autumn; especially for hens prior to egg laying (Wallestad et al. 1975, Barnett and Crawford 1994, Drut et al. 1994). Pre-laying hens require a diet of forbs rich in calcium, phosphorus and protein in order to produce healthy clutches (Barnett and Crawford 1994). Thus, the condition of breeding habitats used by pre-laying hens plays an important role in overall reproductive success (Barnett and Crawford 1994, Coggins 1998).

Broods feed heavily on insects during their first weeks of life (Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990, Drut et al. 1994, Pyle and Crawford 1996). As chicks grow, they eat more forbs, gradually switching to a diet that consists primarily of forbs (Peterson 1970). Forbs consumed include desert parsley (*Lomatium* spp.), hawksbeard (*Crepis* spp.), prickly lettuce, common dandelion (*Taraxacum officinale*), mountain dandelion (*Agoseris* spp.), western yarrow (*Achillea millefolium*), pale agoseris (*Agoseris glauca*), clover (*Trifolium* spp.), yellow salsify, everlasting (*Antennaria* spp.), vetch (*Vicia* spp.), milkvetch, alfalfa (*Medicago sativa*), aster (*Aster* spp.) and long-leaf phlox (*Phlox longifolia*) (Wallestad et al. 1975, Drut et al. 1994, Barnett and Crawford 1994). The availability of forbs and insects influences sage-grouse chick survival (Johnson and Boyce 1991).

LIMITING FACTORS

In Washington, the lack of extensive good quality shrub-steppe vegetation limits sage-grouse (Washington Department of Fish and Wildlife 1995, Hays et al. 1998, Schroeder et al. 2000). Habitat loss, degradation and fragmentation of shrub-steppe can be attributed to land conversion, development, grazing, sagebrush removal and burning, erosion, mining, military activity, noise, power lines and roads (Klebenow 1972, Braun 1986, Swenson et al. 1987, Hofmann 1991, Remington and Braun 1991, Washington Department of Fish and Wildlife 1995, Schroeder et al. 2000).

MANAGEMENT RECOMMENDATIONS

Conversion of Shrub-Steppe

The reduction in sage-grouse numbers and distribution is primarily attributed to the loss, fragmentation, and degradation of shrub-steppe habitat through land conversion and mismanagement (Braun 1998). Most of the remaining shrub-steppe habitats are characterized by relatively shallow soil; hence they are usually undesirable for crop production (Dobler et al. 1996, Jacobson and Snyder 2000, Vander Haegen et al. 2000). Nevertheless, further conversion of shrub-steppe habitat within sage-grouse management areas should be strongly discouraged (Washington Department of Fish and Wildlife 1995). Despite the importance of shrub-steppe to many declining Species of Concern, conversion of shrub-steppe habitat on public and private lands is continuing (Hays et al. 1998). Conservation of shrub-steppe habitat in and around croplands in Douglas County is also extremely important because these sites are a source of sagebrush seed that germinate on the extensive lands that are enrolled in the Federal Conservation Reserve Program in this county (Hays et al. 1998).

Sagebrush Alteration

Removal or alteration of sagebrush should be avoided within sage-grouse management areas, particularly near leks, brood-rearing and in nesting and wintering areas (Connelly et al. 2000). Sage-grouse depend upon sagebrush stands for most of their life needs throughout the year, therefore sagebrush should not be eradicated (Connelly et al. 2000). Sagebrush should not be removed within 300 m (984 ft) of sage-grouse foraging sites along riparian areas, meadows, lakes, and farmlands (Connelly et al. 2000). Sagebrush removal should not occur where live sagebrush cover is <25% in nesting areas, and <30% in wintering areas (Connelly et al. 2000). Sagebrush should also not be controlled on slopes $\geq 20\%$ and/or on slopes with shallow soils where big sagebrush is <30 cm (12 in) in height (Call and Maser 1985). Anyone planning to remove sagebrush should carefully consider the method of removal (fire, mechanical means, herbicides), amount removed, species removed, post-removal management, mitigation measures, and the effects on the sage-grouse population (see references in contact section for assistance).

Fire

Wildfires pose a substantial threat to sage-grouse in Washington and occupied habitat should be a high priority for fire suppression and prevention (Connelly et al. 2000). Prescribed fire has been used to reduce sagebrush that in turn increases grass and forb cover (Pyle and Crawford 1996). However, Wambolt et al. (2002) pointed out that there is no empirical evidence demonstrating the benefits of fire to sage-grouse.

Where fire is used as a management tool to restore potential habitat, controlled burns are recommended in late April to early May when fuels left from the prior growing season are able to carry a relatively cool fire (Autenrieth 1981). These prescribed fires should be ≤ 50 ha in size and cover less than 20% of an area used by sage-grouse during winter within any 20–30 year interval (depending on estimated recovery time for the sagebrush habitat) (Connelly et al. 2000). Because the availability of critical wintering habitat is likely the most significant limiting influence on sage-grouse, any burning conducted in wintering habitat should only be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season (Connelly et al. 2000). Avoid using fire without including plans to control cheatgrass competition in the understory (e.g., through the use of a pre-emergent herbicide [e.g., Oust[®], Plateau[®]]) where an increase of or an invasion by cheatgrass (*Bromus tectorum*) is likely (Connelly et al. 2000). Annual grassland establishment following fire is very detrimental to sagebrush habitat integrity (Young and Longland 1996). In addition, habitat recovery following a fire may require several decades before sagebrush regrowth is sufficient to support sage-grouse (Connelly et al. 2000). Changes in livestock management (e.g., exclusion, change in season and/or intensity of use) following planned burns and wildfires is essential to the reestablishment of native shrubs and forbs (Beck and Mitchell 2000).

Fire should not be used in breeding habitat dominated by Wyoming big sagebrush (Connelly et al. 2000). Controlled burning should not be considered for any type of sage-grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high (Washington Department of Fish and Wildlife 1995).

Grazing and Browsing

Livestock grazing has been a common use of shrub-steppe lands within the range of sage-grouse in Washington (Hays et al. 1998). Although it is difficult to document positive effects of livestock grazing on sage-grouse, the existence of healthy sage-grouse populations in areas long grazed suggests that certain grazing levels may be compatible with sage-grouse populations (Wambolt et al. 2002). Vegetation characteristics of sage-grouse breeding, brood-rearing, and winter habitats (Table 1) should be used as guidelines in developing livestock grazing management plans, but these plans should also consider the long-term sustainability of the habitat, the likelihood of drought, and the potential for expansion of noxious weeds.

Light grazing in sage-grouse habitat should be managed for optimum growth and reproduction of native sagebrush, forbs and grasses (Table 1) (Beck and Mitchell 2000). The type and stocking rates of livestock, season of use, and grazing duration should be carefully planned based on available forage resources, and monitored on a site specific basis, with the goal of providing optimal sage-grouse habitat (Beck and Mitchell 2000) and long-term sustainability. This is particularly important in nesting areas, where sage-grouse are dependent on residual cover for concealment from predators. During drought periods (≥ 2 consecutive years), it may be necessary to reduce stocking rates or change livestock management practices if herbaceous height requirements for cover (Table 1) during the nesting and brood-rearing periods are not met (Gregg et al. 1994, Sveum 1995, Connelly et al. 2000, Livingston and Nyland 2002).

Biological soil crusts are a common feature of many shrub-steppe plant communities, particularly in the lowest precipitation zones (Belnap et al. 2001). Biological crusts are comprised of lichens, mosses, cyanobacteria, green algae, microfungi, and other bacteria that might indirectly benefit grouse through aiding nitrogen fixation of plants, increasing the nutrient value of plants, increasing native plant germination rates, and by inhibiting the expansion of exotic species including cheatgrass (Belnap et al. 2001; J. Belnap, personal communication). These organisms form a living soil crust that is easily damaged by livestock grazing (Daubenmire 1940, Mack and Thompson 1982, Belnap et al. 2001). Belnap et al. (2001) describes grazing practices that can help reduce damage to biological soil crusts. Although most soil crust studies were conducted in more arid environments, precipitation levels in some of these studies rival the drier areas of eastern Washington. Research is needed to fully understand the ecological function, impacts of disturbance, and the means to reduce impacts to biological crusts in eastern Washington's shrub-steppe.

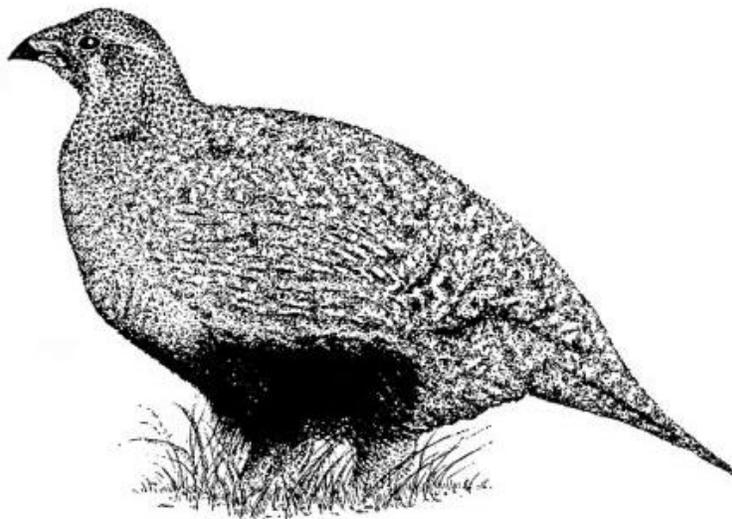


Table 1. Characteristics of sagebrush communities needed for productive sage-grouse habitat (Connelly et al. 2000).

	Breeding		Brood-rearing		Winter ^e	
	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Mesic (moist) sites ^a						
Sagebrush	40 – 80	15 – 25	40 – 80	10 – 25	25 – 35	10 – 30
Grass-forb	> 18 ^c	≥ 25 ^d	variable	> 15	N/A	N/A
Arid sites ^a						
Sagebrush	30 – 80	15 – 25	40 – 80	10 – 25	25 – 35	10 – 30
Grass-forb	> 18 ^c	≥ 15 ^d	variable	> 15	N/A	N/A
Area ^b	> 80		> 40		> 80	
Approximate period of use	late winter – late spring		late spring – early autumn		autumn – late winter	
General characteristics	Open areas surrounded by sagebrush.		Open sagebrush-dominated habitats with an abundance of insects/succulent forbs.		Areas that allow sagebrush access under various snow conditions.	

a. Mesic and arid sites should be defined on a local basis; annual precipitation, herbaceous understory, and soils should be considered (Tisdale and Hironaka 1981, Hironaka et al. 1983).

b. Percentage of seasonal habitat needed with indicated conditions.

c. Measured as “droop height”; the highest naturally growing portion of the plant.

d. Coverage should exceed 15% for perennial grasses and 10% for forbs; values should be substantially greater if most sagebrush has a growth form that provides little lateral cover (Schroeder 1995).

e. Values for height and canopy coverage are for shrubs exposed above snow.

Wild (as well as domestic) herbivores can significantly influence and alter plant community composition and structure to varying degrees among different ecosystems (Augustine and McNaughton 1998, Opperman and Merenlender 2000). The forbs and bunchgrasses native to shrub-steppe in Washington are not tolerant to intensive and prolonged grazing because large grazing animals were presumably not present in large numbers for several thousand years prior to the introduction of domestic livestock (Mack and Thompson 1982, Lyman and Wolverson 2002). In some instances, the exposure of sagebrush communities to deer (*Odocoileus* spp.) and elk (*Cervus elaphus*) browsing can suppress the production, germination and survival of sagebrush and increase the production of annual plant species (McArthur et al. 1988, Singer and Renkin 1995), potentially influencing grouse habitat. If necessary, wildlife resource agencies may consider means of reducing the impacts of wild ungulates on grouse habitat that might include altering supplemental feeding programs, adjusting hunting regulations, and temporary fencing.

The effects of livestock grazing on shrub-steppe vegetation largely depend on the timing, frequency, and intensity of grazing. Over-grazing (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community) should be discouraged within sage-grouse management areas (Washington Department of Fish and Wildlife 1995, Beck and Mitchell 2000, Connelly et al. 2000). Frequent heavy grazing (i.e., removal of >50% of current year’s growth) deteriorates the species composition and structure of native plant communities (Holechek et al. 1999). Although light grazing of healthy shrub-steppe may not cause habitat degradation (Klebenow 1981, Call and Maser 1985, Beck and Mitchell 2000), the intensity of grazing that is tolerable is not clear, but may be ≤ 25% utilization of the current year's growth of key forage species (Galt et al. 2000, Holechek et al. 2003). It is especially important that this level of grazing not be exceeded in areas where habitat restoration and maintenance is the objective (Galt et al. 2000), during drought years (Holechek et al. 2003), and/or following fires (Beck and Mitchell 2000). When habitat is degraded by over-grazing, recovery of the native plant community likely requires a dramatic reduction (if not a cessation) of grazing for a long period of time (Anderson and Inouye 2001). However, restoring severely altered habitat (e.g., area devoid of its native species and seed sources) often requires more than simply removing cattle to recover the native plant community (Bunting et al. 2002).

Chemical Treatments

Herbicides may be necessary to improve sage-grouse habitat where noxious weeds have replaced native vegetation (Washington Department of Fish and Wildlife 1995). Herbicide application should be followed with restoration efforts designed to enhance native vegetation or establish a desirable plant community. The herbicide 2,4-D should not be used for sagebrush control because its application results in a significant loss of native forbs (Call and Maser 1985). Tebuthiuron (e.g., Spike[®]) should not be used, except in small scale experiments, until it is demonstrated that it has no long-lasting impacts to sage-grouse habitat (Connelly et al. 2000).

Insecticides should not be applied to sage-grouse summer habitat, particularly organophosphorus and carbamate insecticides, which are highly toxic (Blus et al. 1989). Insects are the primary food source for young sage-grouse chicks, and insecticide use can be directly and indirectly detrimental to sage-grouse (Beck and Mitchell 2000).

Land managers should be encouraged to use integrated pest management that targets specific pests or noxious weeds, to use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on alternatives such as integrated pest management, contact your county Washington State University Cooperative Extension Service or the USDA Natural Resource Conservation Service. Additional contacts are found in Appendix A.

Human Disturbance

Disturbances should be minimized from mid-February through early June within breeding and nesting areas (Hofmann 1991). Although nesting areas have been generally defined as locations within 3.2 km (2 mi) of leks, recent studies suggest that many nests are >3 km (2 mi) from leks (Wallestad and Pyrah 1974, Autenrieth 1981, Connelly et al. 1988, Eberhardt and Hofmann 1991, Wakkinen et al. 1992, Schroeder 1994).

Viewing and censusing sage-grouse leks should be conducted in a way that avoids disturbing the birds (Call and Maser 1985). Agencies should not provide lek locations to people who wish to view birds without supervision (Connelly et al. 2000). If public interest in viewing leks is high, agencies should consider constructing viewing blinds at specific locations for public use (Connelly et al. 2000). Camping on or near active leks should not be permitted (Connelly et al. 2000). On the Yakima Training Center, vehicle activity has been shown to disturb sage-grouse in critical areas (e.g., leks) (Hays et al. 1998). Therefore, activity on roads traversing sage-grouse leks should be restricted during hours when birds are active (sunset - 3 hours after sunrise) during the lekking season.

Fences, utility wires, and other structures can be hazardous to flying grouse. New and existing fences should be made more visible with flagging or by other means, within 1 km (0.6 mi) of sage-grouse habitat (Connelly et al. 2000). Woven wire fences negatively influence sage-grouse because they cannot quickly fly or travel through them (Braun 1998). Utility wires can also create hazards for sage-grouse (Borell 1939). Wind turbines should not be located in habitat known to be occupied by sage-grouse because this species avoids vertical structures and is sensitive to habitat fragmentation (U.S. Fish and Wildlife Service 2003). In grouse habitat, avoid placing turbines within 8 km (5 mi) of known leks (U.S. Fish and Wildlife Service 2003). The expansion of roads near shrub-steppe habitat used by grouse leads to habitat loss and fragmentation, direct mortality (Braun 1998), and the spread of invasive weeds. Consequently, limitations should be placed on the expansion of roads within grouse habitat.

Predation

The establishment of red fox and other non-native predators should be prevented in sage-grouse habitat (Connelly et al. 2000). Avoid building tall structures that provide raptor perch sites, such as utility structures, within 3 km (1.9 mi) of sage-grouse habitat. If structures are unavoidable or already exist, they should be modified to discourage raptors from perching on them (Connelly et al. 2000). Raptor-proofing techniques might include, but are not limited to placing power-lines underground, covering horizontal surfaces (e.g., ledges) and other structures with steeply angled slanting boards or sheets metal or placing low-voltage, electrically charged wires over perching structures. Fences with adjacent pathways (e.g., trails, roads) negatively impact sage-grouse because they provide travel

corridors for potential predators (Braun 1998). Additionally, fences with wood posts provide perch sites for potential avian predators (Braun 1998).

Habitat alteration associated with grazing, drought, and wildfire may increase the rate of predation on juveniles, but this relationship is unclear and predation has not been identified as a major limiting factor for sage-grouse (Gregg et al. 1994, Connelly and Braun 1997, Schroeder and Baydack 2001). In general, management that retains or produces good quality grouse habitat should be used as the most cost-effective tool for minimizing the negative effects of predation (Schroeder and Baydack 2001).

Conservation and Restoration

Restoration of degraded shrub-steppe is a priority (Washington Department of Fish and Wildlife 1995). Efforts to restore depleted or converted habitat should concentrate on reestablishing locally adapted, native shrub-steppe vegetation (Connelly et al. 2000) and reducing grazing pressure when necessary (Beck and Mitchell 2000). Where introduced species are the only available alternative, use species that mimic the structural characteristics of the native species and that provide food (Connelly et al. 2000). Seeding of areas with highly competitive and structurally dissimilar species such as crested wheatgrass (*Agropyron cristatum* or *Agropyron desertorum*), intermediate wheatgrass (*Agropyron intermedium*), pubescent wheatgrass (*Agropyron trichophorum*), or smooth brome (*Bromus intermis*) should be discouraged (Beck and Mitchell 2000, Connelly et al. 2000, A. Sands, personal communication). Habitats that have been degraded should be managed to promote habitat recovery. Areas that possess an understory of native forbs and bunchgrasses prior to wildfire may not need re-seeding (M. Livingston, personal communication). However, sagebrush seeding might be necessary depending on fire size and intensity as well as the distance to seed sources.

Agricultural set-aside programs (such as the Conservation Reserve Program and the Wetlands Reserve Program) and other types of voluntary conservation incentive programs (e.g., Candidate Conservation Agreements, Partners for Fish and Wildlife) should be encouraged in sage-grouse management areas in Washington (Washington Department of Fish and Wildlife 1995). Set-aside conservation programs should be structured to encourage enrollees to plant a diverse range of perennial shrubs, grasses, and forbs and to retain annual residual cover (Hays et al 1998).

Local and regional government programs should be reviewed to ensure they address long-term conservation of sage-grouse populations and habitat. Specifically, critical areas protection that falls under Washington's Growth Management Act are intended to protect State-listed species and can be an effective conservation tool. Local development regulations could require mitigation standards and provide incentives to reduce impacts from projects that potentially affect sage-grouse habitat. Many resource agencies, including Washington Department of Fish and Wildlife, have staff that can provide assistance in critical areas planning.

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KEY POINTS

Habitat Requirements

- Sage-grouse depend on sagebrush for food and cover. Big sagebrush is a predominant species in sage-grouse habitat.
- During spring, males congregate on display sites (leks) to breed with females. Leks are typically located in open areas near relatively dense stands of sagebrush used for food and escape cover.
- Sage-grouse commonly nest in habitat containing sagebrush approximately 30-80 cm (12-31 in) in height, and relatively tall, dense herbaceous cover.

- Broods require an abundance of insects and forbs and often use wet meadows, irrigated farmland and areas at higher elevations.
- Sage-grouse winter in relatively dense sagebrush. Good wintering areas are found at a variety of elevations, and include windswept ridges and sagebrush flats.
- Adult sage-grouse feed almost entirely on sagebrush and forbs year-round. Forbs are consumed in spring, summer and early autumn. Insects and forbs are a critical food source to chicks.

Management Recommendations

- Conversion of shrub-steppe habitat is strongly discouraged.
- Removal or alteration of sagebrush is discouraged within sage-grouse management areas, particularly near leks and in nesting and wintering areas. Sagebrush should not be removed within 300 m (984 ft) of sage-grouse foraging areas along riparian areas, meadows, lake beds, and farmlands.
- Sagebrush removal should not occur where live sagebrush cover is <25% in nesting areas, and <30% in wintering areas, on slopes >20% and/or on slopes with shallow soils where big sagebrush is <30 cm (12 in) in height.
- Prescribed fires should be # 50 ha in size and cover less than 20% of an area used by sage-grouse during winter within any 20–30 year interval (depending on estimated recovery time for the sagebrush habitat). Because the availability of critical wintering habitat is likely the most significant limiting influence on sage-grouse, any burning conducted in wintering habitat should only be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season. Avoid using fire where increase of or invasion by cheatgrass is likely.
- Develop grazing management plans based on the vegetation characteristics of sage-grouse breeding, brood-rearing, and winter habitats (see Table 1).
- Grazing in sage-grouse breeding, brood-rearing, and winter habitats should be light enough to promote long-term sustainability of habitat and stocking rates should be reduced during drought.
- Dramatically reduce or cease all grazing for a long time period when site is degraded by over-grazing to allow recovery of the native plant community. The cessation of grazing alone will likely not restore sites that have been completely overtaken by annual species.
- Insecticides should not be applied to sage-grouse summer habitat. Organophosphorus and carbamate insecticides are especially toxic.
- Use integrated pest management techniques within sage-grouse management areas.
- Minimize human disturbances from mid-February through early June within breeding and nesting areas. Restrict activity on roads traversing sage-grouse leks during hours when birds are active during lek season.
- Avoid building powerlines, wind turbines and other tall structures within 3 km (1.9 mi) of grouse habitat or within 8 km (5 miles) of leks. Fences should be constructed or modified in a manner that will reduce associated mortality.
- Support agricultural set-aside programs (such as the Conservation Reserve Program and the Wetlands Reserve Program) in sage-grouse management areas. Set-aside conservation programs should be structured to encourage enrollees to plant a diverse range of perennial shrubs, grasses, and forbs and to retain annual residual cover.

Wild Turkey

Meleagris gallopavo

Last updated: 1999



Written by John T. Morgan, David A Ware, Michelle Tirhi, and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Wild turkeys (*Meleagris gallopavo*) are native to North America. They have been successfully introduced into approximately 10 states outside of what is thought to be their ancestral range. They currently occur in 49 states, three Canadian provinces, and northern Mexico (Kennamer et al. 1992).

Three subspecies of wild turkey have been introduced in Washington. Merriam's turkeys occur in the northeastern and south-central part of the state, eastern wild turkeys occur west of the Cascades, and Rio Grande turkeys occur in the southeastern corner and scattered locations in the central part of the state (see Figure 1).

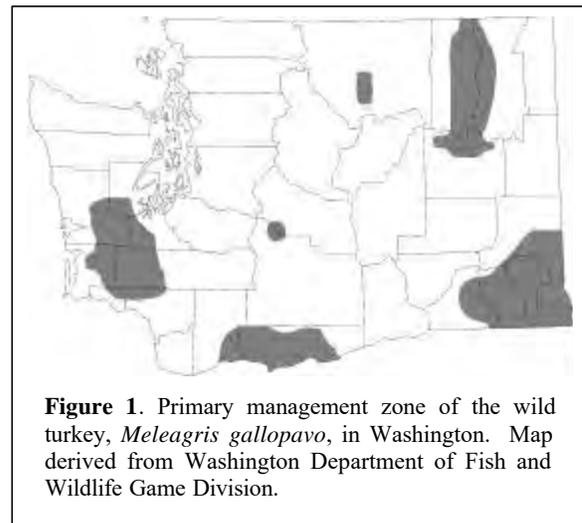


Figure 1. Primary management zone of the wild turkey, *Meleagris gallopavo*, in Washington. Map derived from Washington Department of Fish and Wildlife Game Division.

RATIONALE

Wild turkeys are a state game species and have high recreational value both for consumptive and nonconsumptive purposes. They are vulnerable to habitat loss or degradation.

HABITAT REQUIREMENTS

Wild turkeys are habitat generalists, adapting to a variety of conditions across their range (Dickson et al. 1978). However, the 2 habitat features wild turkeys depend on are trees and grasses. Trees provide food, escape cover, and roost sites, while grasses provide food for adults and an environment that allows poults (juvenile turkey) to efficiently forage for insects (Porter 1992).

Turkeys have been introduced to Washington and are established in a variety of habitats, though each population exists in habitat similar to that from which it came. Turkeys in western Washington are from the eastern subspecies, and occur in forests with open understories interspersed with agricultural areas and natural openings. Turkeys in

northeast and southern Washington are native to the southwestern United States (Merriam's subspecies), and use hardwood draws and riparian areas associated with mature ponderosa pine. They are also associated with pine-oak habitats in south-central Washington. Turkeys in southeast and central Washington are from the Rio Grande subspecies, which originated in the south-central United States. They have become established in very open areas, such as open ponderosa pine, grasslands, and shrub-steppe interspersed with agricultural areas.

Nesting

Turkeys nest in a variety of habitats, though the key component appears to be lateral or horizontal cover (Porter 1992). Horizontal cover includes terrain and/or dense woody and herbaceous vegetation that helps conceal the nest (Beasom and Wildon 1992, Hurst and Dickson 1992, Lewis 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). These conditions are found in timbered stands with a dense understory, fields, clearcuts, utility right-of-ways, young pine plantations, and some agricultural fields. In south-central Washington, Mackey (1982) noted that turkey nests were typically found at the base of a tree, partially covered by dead limbs or understory vegetation, in oak, oak/pine, or oak/fir forest types.

Shaw and Mollohan (1992) described Merriam's turkey nest sites as having complete protection on one side (either dense vegetation or terrain), dense cover on the remaining 3 sides between 0.0 m and 0.5 m (0-1.5 ft), and unrestricted visibility on 3 sides from 0.5 m to 0.9 m (1.5-3.0 ft). Also, nest sites had relatively solid cover 2.4-3.7 m (8-12 ft) above the nest and a forest canopy overhead. In south-central Washington, turkeys were found nesting in areas with understory height averaging 63 cm (25 in), understory canopy coverage of 36%, and forest canopy coverage of 70% (Mackey 1982). In parts of Washington without oak, turkeys nest in stands of other timber species with characteristics similar to that found by Mackey (1982) in south-central Washington.

Brood Range

Porter (1992) described three ingredients essential for brood habitat during the first 8 weeks after hatch. First, there must be an environment that produces insects and in which poults can efficiently forage. Additionally, good brood habitat must have features to permit frequent foraging throughout the day. Lastly, brood habitat must provide enough cover to hide poults while simultaneously allowing the adult female an unobstructed view to avoid predators. All of these must occur within a relatively small area because the weekly home range of a turkey brood has been reported as only 30 ha (75 ac) and a total summer home range of 100 ha (250 ac) (Speake et al. 1975, Porter 1980).

Brood habitat for wild turkeys consists of timbered areas adjacent to grassy openings. Grassy, herbaceous areas provide poults with insects for forage and cover from predators. Trees are also needed for thermal cover to protect poults from cold, wet conditions, particularly during the first 2 weeks after hatching, and as escape cover once poults can fly (10-12 days after hatching). Ideal brood habitat in Minnesota has been described as a 4:1 field-to-forest ratio (Porter 1980). Vegetation approximately 30-70 cm (12-28 in) in height allows poults to hide while allowing females to see predators (Porter 1980). Edge is important because broods usually remain near the field-forest ecotone during the first 2 weeks after hatching and later venture further into openings. Habitats meeting such conditions include forest stands interspersed with pastures and hayfields, utility right-of-ways, savannas, and cutover lands in early stages of succession.

In south-central Washington, broods were found to prefer oak and pine/oak habitats over open rangeland habitats during the first 2 weeks after hatching (Mackey 1982). This was probably because these forest types are very open (51-60% canopy coverage) and can provide an adequate insect prey base as well as cover. In parts of the state with denser forest canopy, interspersion of open areas will be much more important for brood habitat.

Roosting

Stands providing good roosting habitat are sheltered from prevailing winds and contain tall, large diameter trees with sizable horizontal branches, high canopy coverage and basal area (Hoffman 1968, Boeker and Scott 1969, Crockett 1973, Hauke 1975). Single large trees are apparently not used for roosting unless they are associated with a stand (Phillips 1980, Mackey 1984). In south-central Washington, Mackey (1982) found that only Douglas-fir stands met the criteria of good roosting habitat as listed above, though he did find smaller sized ponderosa pine and oak trees used as well. In Oregon, roosts are typically located in multi-layered, mature, mixed-conifer cover types, specifically ponderosa pine and Douglas-fir in the winter and ponderosa pine in the spring (Lutz and Crawford 1987a). In Montana, Jonas and Eng (1964) found that turkeys most often used mature ponderosa pine communities for roosting.

Fall and Winter

During fall and winter, turkeys switch to habitats that offer the best food resources, environmental conditions, and thermal cover for protection from colder temperatures and snow. Typically, this means greater use of stands of larger trees with greater canopy coverage and basal area; springs, seeps, and other riparian areas with denser vegetation; and areas with more abundant hard mast. It also means a decreased use of open areas (Beasom and Wilson 1992, Hurst and Dickson 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). Turkeys may also exhibit an increase in flocking behavior during winter, particularly if available food is concentrated in specific areas (Thomas et al. 1966, 1973; Wunz and Pack 1992).

Food

Poults feed exclusively on high protein invertebrates in the first and second week after hatching, and by the third week they have switched to a diet dominated by plants (Jonas and Eng 1964, Rumble 1990, Hurst 1992, Rumble and Anderson 1996). The diet of both juvenile and adult turkeys is comprised of 75-85% plant matter and the remainder animal matter (Hurst 1992). Important year-round food items include fruits, grains, hard masts, insects, and the green leaves, flowers, and seeds of grasses, forbs, and sedges (Jonas and Eng 1964, Smith and Browning 1967, Burke 1982, Mackey 1982, Wise 1987, Rumble 1990, Hurst 1992, Rumble and Anderson 1996). During spring and summer, wild turkeys often prefer natural grassy meadows and agricultural fields due to the abundance of insects found within them (Burke 1982). Mast-producing tree and understory species are also an important food source (Wunz and Pack 1992). In fall and winter when green vegetation becomes scarce, turkeys switch to a diet composed more of grass seeds, fruits, ponderosa pine nuts, acorns, and other hard mast. Agricultural crops (wheat, barley, oats, legumes) also can serve as a valuable fall/winter food source. During the winter months, turkeys have been observed feeding on cow manure spread on croplands, corn stubble, and hay strips bordering fields of stubble corn (Vander Haegen et al. 1989).

Water

Turkeys can meet their needs for moisture through berries and other succulent vegetation when available. Whether or not turkeys drink water appears to depend on its availability and the ability of food items to provide moisture (Wunz and Pack 1992). When forage cannot meet their needs, turkeys obtain water from pools, ditches, streams, rivers, lakes, wetlands, snow, and dew. Turkeys in moist environments need less free water than those in more arid areas (Beasom and Wilson 1992, Hurst and Dickson 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). Thus, turkeys in the eastern U.S. probably rely less on open water than those in the southwest or plains states. However, during times of drought or in drier eastern environments, open water may be important. Likewise, in more mesic western habitats, open water may be less important.

LIMITING FACTORS

Turkeys are limited by a number of natural and artificial factors. The northern natural range of turkeys in the east seems to be limited by the condition, depth, and duration of snowfall (Healy 1992). In the mid-west, central, and southwest United States, the range of the turkey is limited by the availability of trees. Nest and poult predation may significantly impact wild turkey populations when natural (predation, disease) and human-related (hunting, habitat change) mortality occur in conjunction (Miller and Leopold 1992). Because turkeys need an interspersed forest and open areas, any management activities that disrupt this habitat diversity or degrade the habitat may impact local turkey populations. For instance, timber operations to open up areas for development or agricultural expansion may eliminate too much of the forest cover and food resource. On the other hand, forest thinning or creation of small openings may benefit turkey populations in some situations. Heavy grazing of grassy openings and understory vegetation may limit turkey populations by reducing food for adults and cover for nests and poults.

MANAGEMENT RECOMMENDATIONS

Regardless of subspecies or location in the state, the basic habitat requirement for wild turkeys is adequate quality, quantity, and distribution of forested and open areas. This can be achieved in mature, mast-producing forests with appropriate brood (open areas) and winter range (dense forest) areas. The actual density of forest cover, species composition, and proportion of forest and open areas will vary in different parts of the state. In areas with limited mast-producing trees, such as western Washington, agricultural fields and/or artificially constructed food plots may be needed to maintain turkey populations.

Mast Producing Vegetation - Wild turkey habitat should be managed so that 50-75% of the area is composed of mature, mast producing tree species. In Washington, this would mean maintaining species such as oak and ponderosa pine. Mackey (1982) found that the forest component of his study area in south-central Washington accounted for 74% of the landscape. Pine/oak habitat was the most preferred type for daytime use by turkeys during all seasons. In areas where food sources are scarce, mast-producing shrubs and small trees should be planted as orchards or as edges in clearings. When reseeded, sow a mixture of grasses and forbs that provide both food and cover for turkeys.

Forest Cover - Forest cover should be maintained in areas where wild turkeys exist. Forested areas are used extensively for nesting, roosting, escape and thermal cover, and even brood rearing in more open forest types. In stands lacking pine and oak, protection of mature timber is still important for cover and roosting habitat. Mackey (1982) noted that Douglas-fir stands were used extensively as roost sites. Sites used by roosting turkeys averaged greater canopy coverage (74%), greater canopy height [19 m (62 ft)], and greater basal area [34 m²/ha (148 ft²/ac)] than control plots (Mackey 1982). To maintain such characteristics in areas inhabited by turkeys, it is recommended that timber harvesting be done selectively and that clearcuts >12 ha (30 ac) should be avoided. Where logging is unavoidable, maintain a tree basal area 20 m²/ha (87 ft²/ac) (Mackey 1984). Turkeys frequently use access roads and trails. Therefore, roads created for timber harvest should be closed, gated, seeded, or tank-trapped following timber operations.

Brood Habitat - Brood-rearing habitat can be achieved through maintenance or creation of open timbered areas and/or natural and artificial openings in denser forest. Open areas can be created or maintained through selective timber harvest, prescribed burns, periodic mowing, and chemical treatments (Wunz and Pack 1992).

Livestock Grazing - Livestock grazing also may be used to maintain natural openings. Continuous light grazing seems to be compatible with wild turkey management (Beasom and Wilson 1992). Various types of grazing rotation systems have been described as providing for turkey food production but not as being good for nesting (Merrill 1975). To reduce the negative impacts of livestock grazing in turkey habitat, provide grazing exclosures within existing grazing systems. Blakey (1944 in Beasom and Wilson 1992) recommends that 40-200 ha (100-500 ac) be excluded from grazing within each 1,200-2,000 ha (3,000-5,000 ac) of rangeland for 24 months. As an alternative or in addition to constructing exclosures, roadside and railroad rights-of-ways or other fenced-out exclosures can be managed for turkeys. Where ungrazed areas are available, provide moderate grazing intensities on remaining areas to stimulate food plant growth (Beasom and Wilson 1992).

Land Management Activities - Turkeys are sensitive to disturbance at their nest sites (Lutz and Crawford 1987b); therefore, major land management activities in nesting habitat should be minimized during April, May, and early June. Construction of houses within turkey habitat should be restricted to nonforested areas that are larger than 2 ha (5 ac) in size (Mackey 1982).

Water - In more arid landscapes, a source of free water should be provided for turkeys. Suggestions from Beasom and Wilson (1992) include: providing water through ground-level ponds or catchments as opposed to standard livestock water troughs; fencing small, ground-level watering sites to exclude livestock; in rotational grazing systems, maintaining water in deferred pastures; in short-duration grazing sites, maintaining a fenced-out water site at least 0.4 km (0.25 mi) from the main livestock watering facility; and constructing gallinaceous guzzlers in more arid regions. Gallinaceous guzzlers collect rainfall on an impermeable apron and store the water in underground tanks that have access ramps for the birds.

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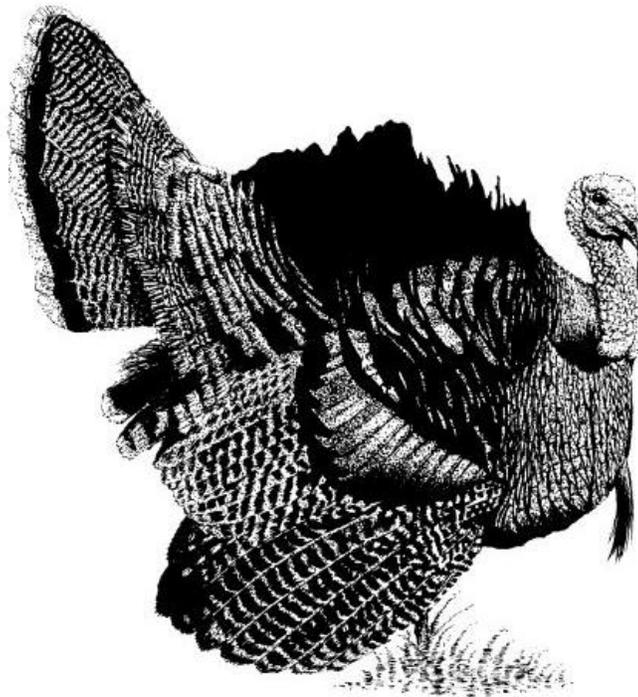
KEY POINTS

Habitat Requirements

- Trees and grass are prominent features of wild turkey habitat.
- Wild turkeys use a combination of forested and open habitats, including conifers, hardwoods, mixed woodlands, riparian areas, open grasslands, and edges of agricultural fields.
- Wild turkeys nest in timber stands with dense understories, weedy fields, clearcuts, utility rights-of-ways, young pine plantations, and agricultural fields. Typical vegetation provides dense cover up to 0.5 m (1.5 ft), unrestricted visibility from 0.5-1.0 m (1.5-3.0 ft), and a canopy of understory and forest trees above the nest.
- Brood range includes open forested areas and natural and artificial openings within close proximity to timbered areas. Ground vegetation should be 30-70 cm (12-28 in) in height to protect poults.
- Good roosting habitat includes stands of timber that are sheltered from prevailing winds and that contain trees that are larger in height, canopy cover, diameter at breast height, and basal area than trees in other stands.
- In climates with more severe winter conditions, turkeys will decrease their use of open areas and will increase their use of stands of larger trees with greater canopy coverage and basal area. Springs, seeps, and other riparian areas, as well as areas with more abundant hard mast, are also used during the winter.
- Poults feed exclusively on high protein invertebrates in the first and second weeks after hatching.
- The diet of juveniles and adults is comprised of 15-25% animal matter and 75-85% plant matter, including green vegetation, grasses, forbs, sedges, fruits, grains, and mast.
- Good turkey range has an adequate supply of water.

Management Recommendations

- Wild turkey habitat should be managed so that 50-75% of the area is composed of mature, mast-producing timber species.
- Timber should be managed through selective cuts in pine and oak habitats, and through selective cuts or small clearcuts [<12 ha (30 ac)] in Douglas-fir habitats. Avoid logging within known roost sites.
- Natural openings should be maintained and created where lacking. Unused logging roads should be closed and reseeded with grasses and legumes, and planted with shrubs and small trees.
- In areas inhabited by turkeys, grazing should be managed through light, continuous use, or with a deferred-rotation system. Provide grazing exclosures within any grazing system.
- Livestock and other disturbances to nesting habitat should be restricted from April to early June.
- Housing development should be restricted to non-forested areas larger than 2 ha (5 ac) in size.
- Sources of free water should be provided in more arid landscapes.





Sandhill Crane

Grus canadensis

Last updated: 2000

Written by Kelly A. Bettinger and Ruth Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The breeding range of the sandhill crane (*Grus canadensis*) includes Siberia, Alaska and Northern Canada, the Great Lakes, and portions of Idaho, Washington, Oregon, Nevada, and California. It also includes the southeastern United States, Cuba, and the Isle of Pines (Tacha et al. 1992). Six migratory populations with distinct wintering areas are recognized. These are the Lower Colorado River, Central Valley, Rocky Mountain, Pacific Flyway, Mid-continent, and Eastern populations. Three additional populations breeding in the southeastern United States and Cuba are nonmigratory (Tacha et al. 1994). Cranes breeding in Washington belong to the Central Valley population and winter in the Central Valley of California (Kramer et al. 1983, Pogson and Lindstedt 1991). This was most recently confirmed when 2 colts banded at Conboy Lake National Wildlife Refuge (NWR) in June 1996 were sighted again near Glenn, California, in January of 1997 (J. D. Engler, personal communication). Migrants moving through Washington belong to both the Central Valley and Pacific Flyway populations.

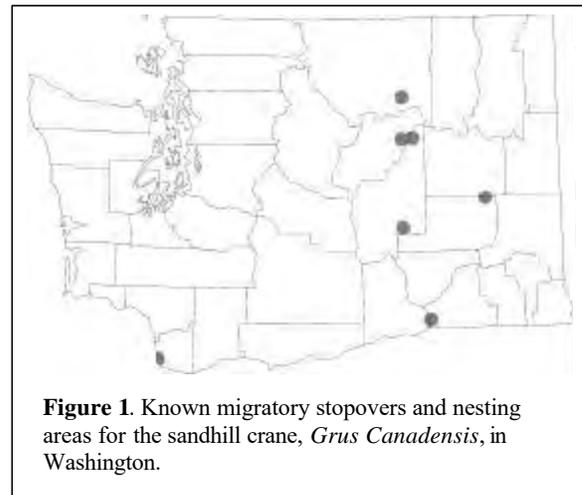


Figure 1. Known migratory stopovers and nesting areas for the sandhill crane, *Grus Canadensis*, in Washington.

Of the 6 recognized subspecies of sandhill cranes, only the greater sandhill crane (*Grus canadensis tabida*) breeds in Washington. According to Jewett et al. (1953), the breeding range was formerly more widespread in Washington and occurred both east and west of the Cascade crest. Historic eastern Washington locales included Okanogan, Collville, Spokane, Prescott, Rockland, Cashmere, Fort Simcoe, and Camas Prairie. Fewer historic western Washington breeding sites are known. Cooper and Suckley (1860) reported sandhill cranes breeding on interior prairies of western Washington, though their most specific location description was "on prairies near Steilacoom." They also reported that sandhill cranes were very abundant on the south Puget Sound prairies during autumn migration.

Between 1975 and 1987, a single pair of sandhill cranes nested at Conboy Lake NWR in Klickitat County (see Figure 1). Since 1988, 2 to 6 pairs/year are known to have nested on the refuge, and in 1996 there were 9 confirmed breeding pairs (Anderson et al. 1996). Nesting cranes were discovered recently at a second site in Washington on the Yakama Indian Reservation in Yakima County, where 1 pair nested in 1994 and 1995, and 2 pairs nested in 1996 (Leach 1995; R. Leach, personal communication).

Migrants of 2 other subspecies, the lesser sandhill crane (*G. c. canadensis*) and the Canadian sandhill crane (*G. c. rowani*), occur in Washington during spring and fall. The largest concentrations are found in the central Columbia Basin. In the spring, lesser sandhills migrating to northwest Canada and Alaska enter Washington east of the Cascades south of Pasco. They regularly stop near Moses Lake and Ephrata in Grant County, and near Mansfield in Douglas County before continuing north through the Okanogan Valley (see Figure 1; Littlefield and Thompson 1981, Kramer et al. 1983). Lesser sandhill cranes migrating west of the Cascades enter the state near Sauvie Island in the Columbia River, and either move north through the Puget Sound region or follow the coast, passing over Cape Flattery toward Vancouver, British Columbia. The same routes are used in the fall (Littlefield and Thompson 1981). Migrating greater sandhill cranes that breed in British Columbia and Canada probably use similar routes.

Breeding sandhill cranes arrive at Conboy Lake NWR in early March. Most nesting occurs from April to June, though a newly hatched colt has been observed as late as early July (H. Cole, personal communication). Breeding cranes and their surviving young leave the state between late September and mid-October.

RATIONALE

The sandhill crane is a State Endangered species. Sandhill cranes are in jeopardy of extinction in Washington because of their limited distribution, low numbers, poor breeding success and colt survival, and loss of shallow marshes or wet meadows for feeding and nesting (Safina 1993). In addition, a large percentage of their wintering habitat is privately owned and subject to potential alteration (Lewis 1980, Pogson and Lindstedt 1991).

HABITAT REQUIREMENTS

Sandhill cranes use large and small tracts of open habitat where visibility is good from all vantage points. Wet meadows, marshes, shallow ponds, hayfields, and grainfields are all favored for nesting, feeding, and roosting. Emergent wetland vegetation is a key component of nesting territories, and nests are typically placed on piles of emergent vegetation, grass, and mud (Safina 1993, Baker et al. 1995). At Conboy Lake NWR, nesting usually takes place in shallow-water marshes with dense emergent plant cover, including reed canarygrass (*Phalaris arundinacea*) and rushes (*Juncus* spp). Bulrushes (*Scirpus* spp.) are often used for nesting in southeastern Oregon (Littlefield and Ryder 1968), but such vegetation is not common at Conboy Lake NWR. Pairs return to the same territory and even the same approximate nest location every year (Littlefield and Ryder 1968, Walkinshaw 1989).

Sandhill cranes are omnivorous, feeding on grains, plant material, invertebrates, amphibians, and small mammals (Reinecke and Krapu 1986, Tacha et al. 1992, Davis and Vohs 1993). Wet meadows or grasslands are used as feeding grounds and are sometimes used for nesting (U.S. Fish and Wildlife Service 1978, Littlefield 1995a). Grainfields and pastures are also important feeding areas (Littlefield and Ryder 1968). Wet meadow or marsh habitats used by sandhill cranes in Washington occur in forested areas (predominantly lodgepole pine [*Pinus contorta*], Douglas-fir [*Pseudotsuga menziesii*], ponderosa pine [*Pinus ponderosa*], and/or grand fir [*Abies grandis*]), and in more open conditions where they are surrounded by grasslands, shrublands, and/or agricultural lands (Tacha et al. 1992).

LIMITING FACTORS

Sandhill cranes are limited by the availability of large tracts of undisturbed marshes or meadows for feeding and nesting, and by adequate water levels during the nesting period (Safina 1993). Low nesting success and colt survival, with subsequent low annual recruitment of new birds into the population can result in a decline of breeding pairs over time (Stern et al. 1985, Stevens 1991, Littlefield 1995b,c).

Sandhill cranes are extremely wary, requiring isolated sites with good nesting cover. Repeated disturbance often results in nest desertion and increases the likelihood of predation on unattended nests (Safina 1993). Pedestrian and vehicle traffic, construction, timber harvest, and low-flying aircraft can potentially disturb breeding and roosting

cranes (Kramer et al. 1983, Norling et al. 1992, Joe Engler, personal communication). Additionally, structures such as power lines and wire fences can pose hazards to cranes that may collide with or become entangled in the wires (U.S. Fish and Wildlife Service 1978, Kramer et al. 1983, Walkinshaw 1989, Morkill and Anderson 1991, Brown and Drewien 1995).

Predator populations near sandhill crane nesting areas can seriously hamper nesting success (Stern et al. 1985). Losses of eggs and chicks to predators have greatly impacted crane numbers on the Malheur National Wildlife Refuge in Oregon (Littlefield 1995b,c). Coyotes (*Canis latrans*) are the most serious predator, followed by ravens (*Corvus corax*), raccoons (*Procyon lotor*), and mink (*Mustela vison*). A combination of habitat improvement (increasing non-woody vegetative cover) and predator control has been highly successful in increasing the breeding crane population on the Malheur National Wildlife Refuge (Littlefield 1995b,c).

Livestock can also cause problems for nesting sandhill cranes. Grazing reduces vegetative cover for nests which can result in increased nest depredation (Braun et al. 1975, Littlefield and Paullin 1990, Littlefield 1995b). Eggs and young are also at risk of being trampled by cattle where spring and summer grazing is allowed (Schlorff et al. 1983). Cattle trails into emergent wetlands provide easy access for mammalian predators, and habitat deterioration from mowing or grazing reduces the small mammal populations that are the favored prey of predators. This leaves predators more likely to feed on alternative prey such as crane eggs and chicks. In addition, cattle crush emergent vegetation while using it for bedding in winter, resulting in decreased cover for crane nests in April and May (Littlefield and Paullin 1990).

Nesting areas must have water shallow enough to support emergent vegetation. Cranes prefer to roost in water less than about 20 cm (8 in) deep (Lovvorn and Kirkpatrick 1981, Norling et al. 1992). Increasing water depth can flood and destroy nests, while lowering water levels can improve predator access to nests. Decreased water levels in June and July can cause a shortage of moist soil and aquatic invertebrates required by young cranes during their first 6 weeks of life, resulting in their starvation (Schlorff et al. 1983).

MANAGEMENT RECOMMENDATIONS

In order for sandhill cranes to survive in Washington, their breeding, migration, and wintering habitats need to be protected and enhanced. It is crucial that further losses of Washington's remaining wetlands are prevented. In some instances, the creation of additional habitat should be considered (Safina 1993, Tacha et al. 1994).

Disturbing cranes during the breeding season (March to September) should be avoided. Road and foot travel should be avoided within 400 m (1,312 ft) of nests, and logging operations within 800 m (2,625 ft) of crane nests should be curtailed during the breeding season (Schlorff et al. 1983). Avoid aircraft activity or keep to high altitudes over areas used by cranes (Kramer et al. 1983). In addition, construction and development within 1.2 km (0.75 mi) of nest sites should be avoided (Joe Engler, personal communication).

New power line corridors should be located away from crane migration and breeding sites, or buried underground. Line markers or other devices should be installed on existing transmission lines that pose hazards to cranes (Kramer et al. 1983, Morkill and Anderson 1991, Brown and Drewien 1995).

All fences that are not essential to controlled grazing and that are near areas used by sandhill cranes, should be removed to prevent cranes from becoming entangled in fence wires (U.S. Fish and Wildlife Service 1978, Walkinshaw 1989).

Predator populations may need to be controlled around nesting areas. A combination of habitat improvement (increasing non-woody vegetative cover) and predator control has been shown to be effective (Littlefield 1995b,c).

Livestock grazing at sandhill crane breeding sites should be limited or eliminated. Grazing and cattle trails reduce vegetative cover for crane nests, increase predator access, and increase the risk of crane eggs and young being trampled by livestock (Braun et al. 1975, Schlorff et al. 1983, Littlefield and Paullin 1990, Littlefield 1995b).

Changes in water levels should be avoided while sandhill cranes are nesting. New water projects such as dams or irrigation ditches that would alter water levels and cause negative changes to vegetation should be avoided in important crane breeding or migration areas (Schlorff et al. 1983).

Meadows should be mowed and hayed no earlier than mid-August to prevent mortality of flightless young cranes hiding in the tall vegetation (Schlorff 1983). Detailed knowledge of a given year's nesting chronology, or of when particular foraging sites are used, could allow for timing flexibility.

Mowing and hay removal conducted after 15 August may benefit cranes by providing feeding areas. All hay should be removed and residual hay cleaned up immediately after mowing to prevent mold development. "Moldy" hay provides favorable conditions for aspergillosis, which is known to infect young cranes (U.S. Fish and Wildlife Service 1978).

Fall plowing of crane feeding habitat should be avoided. Waste grain is more useful if knocked over rather than left standing (Johnson and Stewart 1972). Wheat is the preferred grain to attract cranes to a feeding site, though barley and corn are favored as well (Littlefield 1986, Sugden et al. 1988).

U.S. Fish and Wildlife Service guidelines for managing greater sandhill cranes of the Central Valley population suggest maintaining ponds and wetlands within 3.2 km (2 mi) of grain sites to provide roost sites for cranes (U.S. Fish and Wildlife Service 1978). In Saskatchewan, Canada, 90% of sandhill cranes foraged in fields within 8.0 km (5.0 mi) of their night roost sites, and observations of cranes decreased with distance from roost centers (Sugden et al. 1988). On the Malheur National Wildlife Refuge in southeast Oregon, all grainfields are within 7.6 km (4.7 mi) of night roosts (Littlefield 1986).

New construction or traffic increases within 800 m (2,625 ft) of feeding areas should be avoided. Additionally, low flying aircraft should be avoided over areas used by cranes (Kramer et al. 1983).

The construction of roads and buildings within 500 m (1,640 ft) of known night roost locations should be avoided. Preferred night roost sites used during migration are usually located away from paved or gravel roads, single dwellings, and bridges (Norling et al. 1992).

Hunting activity should be avoided near established roosts, or restricted to 4 hours after sunrise until 2 hours before sunset. Hunting should also be avoided near major feeding areas (Lovvorn and Kirkpatrick 1981, Littlefield 1986).

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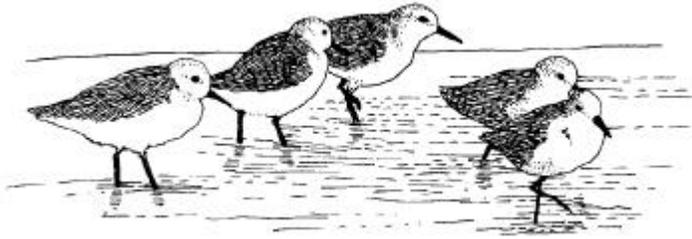
KEY POINTS

Habitat Requirements

- Sandhill cranes use large and small tracts of open habitat where visibility is good from all vantage points.
- Wet meadows, marshes, shallow ponds, pastures, hayfields, and grainfields are all used for nesting, feeding, and/or roosting.
- Dense, emergent wetland vegetation is a key component of nesting territories. Nests are typically placed on piles of emergent vegetation, grass, and mud.
- Ideal nesting locations have good visibility, are near feeding areas, and are free from human disturbance.
- Migrating sandhill cranes use roost sites with shallow water (<20.0 cm [8.0 in]) deep) that are close to feeding sites and are free from human disturbance
- Sandhill cranes are highly omnivorous, feeding on grains, plant material, invertebrates, amphibians, and small mammals.

Management Recommendations

- Sandhill cranes should not be disturbed during their breeding season (March - September).
- Vehicle and foot traffic should be avoided within 400 m (1,312 ft) of nesting areas during the breeding period (March - September).
- Logging should be avoided within 800 m (2,625 ft) of nests during the breeding period.
- Aviation balls or other markers should be used to make existing transmission lines visible to flying cranes.
- Avoid building new power lines in areas used by cranes, or place lines underground.
- All unnecessary wire fences should be removed from areas used by cranes.
- Cattle should be excluded from crane nesting marshes.
- Predator control may be necessary in some situations.
- Water levels should not be altered in wetlands used by cranes. New water projects that might alter water levels or change vegetation should be avoided in nesting or migration areas.
- Meadows should be mowed after 15 August, and all hay should be removed soon after mowing to prevent mold.
- Grainfields should not be fall-plowed; waste grain should be knocked down.
- Wetlands should be maintained within 3 km (2 mi) of upland feeding areas.
- Construction and road building should be avoided within 800 m (2,625 ft) of feeding areas.
- The construction of new roads or buildings should be avoided within 500 m (1,640 ft) of night roosts.
- Hunting near roosts should be avoided, or restricted from 4 hours after sunrise until 2 hours before sunset.



Shorebirds: Plovers, Oystercatchers, Avocets and Stilts, Sandpipers, Snipes, and Phalaropes

Last updated: 2000

Written by Joseph B. Buchanan

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Shorebirds are represented in Washington by many families, including plovers, oystercatchers, avocets and stilts, sandpipers, snipes, and phalaropes (Paulson 1993). In Washington, shorebirds occur as year-round residents, breeding or summer residents, spring and/or fall migrants, and migrants that winter in the region (Table 1). Some species, such as the killdeer and spotted sandpiper, have resident and migrant sub-populations.

The vast majority of wintering and migratory shorebirds in Washington occur at coastal estuaries (Figure 1). These areas include the Columbia River estuary, Willapa Bay, Grays Harbor, coastal Washington beaches, the Strait of Juan de Fuca, Hood Canal, the San Juan Islands, and the Greater Puget Sound region (Figure 1). The highest counts of wintering birds are from Willapa Bay (38,000-90,000 shorebirds; Buchanan and Evenson 1997), Grays Harbor (approximately 20,000 shorebirds annually during 1979-1988; Paulson 1993, Brennan et al. 1985), and the northern estuaries of Puget Sound (>10,000 shorebirds at several estuaries and >50,000 shorebirds in the region; Evenson and Buchanan 1995, 1997).

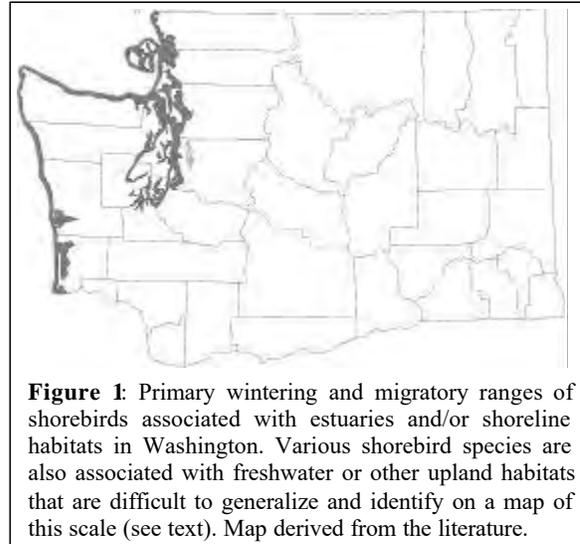


Figure 1: Primary wintering and migratory ranges of shorebirds associated with estuaries and/or shoreline habitats in Washington. Various shorebird species are also associated with freshwater or other upland habitats that are difficult to generalize and identify on a map of this scale (see text). Map derived from the literature.

The most significant areas during migration include Grays Harbor (>one million shorebirds during spring; Herman and Bulger 1981), Willapa Bay (>100,000 shorebirds during spring; Buchanan and Evenson 1997), and the many estuaries of Puget Sound (>50,000 shorebirds during spring; Evenson and Buchanan 1997). Species such as the red-necked phalarope may occur in large numbers offshore during migration (Jehl 1986). Other significant wintering and migratory staging areas in the region include Boundary Bay and the Fraser River delta in southern coastal British Columbia, Canada (Butler and Campbell 1987, Butler 1994, Vermeer et al. 1994).

Other habitats in western Washington are also important for shorebirds. Flocks of black-bellied plovers and dunlins occasionally occur at non-estuarine sites in western Washington (e.g., flooded fields in the Wynoochee and Chehalis River valleys) during migration or winter periods (J. Buchanan, unpublished data). Some of these birds may have been temporarily displaced by flooding (Strauch 1966) or other conditions that reduced prey availability at coastal estuaries (Townshend 1981). Large numbers of shorebirds forage and roost on ocean beaches during winter (Buchanan 1992) and migration (Myers 1988-89, Myers et al. 1986). Other important habitats include rocky shorelines and the pelagic zones (Paulson 1993).

Compared to the coastal region, shorebirds are far less abundant at wintering and migratory stop-over areas in the eastern part of the state where they occur at widely scattered ponds, "potholes" and lakes, marshes, flooded fields,

and riverine systems (Paulson 1993). As is true in other interior regions in North America, the seasonal distribution and abundance of shorebirds in this part of the state is somewhat unpredictable in that the suitability of shorebird habitats in many areas is dependent on changing water levels that are sensitive to varying water use practices, drought, and other environmental conditions (Fredrickson and Reid 1990, Skagen 1997). The highest counts of migratory shorebirds (most counts are <1,000 birds) in the interior region of Washington are from Lake Lenore (i.e., red-necked phalarope), Soap Lake, Turnbull National Wildlife Refuge, Yakima River delta, and water bodies near Reardan (Paulson 1993). It is likely that other areas of concentrated use by shorebirds have not been documented. In Washington, the primary breeding ranges of the American avocet, black-necked stilt, and Wilson's phalarope occur within the Columbia Plateau region in the eastern part of the state.

Breeding and Wintering Ranges

The breeding distribution of migrant shorebirds includes species that nest locally, such as the spotted sandpiper and American avocet (Jewett et al. 1953), and also species that nest in the arctic and subarctic, such as the dunlin and western sandpiper. The wintering range of nearctic shorebirds is vast, extending from southeastern Alaska to southern South America (Morrison 1984) and generally falls within 3 categories: 1) wintering areas primarily within North America, 2) wintering areas extending throughout much of the western hemisphere, and 3) wintering areas primarily within South America.

Distribution of Age and Sex Classes

The age and sex compositions of some shorebird populations vary spatially and temporally across their ranges. Examples of local or regional spatial segregation can be found, although the population structure of most species is poorly known. For example, adult male and juvenile western sandpipers winter primarily in western North America whereas most females of this species winter in South America (Page et al. 1972). Additionally, populations of wintering dunlins exhibit pronounced local and regional segregation by age class (Kus et al. 1984, van der Have and Nieboer 1984, Buchanan et al. 1986).

Temporal segregation of age and sex classes occurs during migration in many species (Morrison 1984, Butler et al. 1987). In Washington, this segregation involves 2 of the most abundant species in western North America, the western sandpiper and dunlin (Page and Gill 1994). An understanding of spatial and temporal segregation can be important for population and habitat management, because habitat loss or degradation at certain wintering or migratory staging areas may significantly impact specific age or sex classes of these or other species at the local, regional, or population level.

RATIONALE

Over 40 species of shorebirds occur in Washington throughout their breeding and nonbreeding seasons (Paulson 1993, Gill et al. 1994). Two of these, the snowy plover (*Charadrius alexandrinus*) and the upland sandpiper (*Bartramia longicauda*), are listed as State Endangered species (the upland sandpiper may be approaching extirpation in Washington). During the nonbreeding period, most shorebird species in Washington aggregate in large single- or multi-species flocks at estuaries, beaches, wetlands, or other foraging and/or roosting locations. Because of the limited distribution of these habitats, and the propensity of shorebirds to form large aggregations, shorebirds are vulnerable to habitat loss; chemical, metal or oil pollution; various disturbance factors; and other potentially significant impacts.

Many shorebird species are long-distance migrants that travel thousands of miles between wintering and breeding areas. The availability of wintering sites and migratory staging areas has decreased throughout North America due to the destruction of biologically rich but economically important areas used by these birds (Page and Gill 1994, Skagen 1997). The number and quality of these sites likely constrains shorebird populations during the nonbreeding season (Myers 1983, Senner and Howe 1984, Myers et al. 1987b), although habitat loss can adversely impact

shorebird populations at any season (Evans and Pienkowski 1984, Goss-Custard and Durell 1990, Sutherland and Goss-Custard 1991).

Nearly all of Washington's shorebird species are represented by individual birds en route to wintering grounds in Central or South America or breeding grounds in Alaska, Canada or the Russian Far East. A number of sites in Washington support substantial shorebird populations (Herman and Bulger 1981, Evenson and Buchanan 1995, Buchanan and Evenson 1997) and qualify as important regional or hemispheric sites in the Western Hemisphere Shorebird Reserve Network (Myers et al. 1987a). Moreover, the region as a whole supports huge numbers of birds during winter and migration. Consequently, during one season or another, this region supports substantial segments of shorebird populations that are truly international in their distribution (Gratto-Trevor and Dickson 1994). For this reason, shorebird populations and the habitats they use in Washington are integral components of a greater hemispherical population of birds and must be managed from this international perspective (Gill et al. 1994).

Large-scale censuses of shorebirds conducted in Britain (Prater 1981, Moser 1987), the Canadian Arctic (Gratto-Trevor et al. 1998), and eastern North America (Howe et al. 1989, Morrison et al. 1994a) indicate that populations of many species are declining. Long-term research from migratory staging areas in eastern North America indicates that several species of shorebirds, including some that also migrate through Washington, have experienced significant population declines along the east coast (scientific names are presented in Table 1): black-bellied plover, semipalmated plover, whimbrel, ruddy turnstone, red knot, sanderling, semipalmated sandpiper, least sandpiper, and short-billed dowitcher (Howe et al. 1989, Morrison et al. 1994a). Populations of American golden-plover, lesser yellowlegs, red-necked phalarope, and red phalarope are also thought to have declined in Canadian breeding areas (Haig et al. 1997, Sauer et al. 1997, Gratto-Trevor et al. 1998).

Other species have experienced population declines as well. For example, the size of the wintering population of rock sandpipers along the Pacific coast of Oregon, Washington, and British Columbia declined suddenly and dramatically (and appears to have shifted north to Alaska) in association with the 1982-83 El Nino event (Buchanan in review). Black turnstone numbers have also declined along the Pacific Northwest coast (Paulson 1993). Species such as the snowy plover and upland sandpiper have also clearly declined in response to habitat destruction (Washington Department of Fish and Wildlife 1995a, 1995b). Analyses of data collected from Breeding Bird Survey routes throughout Washington indicate the occurrence of significant population declines at one or more spatial or temporal scales for the following four species of locally-nesting shorebirds: spotted sandpiper in the Columbia Basin, (-9.1% between 1966 and 1996), killdeer statewide (-2.3% between 1966 and 1996 and -4.1% between 1980 and 1996), common snipe in the Columbia Basin (-3.2% between 1966 and 1996) and statewide (-5.5% between 1980 and 1996), and Wilson's phalarope in the Columbia Basin (-10.9% between 1980 and 1996) (Sauer et al. 1997).

Table 1. Seasonal abundance and habitat use of shorebirds in Washington. Habitats are described in Paulson (1992, 1993). Bold text refers to primary habitat or area where the species is locally or seasonally common; standard text refers to secondary habitats. Abundance codes are from (Paulson 1993). Seasonal abundance codes may differ from Paulson (1993) based on other available information. Codes with an asterisk (*) represent unique local populations. Abundance codes in parentheses refer to interior Washington.

Species	Abundance by season ^a				Habitat
	Winter	Spring	Summer	Fall	
Black-bellied plover (Pluvialis squatarola)	VA	VA (VU)	FC	VA (U)	coastal and estuarine sand beaches and mud flats , exposed shorelines of ponds and lakes, farmland, wet lowland meadow
American golden-plover (Pluvialis dominica)		R		C (U)	coastal and estuarine mud flats and saltmarsh , exposed shorelines of ponds and lakes, farmland, alpine/subalpine meadow, wet lowland meadow
Pacific golden-plover (Pluvialis fulva)	VR	R		C	coastal and estuarine mud flats and saltmarsh , exposed shorelines of ponds and lakes, farmland, alpine/subalpine meadow, wet lowland meadow
Snowy plover (Charadrius alexandrinus)	U	FC*	FC*	FC*	coastal sand beaches
Semipalmated plover (Charadrius semipalmatus)	FC	A (VU)	U	A (U)	coastal and estuarine sand beaches and mud flats, exposed shorelines of ponds and lakes
Killdeer (Charadrius vociferus)	C (U)	C (C)	C (C)	C (C)	estuarine mud flats and saltmarsh; exposed shores of ponds, lakes , and large rivers; fresh marsh, wet lowland meadow, grassy areas and farmland
Black Oystercatcher (Haematopus bachmani)	FC	FC	FC	FC	coastal rocky shore
Black-necked Stilt (Himantopus Mexicanus)		VU (U)	(FC)		shallow marshy ponds and lakes

Species	Abundance by season ^a				Habitat
	Winter	Spring	Summer	Fall	
American avocet (Recurvirostra americana)		R (FC)	(C)	R (A)	shallow marshy ponds and lakes
Greater yellowlegs (Tringa melanoleuca)	VC (VU)	VC (FC)	R	VC (FC)	estuarine mud flats, shorelines of shallow ponds, lakes and large rivers, flooded fields
Lesser yellowlegs (Tringa flavipes)		VU (U)		FC (FC)	estuarine mud flats, shorelines of shallow ponds and lakes , flooded fields,
Solitary sandpiper (Tringa solitaria)		U (VU)	(R)	VU (U)	shorelines of shallow ponds and lakes, including those found in wooded settings; flooded fields and other ephemeral freshwater areas
Willet (Catoptrophorus semipalmatus)	U*	VU (VU)	(U)	VU (VU)	shorelines of shallow ponds and lakes, estuarine mud flats
Wandering tattler (Heteroscelus incanus)		FC		FC	coastal rocky shores
Spotted sandpiper (Actitis macularia)	U*	U (U)	U (R)	U (VU)	shorelines of streams, rivers, shallow ponds and lakes, marshes; rocky shore, estuarine mud flats
Upland sandpiper (Bartramia longicauda)			(VU)		wet meadow/ grassland
Whimbrel (Numenius phaeopus)	VU*	VC	FC	VC	coastal and estuarine sand beaches and mud flats, saltmarsh
Long-billed curlew (Numenius americanus)	U*	VU (FC)	(FC)	VU (FC)	dry grassland, farmland; estuarine mud flats, saltmarsh

Species	Abundance by season ^a				Habitat
	Winter	Spring	Summer	Fall	
Bar-tailed godwit (<i>Limosa lapponica</i>)				R	coastal and estuarine sand beaches and mud flats
Marbled godwit (<i>Limosa fedoa</i>)	C*	FC (FC)	R	FC (FC)	coastal and estuarine sand beaches and mud flats, exposed shorelines of interior ponds and lakes
Ruddy turnstone (<i>Arenaria interpres</i>)	VU	C		FC	coastal rocky shore, sand beaches, mud flats
Black turnstone (<i>Arenaria melanocephala</i>)	C	C		C	coastal rocky shore
Surfbird (<i>Aphriza virgata</i>)	C	C		C	coastal rocky shore
Red knot (<i>Calidris canutus</i>)	VU	VC	R	U (R)	estuarine sand and mud flats, coastal sand beaches
Sanderling (<i>Calidris alba</i>)	VA	VA (R)	VU	VA (U)	coastal sand beaches, estuarine sand and mud flats, coastal rocky shore
Semipalmated sandpiper (<i>Calidris pusilla</i>)		VU (U)		U (U)	Exposed shoreline of shallow ponds, mud flats
Western sandpiper (<i>Calidris mauri</i>)	VC*	VA (U)	U	VA (C)	coastal and estuarine sand beaches, mud flats, and salt marsh; exposed shoreline of shallow ponds and lakes; freshwater low marsh
Least sandpiper (<i>Calidris minutilla</i>)	FC	VC (C)		VC (C)	estuarine mud flats, salt marsh; exposed shoreline of shallow ponds and lakes; freshwater low marsh
Baird's sandpiper (<i>Calidris bairdii</i>)		VU (U)		FC (FC)	coastal sand beaches, mud flats, exposed shoreline of shallow ponds and lakes, grassy areas, alpine/subalpine meadow

Species	Abundance by season ^a				Habitat
	Winter	Spring	Summer	Fall	
Pectoral sandpiper (<i>Calidris melanotos</i>)		VU		C (FC)	estuarine and freshwater marsh , mud flats
Sharp-tailed sandpiper (<i>Calidris acuminata</i>)				U	estuarine salt marsh , mud flat edges
Rock sandpiper (<i>Calidris ptilocnemis</i>)	FC	FC		FC	coastal rocky shore
Dunlin (<i>Calidris alpina</i>)	VA	VA (U)	U	VA (VU)	coastal and estuarine sand beaches and mud flats, flooded fields , rocky shores
Curlew sandpiper (<i>Calidris ferruginea</i>)				R	estuarine marsh, sand beaches, mudflats; freshwater low marsh
Stilt sandpiper (<i>Calidris himantopus</i>)				VU (VU)	fresh and brackish marsh; sewage lagoons , flooded fields
Buff-breasted sandpiper (<i>Tryngites subruficollis</i>)				VU	grassy areas, coastal sand beaches
Ruff (<i>Philomachus pugnax</i>)				VU	estuarine mud flats, salt marsh; flooded fields, shallow ponds
Short-billed dowitcher (<i>Limnodromus griseus</i>)		VA (R)	FC	VA (VU)	estuarine mud flats , coastal sand beaches, flooded fields, freshwater areas
Long-billed dowitcher (<i>Limnodromus scolopaceus</i>)	FC		C (VC)	VC (VC)	exposed shoreline of shallow ponds and lakes; estuarine mud flats (winter) , freshwater marsh

Species	Abundance by season ^a				Habitat
	Winter	Spring	Summer	Fall	
Common snipe (<i>Gallinago gallinago</i>)	FC (U)	U (FC)	U (FC)	FC (FC)	estuarine and freshwater marsh; flooded grassy fields, farmland
Wilson's phalarope (<i>Phalaropus tricolor</i>)		U (FC)	VU (FC)	VU (FC)	ponds and lakes, freshwater marsh, sedge meadows
Red-necked phalarope (<i>Phalaropus lobatus</i>)		A (FC)		A (FC)	marine waters; ponds and lakes
Red phalarope (<i>Phalaropus fulicaria</i>)	U	FC		VC	off-shore marine waters

VA = Very Abundant (over 1,000 individuals observed per day), A = Abundant (200-1,000 individuals per day), VC = Very Common (50-200 individuals per day), C = Common (20-50 individuals per day), FC = Fairly Common (7-20 individuals per day), U = Uncommon (1-6 individuals per day), VU = Very Uncommon (more than 6 individuals per season in the region, but not seen every day), R = Rare (1-6 individuals per year in the entire region). The list does not include very rare (over 6 total records), casual (2-6 records), or accidental (1 record) species in the region.

^a Winter refers to the period of local residency following autumn migration. The winter period for most species is November through March. Spring migration for most species is generally April through mid-May although some species begin migrating in Washington during March and others extend into June. Fall migration extends from late June to late October; some fall migrants occasionally remain in Washington until mid-November.

Other species, for which adequate information is lacking, are likely at risk of population-level impacts due to the vulnerability of their primary habitats (species to which Page and Gill [1994] assigned high vulnerability scores [a score ≥ 10 is used here to define 'high'] include American avocet, black-necked stilt, common snipe, killdeer, marbled godwit, snowy plover, upland sandpiper, willet, and Wilson's phalarope) and may be declining (Paulson 1992, Morrison et al. 1994b), although population monitoring data are generally lacking (see exceptions above). Finally, a number of species, including red knot, and various species of plovers, curlews, godwits, and dowitchers suffered substantial, if not catastrophic, population declines between 1870 and 1927 in response to unregulated hunting (Page and Gill 1994; see Cooke 1910, Forbush 1912, Grinnell et al. 1918). Populations of some of these species have not recovered and the likelihood of recovery appears low due to the negative effects of additional or more recent impacts, such as habitat loss (Paulson 1993, Page and Gill 1994).

HABITAT REQUIREMENTS

Most shorebird species exhibit unique migratory strategies that include preferences for specific habitat components (Davidson and Stroud 1996). Research on habitat selection by birds indicates that a range of habitats may be used although certain habitats are preferred and selected when possible (Fretwell and Lucas 1970). Although research on habitat selection by shorebirds has not been conducted in Washington, the habitat preferences of most species are obvious, assuming the predominant patterns of distribution and abundance reflect habitat preference (Ruggiero et al. 1988; Table 1). Some secondary habitats are used on occasion, however, and may be locally important, particularly during periods of adverse weather or depletion of food sources (Warnock et al. 1995, Davidson and Stroud 1996).

Coastal Environments

Most shorebirds in Washington occur as migrants or winter residents (Table 1). During the nonbreeding period, most can be found concentrated at beach or estuarine sites where fat and protein reserves required for overwintering or continued migration are replenished (Evans et al. 1991). The primary habitat requirements of these birds relate to the availability of adequate foraging and roosting areas. The foraging requirements of many shorebirds in western Washington are met primarily in estuarine ecosystems associated with silt or silt/sand intertidal areas and adjacent beaches or salt marshes, where tidal mud flats provide foraging substrates for many species. Black-bellied plover, dunlin, western sandpiper, and dowitchers forage on mud flats with high levels of silt, whereas semipalmated plovers and sanderlings forage in sandy or silt/sand areas (Paulson 1993). Other species, such as rock sandpiper, surfbird, and wandering tattler are found almost exclusively along rocky intertidal shores (Paulson 1993). Many species in eastern Washington use wet meadows, flooded fields and other areas of shallow water. The habitat associations of shorebirds in Washington are summarized in Table 1.

As a group, shorebirds are behaviorally and morphologically adapted to forage in a rather narrow range of microhabitat conditions (Burton 1974, Gerritsen and van Heezik 1985), including exposed tide flats or beaches, shallow water, salt marshes, and even open water. Consequently, the selection of invertebrate prey by shorebirds during the nonbreeding season is related to shorebird morphology and environmental factors that influence prey availability. These factors include tidal range, tidal exposure, wave action and tidal current, substrate slope, sediment mobility, organic pollution, local or regional climate, microhabitat conditions, and invertebrate behavior (Bryant 1979, Pienkowski 1981, Quammen 1982, Ferns 1983, Grant 1984, Hicklin and Smith 1984, Gerritsen and van Heezik 1985, Reise 1985, Esselink et al. 1989, Hockey et al. 1992, Beukema et al. 1993, Nehls and Tiedemann 1993, Wanink and Zwarts 1993, Zwarts and Wanink 1993).

Shorebirds use a variety of habitats for roosting. They often roost in salt marshes adjacent to intertidal feeding areas, even when these areas are extremely limited in size (Brennan et al. 1985, Buchanan 1988). Shorebirds at Grays Harbor and Willapa Bay often roost in large flocks on Pacific beaches, occasionally concentrating near the mouths of small creeks where they bathe and preen (Buchanan 1992). In some areas, shorebirds roost on natural and dredge spoil islands and on higher elevation sand beaches (Herman and Bulger 1981, Brennan et al. 1985). Some species also roost in fields or other grassy areas near intertidal foraging sites (Brennan et al. 1985, Butler 1994); shorebirds may forage at these or other roost sites if suitable prey are present. Shorebirds occasionally roost on pilings, log rafts, floating docks, and other floating structures when natural roost sites are limited (Buchanan 1988; Wahl 1995; J. Buchanan, unpublished data).

Shorebirds will fly considerable distances between foraging and roosting locations where roost sites are limited (Page et al. 1979). Distances >16 km (10 mi) have been documented (Symonds et al. 1984, Buchanan et al. 1986). On rare occasions, some species (i.e., dunlins) will engage in continuous flight during the high tide period, even though suitable roosting habitat is available (Prater 1981, Brennan et al. 1985). The reason for this behavior is not understood. In addition, shorebirds will also fly for extended periods when disturbed at a roost site. The energetic costs associated with extensive flights at or among roosting and foraging locations are not well understood.

Other habitats used by shorebirds in this region include pasture and agricultural land. Thousands of shorebirds roost (and occasionally forage) in pastures near Raymond and Bay Center on Willapa Bay during winter and spring migration (Buchanan and Evenson 1997). Large concentrations of roosting birds have been observed on fallow fields at Nisqually delta, Skagit Bay, Samish Bay, Lummi Bay, and adjacent to other large estuaries in northern Puget Sound and the Fraser River Valley (Brennan et al. 1985, Butler 1994, Wahl 1995, Evenson and Buchanan 1997). This type of habitat use has been documented in other areas (Townshend 1981; Colwell and Dodd 1995, 1997; Rottenborn 1996).

Use of artificial wetlands by shorebirds has not been documented in Washington. However, many species of shorebirds, including at least 12 species that occur in western Washington, used managed coastal wetlands in South Carolina (Weber and Haig 1996) indicating that such habitats, if suitable, would likely be used in this state. Salt marsh created at the Jay Dow Sr. wetlands in northeastern California provides important habitat for shorebirds migrating through and breeding in that region (Robinson and Warnock 1996). Similarly, salt evaporation ponds are an important habitat used by over-wintering and spring migrant western sandpipers in San Francisco Bay (Warnock and Takekawa 1995) and by shorebirds in other parts of the world (Davidson and Evans 1986, Martin and Randall

1987, Sampath and Krishnamurthy 1988, Velasquez and Hockey 1992). Shorebirds also forage, usually in comparatively small numbers, in sewage lagoons associated with waste treatment facilities.

Shorebirds are generally site-faithful to specific wintering areas (Townshend 1985, Myers et al. 1986) although some individuals may move considerable distances among sites (Warnock et al. 1995, Warnock 1996). This fidelity to particular sites has important ramifications for conservation management and mitigation. For example, because shorebirds do not settle in their winter quarters in a random manner, but rather return to areas used in previous years, mitigation efforts must recognize that habitat loss will most likely result in density dependent competition (e.g., greater competition for the same level of resources due to a greater density of birds at a given site) at other sites in the region (see the "Habitat Loss" section below).

Freshwater Environments

Most shorebirds that forage in freshwater areas require ponds and pools that have exposed shorelines or that are shallow enough to allow foraging by wading birds. As with estuarine sites, the availability of appropriate prey (e.g. various invertebrates) and roost sites are important habitat requirements.

Locally nesting species have specific nest site requirements. Killdeer and spotted sandpiper both nest on gravel/cobble substrates, however they often occupy vastly different environments (Paulson 1993). Killdeers nest in habitats including dry lake beds, short-grass fields, and unpaved margins of roadways. In contrast, spotted sandpipers typically nest where there is herbaceous cover in sandy or rocky substrates along creeks, rivers and lakes in both forested and arid environments (Oring et al. 1997). American avocets, black-necked stilts, common snipes, and Wilson's phalaropes also nest in Washington, primarily in the eastern part of the state. Avocets and stilts nest in rather open areas in or near marshes or other bodies of water, while phalaropes and snipes nest in wet meadows and marshes (Paulson 1993). Other habitats used by shorebirds include marshes, pastures, flooded fields, reservoirs, impoundment drawdowns, sewage treatment ponds, stormwater wetlands, and other artificial wetlands (Rundle and Fredrickson 1981, Perkins and Lawrence 1985, Duffield 1986, Paulson 1993). Habitat associations of interior species are summarized in Table 1.

LIMITING FACTORS

Habitat Loss

Effects of Habitat Loss or Degradation During the Nonbreeding Season - During the past century the amount of coastal estuarine wetlands in North America has been severely reduced (Dahl 1990). In Washington, approximately 66% of the coastal wetlands were destroyed over this period (Boule et al. 1983). Most of Washington's wintering and migrant shorebird species are dependent on these estuarine areas for essential foraging and roosting requirements. The most typical form of habitat loss occurs when wetlands or intertidal areas, including roost sites (Burton et al. 1996), are filled for development purposes (Page and Gill 1994).

Activities that degrade rather than destroy habitat also have the potential to impact shorebirds. Temporary or permanent reductions of habitat quality may reduce foraging efficiency and increase shorebird energetic requirements and/or mortality rates. Mineral extraction activities such as removal of sand from coastal beaches (Phipps 1990) or gravel from river beds, may degrade or destroy foraging, roosting and nesting habitat used by shorebirds.

For some shorebird populations, the loss of nonbreeding habitats, including roosting sites (Burton et al. 1996), results in increased density-dependent mortality (Sutherland and Goss-Custard 1991). This increased mortality occurs when shorebirds are forced to leave degraded or destroyed sites and settle elsewhere. Such movement to other sites increases the density of birds at remaining sites and results in greater competition for limited resources (Goss-Custard 1977, Evans et al. 1979, Goss-Custard 1979, Schneider and Harrington 1981, Goss-Custard 1985, Moser 1988, Lambeck et al. 1989) because of higher rates of prey depletion and increased rates of competitive interference (Goss-Custard and Durell 1990, Sutherland and Goss-Custard 1991, Evans 1991). It is likely that these movements force some birds to occupy lower-quality sites where competition for marginal resources is more intense

(Evans 1976, Sutherland and Goss-Custard 1991). These movements may have a greater impact on juvenile shorebirds (Goss-Custard and Durell 1987) and may therefore considerably influence population structure; this may have occurred in a wintering population of dunlins in Europe (Sutherland and Goss-Custard 1991).

For shorebird species that forage on invertebrates associated with kelp windthrow, the health of offshore kelp forests may be important for maintaining stable populations in this region. In coastal California, linear densities of spotted sandpiper, wandering tattler, whimbrel, black turnstone, and ruddy turnstone were higher on the Palos Verdes Peninsula in 1985-86, after offshore kelp forests had been restored, than in 1969-73 when kelp was absent (Bradley and Bradley 1993). Although these relationships were highly significant, the authors cautioned against generalizing their results to other regions because other factors may have partially contributed to the observed population changes.

Effects of Habitat Loss or Degradation on Reproductive Capability - The loss or degradation of habitat at migratory stop-over sites may influence survival rates and annual productivity of shorebirds on their Subarctic/Arctic breeding grounds. The timing of arrival at the breeding grounds sometimes occurs during periods of adverse weather or depleted prey availability. Survival at this time is more likely if the birds have accumulated sufficient fat and protein reserves at temperate staging sites (Morrison and Davidson 1989). Some shorebirds carry more fat than is needed to make flights between staging areas and the breeding range (Davidson and Evans 1989, Evans and Davidson 1990) and it is thought that these reserves provide insurance in the event of adverse conditions during migration or upon arrival at the breeding grounds. When shorebirds are delayed at staging areas or are otherwise unable to adequately accumulate these body reserves before or during migration, they are more likely to experience nest failure due to late arrival or poor physiological condition at the breeding grounds (Davidson and Evans 1989, Evans and Davidson 1990). Consequently, marginal environmental conditions at wintering or migratory staging areas in Washington may influence shorebird productivity at breeding areas thousands of miles away.

Bivalve Management - A number of economically important bivalve species are produced and harvested in Washington's sheltered marine waters, but there have been no studies on the relationship between their presence or harvest and shorebird behavior or abundance. The geoduck clam (*Panopea abrupta*) is generally harvested in waters ≥ 6 m deep at mean low low-water or ≥ 200 m from shore and its management therefore does not appear to have a direct bearing on shorebirds. Other bivalve species, however, are managed in intertidal areas that are also used by shorebirds. These areas are either privately owned or leased from the Washington Department of Natural Resources.

Bivalve management, when conducted on silt or silt-sand tide flats, clearly alters substrate conditions (Simenstad et al. 1991). These substrate alterations influence the quality of sites and in some cases may render a site less suitable or unsuitable for shorebird species associated with fine-silt substrates. The only study to address shorebird response to aquaculture activities, conducted in Tomales Bay, California, found far lower densities of dunlins and western sandpipers in aquaculture plots than in adjacent control plots (Kelly et al. 1996). The significance of substrate alteration and the resulting changes in suitability of foraging habitat to local shorebird populations is unknown. It should be noted that some shorebirds may benefit from bivalve management. The density of willets, an uncommon species in Washington, was greater in aquaculture plots than in control plots at Tomales Bay, California (Kelly et al. 1996). Shorebirds in Washington, particularly greater yellowlegs, occasionally forage in tidal pools associated with aquaculture operations (J. Buchanan, unpublished data). The significance of this potential association is also unknown.

Water Diversion - Habitat loss in interior regions of Washington occurs primarily when wetland areas are drained and used for agricultural or development purposes. It is possible that changes in the water table resulting from irrigation demands on local drainages has reduced or eliminated some areas of wetland or moist habitats (Hallock and Hallock 1993, Neel and Henry 1996). Such habitat losses may increase density-dependent effects on shorebirds in the manner described above.

Water Salinization - Changes in water chemistry, manifested through salinization, may adversely effect shorebirds or their habitats in the Columbia Basin. Although a natural phenomenon in the intermountain west (defined as the portion of western North America that lies between the Cascade and Rocky Mountain ranges), water salinization increases as greater demands are placed on limited water resources (American Society of Civil Engineers 1990). Water salinization occurs when water is diverted for other uses. Diversion of water typically results in less water delivered to wetlands and other water bodies. As a result, wetlands and ponds become shallower and more saline

through evaporative concentration (Rubega and Robinson 1996). The extent to which water salinization has occurred in interior Washington is unknown. In addition, it is not clear how to best manage saline wetlands for shorebirds or other wildlife (Rubega and Robinson 1996).

Salinization may directly effect shorebirds in a number of ways. First, salinization interferes with their ability to regulate water balance through excretion of excess salt (Rubega and Robinson 1996). Although some birds have well developed salt glands that enable them to excrete excess salt (Schmidt-Nielson 1960), it is not clear that all shorebirds have this capability (Rubega and Robinson 1996). An inability to maintain water balance results in dehydration and death (Rubega and Robinson 1996).

Second, water salinization may influence shorebird behavior. Shorebirds in highly saline areas often concentrate near freshwater sources such as springs (Rubega and Robinson 1996; J. Buchanan, personal observation). If these freshwater sources are scarce it is likely that energetic costs will be increased for birds that travel to these sites. Like all birds, shorebirds bathe regularly. It is thought that salinization may increase feather wetting, which in turn may increase thermoregulatory demands (Rubega and Robinson 1996). Water balance and thermoregulatory considerations may be particularly significant to fledglings (Rubega and Robinson 1996).

Water salinization may also result in changes in emergent vegetation as well as in the composition of the invertebrate community (Wolheim and Lovvorn 1995). These changes may influence the composition of shorebirds using particular sites by reducing the species richness of potential prey species (Rubega and Robinson 1996). Research is clearly needed to investigate the relationship between increasing water salinization and the health and behavior of shorebirds that migrate through or nest in the Columbia Basin.

Effects of Livestock Grazing - A number of research projects indicate that livestock grazing has a variety of positive and negative effects on shorebirds and their habitats in the interior portion of western North America (Powers and Glimp 1996). The direct effects, including trampling and disturbance, are negative, whereas the indirect effects are either positive or negative and include habitat changes and factors related to foraging and predation (Powers and Glimp 1996). The potential significance of these effects are thought to be related to the species of grazer and the timing and distribution of grazing (Powers and Glimp 1996).

The effects of trampling by livestock include destruction of eggs or nests (Rohwer et al. 1979, Guldmond et al. 1993), abandonment of disturbed nests (Delehanty and Oring 1993), and increased time adult birds spend away from their nests (Graul 1975), which likely results in increased exposure of eggs. Although each of these effects has been noted in shorebirds (Powers and Glimp 1996), research on these topics is lacking from the intermountain west.

Livestock may also impact shorebird habitats by altering attributes of the environment. For example, livestock grazing can alter vegetation composition, compact soil, and increase erosion (Kadlec and Smith 1989, Powers and Glimp 1996). These changes have been demonstrated to result in reduced populations of invertebrates (Mono Basin Ecosystem Study Committee 1987), reduced use of habitats by shorebirds (Bowen and Kruse 1993), and increased egg depredation and predation upon chicks and adults (Redmond and Jenni 1986, Bowen and Kruse 1993).

Conversely, livestock grazing has certain demonstrated or potential benefits to shorebird habitats, depending on the timing and intensity of grazing. Grazing was thought to control the growth of vegetation that would otherwise have been too tall or dense to allow use by shorebirds (Crouch 1982, Kohler and Rauer 1991, Nilsson 1997). In addition, several studies in non-arid regions indicate that grazed lands supported greater populations of invertebrate prey species and that shorebird foraging and body condition was enhanced at those sites (Galbraith 1987, Granval et al. 1993). It is unknown whether these potential benefits of livestock grazing would occur in the intermountain west.

Effects of Exotic Plants - Three exotic species of cordgrass (*Spartina* spp.) have invaded the intertidal areas of Washington (Frenkel and Kunze 1984). Although *Spartina alterniflora* was introduced to Willapa Bay in 1894, and was recognized as a potential problem in 1942, its spread has increased dramatically in the past decade (Mumford et al. 1991). Cordgrass grows in dense stands that effectively trap sediments; this process leads to changes in substrate elevation that may substantially degrade the original salt marsh environment (Sayce 1988, Landin 1991). Research in Europe indicates that tidelflat areas with *Spartina* growth have lower densities of the invertebrate prey of shorebirds (Millard and Evans 1984, Atkinson 1992). Moreover, an association between the spread of *Spartina* and a decline in shorebird abundance was reported in Great Britain (Goss-Custard and Moser 1988). Observations near the mouth of the Willapa River in Willapa Bay in spring 1998 indicate that extensive areas used by red knots and

western sandpipers in the early 1980s are now covered by cordgrass and no longer appear to be used by these shorebirds (Chris Chappell, personal communication). Consequently, although the information for North America is rather limited, it appears that the colonization and alteration of tideflats by cordgrass has the potential to influence the availability of shorebird foraging and roosting habitats in Washington.

Another exotic species, purple loosestrife (*Lythrum salicaria*), has invaded the Columbia Basin (Engilis and Reid 1996). Loosestrife is a dense, woody plant that can grow to over two meters in height along the margins of ponds, lakes and wetlands. This fast-growing plant can render invaded shoreline areas unsuitable for shorebirds. Additional exotic species that may cause habitat degradation, although likely at a lesser scale, include *phragmites* which grows along salt marsh margins, and reed canarygrass (*Phalaris arundinacea*), which grows along margins of freshwater wetlands and flooded fields that might be used by shorebirds.

Effects of Exotic Vertebrates and Invertebrates - Numerous exotic vertebrate and invertebrate species have been introduced to coastal and interior wetlands (Carlton and Geller 1993). The common carp (*Cyprinus carpio*) was introduced to many wetland areas in the intermountain west and appears to be degrading wetland habitats (Engilis and Reid 1996). The foraging behavior of this exotic species disturbs aquatic plant beds which increases turbidity and reduces photosynthetic activity by submerged plants (Robel 1961). The likely consequence is a change in wetland vegetation composition and a reduction in invertebrate populations.

A number of exotic marine invertebrates, transported and introduced via ballast water introduction (Cordell 1998), have the potential to impact shorebird prey populations in Washington's estuaries. The Asian clam (*Potamocorbula amurensis*) has recently become established in San Francisco Bay, California (Carlton et al. 1990). The invasion of this clam was very rapid and in some areas of San Francisco Bay it now dominates the macrobenthic fauna (Nichols et al. 1990). We have no evidence to suggest that this species has colonized estuarine sites in Washington. The European green crab (*Carcinus maenas*) was documented in coastal estuaries of Washington in 1998. It too has the capability to dramatically alter the macrofaunal community of marine estuaries. Such changes would be potentially deleterious to shorebird and other wildlife populations associated with marine estuaries.

Similarly, various Asian copepods have recently been introduced via ballast waters to coastal estuaries in the Pacific Northwest (Cordell 1998, Cordell and Morrison 1996). Although the outcome of these invasions is not clear, potentially significant deleterious effects similar to those associated with other invasions of this type are likely to occur (Carlton et al. 1990, Nichols et al. 1990, Cordell 1998).

Utility Lines - Collisions with utility lines have been documented for a wide variety of bird species including shorebirds (Kitchin 1949, Bevanger 1994, Brown and Drewien 1995, Janss and Ferrer 1998). Placement of utility lines adjacent to intertidal areas may degrade habitat quality by increasing the likelihood of in-flight collisions (Scott et al. 1972, Lee 1978). Fatal injuries to shorebirds following collisions with utility lines have occurred where utility lines were situated adjacent to intertidal foraging areas in western Washington and at the Fraser River estuary in British Columbia (Kitchin 1949; J. Buchanan, unpublished data; R. Butler, personal communication; S. Richardson, personal communication).

Wind Turbines - Mortality of shorebirds has been documented at wind turbine sites in the Netherlands (Musters et al. 1995, 1996) and in the United States (Erickson et al. 2001), although the rate of documented mortality was generally low. It is likely, however, that mortality would be greater at complexes of turbines situated along flight corridors used by large concentrations of shorebirds. Wind turbine sites in southeastern Washington occur near areas used by a relatively small flyway of migrating shorebirds, but the potential impact of the turbines on those shorebirds is currently unknown. There are relatively few wind turbine sites in Washington at present, but it is expected that many such sites will be established in the near future as the technology for managing this efficient source of energy is refined. The significance of wind turbines as a source of mortality will likely depend on the number and location of these complexes built in the coming years.

Other Potentially Hazardous Structures - One million or more birds are killed annually across North America in collisions with structures such as skyscrapers and communication towers (see www.towerkill.com [1998]). Because of their great height, these structures are a hazard to low-flying migrant birds. Even the illumination from safety lights is thought to confuse birds, causing circling behavior around the structure that increases the likelihood of collisions with support cables or the structure itself (Avery et al. 1976). As of November 1998, there were 241

towers exceeding 61 m (200 ft) in Washington, including 19 towers of at least 152 m (500 ft). Many of these towers are located in the Puget Trough; the presence of these towers may be a mortality factor for shorebirds that overwinter and/or migrate through this region. The potential magnitude of this factor has not been addressed (see www.towerkill.com [1998]). Shorebirds have also been documented colliding with coastal lighthouses; multiple incidents involving red-necked phalaropes occurred at the Destruction Island lighthouse in 1916 (Bowles 1918). Such occurrences are poorly documented, but this is likely related to limited access and search efforts at such sites.

Pollution

Chemicals and Heavy Metals - Research from other temperate coastal regions indicates that rather high levels of organochlorine contaminants (White et al. 1980, White et al. 1983) and heavy metals (Goede 1985, Goede and de Voogt 1985, Blomqvist et al. 1987, Ferns and Anderson 1994) occur in shorebird tissues. Although the effects of these contaminants on shorebirds are not known, physiological and behavioral abnormalities associated with high contaminant levels have been reported for other temperate marine bird species (Gilbertson et al. 1976, Gilbertson and Fox 1977, Sileo et al. 1977, Fox et al. 1978).

Contaminant levels have been reported in black-bellied plovers, dunlins, and western sandpipers wintering in western Washington (Schick et al. 1987, Custer and Myers 1990). Both studies found levels of organochlorine contaminants below those known to affect the survival or reproduction of shorebirds. However, some spring migrants from Grays Harbor carried very high DDE residues (Schick et al. 1987). Black-bellied plovers from two Puget Sound sites carried low levels of mercury and elevated levels of selenium (Custer and Myers 1990). In addition, dunlins occasionally ingest lead shot (Kaiser et al. 1980, J. Buchanan, unpublished data), but residue levels of lead in shorebirds are unreported for this area. Given the lack of current data on concentrations of organochlorine and heavy metal contaminants in shorebirds in this area (Schick et al. 1987, Custer and Myers 1990), it is difficult to assess the potential current effects related to these contaminants. Other contaminants, such as organophosphorus insecticides, also occur in the environment; there is no information on the presence or effects of these contaminants on shorebirds in this region (Morrison 1991).

Contaminants known or suspected to have originated from upland agricultural areas have been documented in shorebirds (White et al. 1980, Zinkl et al. 1981, DeWeese et al. 1983, White et al. 1983, Schick et al. 1987, Custer and Mitchell 1991). The discovery of contaminants (i.e., selenium) in waterfowl and wading birds that use freshwater marshes (Ohlendorf et al. 1986, Saiki and Lowe 1987, DuBowy 1989, Williams et al. 1989) suggests that common snipe, American avocet, black-necked stilt, and Wilson's phalarope may be vulnerable to exposure to a similar variety of contaminants. Two incidents of dunlins killed after exposure to agricultural chemicals have been reported from northern Puget Sound (Lora Leshner, personal communication). In California, killdeers and dunlins died after ingesting grain poisoned by strychnine (Warnock and Schwarzbach 1995); the likelihood of such an event occurring in Washington is unknown.

Heavy metals and other contaminants are present in naturally-occurring and dredged sediments in estuaries, and accumulate in fish, birds, mammals, and invertebrates (Goerke et al. 1979, Seelye et al. 1982, Duinker et al. 1984). Contaminants can also be released from sediments by bait digging in the intertidal zone (Howell 1985). Intake of these contaminants occurs when shorebirds forage in intertidal areas. Other sources of pollutants include waste discharge, which has been associated with the disappearance of invertebrate prey species of shorebirds in the Netherlands (Esselink et al. 1989, van Impe 1985). The significance of waste discharge on shorebird abundance or physical condition in this region is unknown.

Oil Pollution - In a summary report on the potential effects of oil spill contamination in northern Puget Sound and the Strait of Juan de Fuca, 10 shoreline habitat types were identified in the order of their sensitivity to oil contamination (Kopinski and Long 1981). Three of the four most sensitive habitat types - sheltered marshes, sheltered tidal shores, and exposed tidal flats - are primary foraging and roosting habitats for numerous shorebird species. The most abundant wintering shorebird species to use these habitats, the dunlin, is considered highly sensitive to oil spill pollution (Vermeer and Vermeer 1975). Other species, such as the sanderling, are likely sensitive as well (Chapman 1984). Certain species that use rocky shoreline habitats may be less vulnerable to some impacts from oil spills (Smith and Bleakney 1969), since oil would have a shorter "residence time" on rocky shorelines exposed to high wind and wave energy. This reduces the time period during which birds would be exposed to oil, although short-term impacts to these species can still be substantial (Andres 1997).

Spill-related avian impacts can be manifested in at least 5 ways. First, direct mortality occurs due to a number of factors related to plumage fouling or toxicity (Leighton 1990). Second, reduced invertebrate food supplies caused by oil pollution (Bellamy et al. 1967, Grassle et al. 1980, Maccarone and Brzorad 1995) may result in reduced survival rates if birds are forced to relocate to densely-occupied or less productive areas (Sutherland and Goss-Custard 1991). This is especially true during winter, when foraging efficiency may be constrained by adverse weather, particularly if body-fat reserves are too low to fuel significant emigrations. Third, the activity associated with the actual cleanup of the spill may disturb shorebirds to such an extent that foraging and roosting patterns are disrupted (Burger 1997). Fourth, research indicates that oiled shorebirds spend more time preening and less time foraging after a spill (Burger 1997). Burger (1997) concluded that this was a potentially negative influence on the condition of the birds upon their departure for migration (and also on their arrival at the breeding grounds; see above), and added that the detrimental effects were magnified by the presence of people (see section on human disturbance). Finally, oiled birds may be more vulnerable to predation, particularly if 1) plumage fouling or thermal stress make them less efficient at avoiding predators, or 2) their marked plumage or altered behavior make them more conspicuous to predators (Curio 1976).

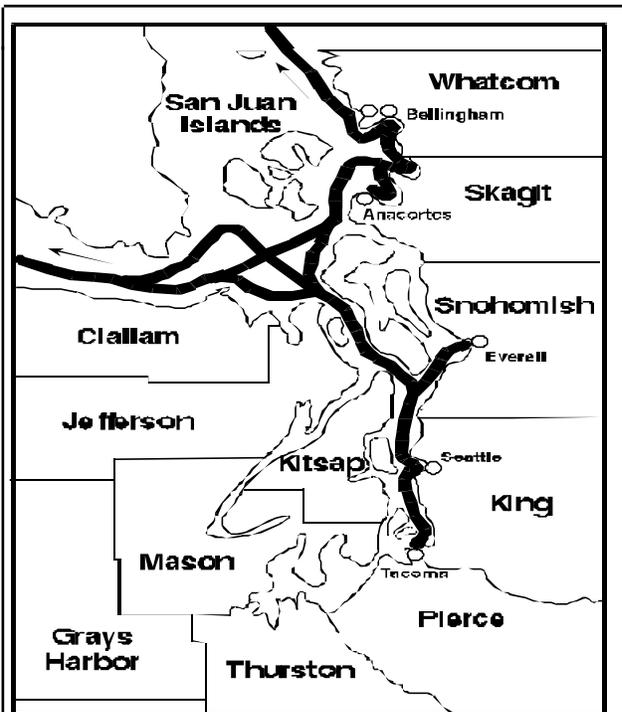


Figure 2: Major shipping lanes in the Puget Sound and the Strait of Juan De Fuca. These lanes extend northwards through the Strait of Georgia, and along Washington's outer coast into the Columbia River.

Recent experience indicates that oil pollution is a significant potential threat to shorebirds in this region. Larsen and Richardson (1990) found that 3,574 of 11,708 shorebirds (mostly dunlins) were still oiled 5 days following the *Nestucca* oil spill off Grays Harbor in December, 1988. This proportion of oiled birds declined over the next 3 weeks, and it was unclear whether the decline was related to self-cleaning, emigration, or mortality. The beaches fouled by this spill support very high overwintering concentrations of sanderlings and roosting dunlins (Buchanan 1992). It is noteworthy that the largest Puget Sound populations of shorebirds in winter, spring, and fall occur at estuaries in close proximity to major shipping lanes and/or oil refineries (Evenson and Buchanan 1995, 1997; Figure 2).

Other Sources of Pollution - Plastic-particle pollution has been documented in most marine waters (Coe and Rogers 1997) and occurs when plastic debris (e.g., packaging material) enters the marine environment from land (Liffmann and Boogaerts 1997, Redford et al. 1997) or at-sea sources (Coe and Rogers 1997). The variety of plastic waste present in the marine environment is quite high and differs from one site to the next (Ribic et al. 1997). Debris surveys conducted at the ports of Seattle and Tacoma and on the beach at Olympic National Park reported high amounts of plastic debris; the park survey in 1992 found an average quarterly accumulation of 1729 pieces of plastic debris/km (Ribic et al. 1997). Plastics digestible by wildlife comprised between 44-74% of the debris found in surveys along the west coast of North America (Ribic et al. 1997).

Plastic pollution in marine environments is potentially detrimental to shorebirds and other wildlife after it is intentionally or accidentally ingested. Small particles are ingested by surface feeding marine birds (Baltz and Morejohn 1976, Day et al. 1985) and have been associated with reduced fat deposits (Connors and Smith 1982, Ryan 1988) and perhaps intestinal blockage and ulcerations in other species (Day et al. 1985). Among shorebirds, the red phalarope appears most vulnerable to this type of contamination in Washington (Bond 1971, Connors and Smith 1982, Day et al. 1985), although other shorebird species have been known to ingest plastic particles (i.e., bar-tailed godwit [*Limosa lapponica*] and red-necked phalarope; Robards et al. 1997).

Human Disturbance

Human disturbance has the potential to influence shorebirds in at least 3 ways (Fox and Madsen 1997). First, substantial disturbances force birds to alter their normal activity patterns resulting in an increase in energetic costs. Second, shorebirds forced to leave an area due to human disturbance may settle in lower-quality alternate habitats. Third, increased energetic costs and use of lower-quality habitats may expose shorebirds to greater risks of predation. The occurrence and potential significance of these patterns is only now beginning to be investigated and understood in North America.

Many human disturbances are related to recreation. Sources of disturbances include beachwalkers, wandering dogs, birdwatchers, hunters, windsurfers, horseback riders, cyclists, vehicles, boats, kayaks, personal water craft (e.g., jet skis), helicopters, and airplanes (Kirby et al. 1993, Goss-Custard and Verboven 1993, Koolhaas et al. 1993, Smit and Visser 1993). In Washington, these types of activities are responsible for both inadvertent and intentional disruption of foraging and roosting behavior (J. Buchanan, unpublished data). Most disturbances from recreational sources are temporary (e.g., birds relocate to a new site following a disturbance). However, cumulative effects of repeated disturbances, particularly during periods of peak human activity (Kirby et al. 1993), or during periods of peak shorebird abundance (e.g., migration; Burger 1986) may be significant (Klein et al. 1995), although this has not been well assessed (Goss-Custard and Verboven 1993). Human disturbance may be most significant in areas where roost sites are limited (Warnock et al. 1995) because the birds do not have alternate sites they can use when disturbed.

Pedestrian and Vehicular Recreational Activities - Perhaps the most common type of human disturbance is recreational walking or other travel on beaches. Pedestrian or vehicle traffic on beaches or other areas used by shorebirds negatively affects shorebird distribution, abundance, foraging efficiency, and behavior (Burger and Gochfeld 1991, Pfister et al. 1992, Goss-Custard and Verboven 1993, Kirby et al. 1993). In fact, local population declines of sanderling, semipalmated sandpiper, short-billed dowitcher, and red knot along the Atlantic coast of North America may be related to site disturbance from moderate levels of vehicle traffic (Pfister et al. 1992). Klein et al. (1995) found that several shorebird species were more common in areas further from roads and trails (or dikes) on a wildlife refuge than in similar habitats near roads and trails. Some species (i.e., black-bellied plover, willet) were particularly sensitive to higher levels of vehicle traffic and responded by moving further from roads (Klein et al. 1995). Limited information suggests that black oystercatchers will abandon areas with regular human activity (Ainley and Lewis 1974, Nysewander 1977, Andres 1998); this may be particularly critical in nesting areas.

Human disturbance occasionally escalates to a point where shorebirds are killed. At North Beach, Washington, a beach open to vehicle traffic, roosting flocks of western sandpipers, dunlins, sanderlings, and dowitchers have been intentionally targeted by speeding motorists; at least 480 birds were killed in 2 separate incidents on this beach (R. Schuver, personal communication; M. Cenci, personal communication). Harassment by motorists of roosting shorebirds is not uncommon on Washington beaches (J. Buchanan, personal observation).

Water-related Recreational Activities - Shorebirds are also disturbed by recreational activities on water (Weston 1997). Smit and Visser (1993) reported that kayakers represent a potentially important source of disturbance to roosting birds because the small draft of a kayak allows close approach to roost sites in intertidal areas. Disturbance by personal motorized water craft (e.g., jet skis) has been documented at a large roost site in Grays Harbor (L. Vicencio, personal communication). These types of disturbances may occur throughout marine areas of Washington.

Waterfowl Hunting - A common human disturbance activity is waterfowl hunting. The noise associated with shotgun blasts disturbs foraging and roosting black-bellied plovers, greater yellowlegs, dunlins, and western sandpipers in Washington and can cause birds to temporarily leave an area (J. Buchanan, unpublished data). In a review of the effects of hunting disturbance on waterbirds (including shorebirds), Madsen and Fox (1995) reported that hunting disturbances can result in temporary disruption of daily activities (foraging, roosting, preening) and displace birds from preferred foraging areas. These responses to hunting disturbance result in greater energetic costs due to under-exploitation of preferred foraging areas. Given that populations of many species may be limited during the winter period the potential significance of the disturbance is clear, though it is unknown whether the level of disturbance from hunting reduces the physical condition or survival of shorebirds in Washington.

Although many shorebird species were hunted formerly (Bent 1927, Page and Gill 1994), the common snipe is the only shorebird game species in Washington. Other species, including dunlin, long-billed dowitcher, and greater yellowlegs, are occasionally shot by hunters who mistake them for snipes (Hainline 1974, J. Buchanan, unpublished data; R. Butler, personal communication; J. Hidy, personal communication). In a small sample of snipe wings submitted anonymously by hunters, 18% of the wings were actually from long-billed dowitchers (Buchanan and Kraege 1998). It is currently unclear whether this source of mortality is as substantive as these preliminary data suggest.

Intentional killing of non-game shorebirds by waterfowl hunters has also been documented at several sites in western Washington, including Samish Bay, Totten Inlet, and Willapa Bay (J. Hidy, personal communication; R. Woods, personal communication, J. Buchanan, unpublished data). The Willapa National Wildlife Refuge is closed to snipe hunting to reduce the likelihood that nontarget species will be shot (J. Hidy, personal communication).

Aircraft - Aircraft traffic and military activities can also disturb shorebirds (Smit et al. 1987, Koolhaas et al. 1993, Smit and Visser 1993). In a review of shorebird disturbance factors in Europe, Smit and Visser (1993) found that the distance at which shorebirds flushed varied among sites, suggesting that shorebirds were less habituated to aircraft disturbances at certain sites. Nonetheless, they reported that shorebirds were usually disturbed (e.g., they flushed from foraging or roosting sites) by aircraft flying at <300 m (990 ft). Similarly, shorebirds were more restless on days with jet activity than on days without (Koolhaas et al. 1993). Helicopters disturbed shorebirds at greater distances than other aircraft, although one study showed no disturbance from helicopters flying at 100-300 m (330-990 ft) 2-3 times per hour, suggesting, perhaps, that habituation had occurred to the regular flights (Smit and Visser 1993). Small and slow flying aircraft were one of the most disturbing phenomena in the Wadden Sea area (Smit and Visser 1993). Additionally, ultralight aircraft may cause impacts because of low flights and associated noise, although there are no data on shorebird responses to this potential source of disturbance (Smit and Visser 1993).

Environmental Conditions, Predation, and Disease

The effects of adverse weather, predation, and disease on the physical condition of shorebirds is important from a management perspective. Although these factors (i.e., general storm patterns, predation) typically operate at a level beyond human influence, their significance may be far greater if coupled with the effects of subsequent human activities (e.g. habitat loss, pollution, disturbance). Consequently, a general understanding of these factors is necessary for effective management.

Adverse Weather Conditions - Reduced body mass, emigration, depleted invertebrate food sources, reduced availability of adequate nesting and foraging areas, and outright mortality are known to occur during winter storms or prolonged periods of flooding or drought. The impact of winter storms may be more severe in regions with normally mild weather conditions because shorebirds maintain fat levels and muscle mass (i.e., protein reserves) adequate for survival under the prevailing environmental regime (Davidson 1981, Davidson and Evans 1982, Davidson et al. 1986a, b; Dugan et al. 1981). Unusual storm events therefore have the potential to catch the birds "off guard".

Flood and drought conditions are known to influence habitat use by shorebirds. Drought in interior areas may result in reduced availability of foraging or nesting habitats, particularly for species that use wetlands (Alberico 1993). Significant flooding in estuarine or interior habitats may inundate foraging, roosting or nesting locations for extended periods, and in estuarine areas may deplete invertebrate populations through erosion or scouring of fine intertidal sediments (Ferns 1983). These conditions are unsuitable for certain species and can result in reduced body condition or site abandonment (Strauch 1966, Rundle and Fredrickson 1981, Hands et al. 1991, Warnock et al. 1995). Extensive winter movements (up to 160 km [100 mi]) in response to adverse weather have been documented in California (Warnock et al. 1995) and appear to occur in Washington (Evenson and Buchanan 1995, 1997).

On the other hand, changes in water levels, particularly at interior sites, may create more suitable conditions for certain shorebird species (Rundle and Fredrickson 1981, Hands et al. 1991, Smith et al. 1991, Taylor et al. 1993). Sites that generally lack adequate foraging areas due to extremely high or low water levels will be used by shorebirds when foraging opportunities are created by changing water levels.

Global Warming - There is currently considerable debate regarding the ecological significance of global warming. A change in global temperature would likely have both predictable and unforeseen impacts on shorebirds. Changes in sea level will likely alter the distribution and extent of estuarine areas, and may reduce the area of intertidal and saltmarsh habitats available to shorebirds (Lester and Myers 1989-90). Other potential responses to global warming include changes in migration timing, migration routes, extent and quality of breeding habitats, and the availability of prey.

Other changes related to climatic conditions are occurring along the Pacific coast of North America. Recent research indicates that significant warming has occurred in waters of the California Current. This warming has been linked to declines in zooplankton and seabird populations (Roemmich and McGowan 1995, Veit et al. 1996). Changing conditions in offshore waters may influence the distribution and abundance of phalaropes migrating through the region. In addition, rock sandpiper numbers have declined substantially in the southern portion of their wintering range during this period of oceanic warming (Buchanan 1999).

Predation - Predation is a potentially significant limiting factor because it is a substantial source of mortality among shorebirds. The overall mortality rate of most shorebird species is very high (Martin-Löf 1961, Boyd 1962, Soikkeli 1967, Gromadzka 1983; see Warnock et al. 1997). The presence of predators in an area typically results in heightened levels of vigilance by shorebirds (Metcalf 1984). This enhanced vigilance, in combination with other sources of disturbance, can have a potentially significant effect on shorebird activity schedules and physical condition (Burger 1997). Perhaps the most significant predators of shorebirds in Washington are the peregrine falcon (*Falco peregrinus*) and merlin (*F. columbarius*), both recognized as priority species in Washington. An estimated 21% of a wintering population of dunlins in California were taken by falcons (Page and Whitacre 1975). In some situations predation by raptors may influence the latitudinal distribution of wintering shorebirds (Whitfield et al. 1988) as well as population structure (Townshend 1984). Some studies show that juvenile shorebirds are preferentially selected by raptors, or that they are more vulnerable to predation because they roost in atypical habitats (Kus et al. 1984, Townshend 1984). Shorebirds also respond to the presence of mammalian predators such as rats; this may be most significant at nocturnal roosts (Burton et al. 1996).

Disease - The significance of disease for most shorebird species is unknown. However, outbreaks of avian cholera and botulism Type C are capable of killing thousands of birds, including shorebirds (Kadlec and Smith 1989).

Political and Management Constraints

Shorebirds as a group are characterized by annual, round-trip flights of enormous distances between wintering and breeding areas. This life history attribute alone makes it difficult for management agencies to identify species of concern and facilitate meaningful protection strategies. Factors that influence the health of shorebird populations may operate on the breeding grounds, the wintering grounds and/or along flyways. Consequently, managing shorebirds, particularly the highly migratory species, requires that these factors be addressed wherever they occur.

Current methods of identifying and protecting species of concern across broad geographical areas are somewhat limited in their utility (unless the species is listed by federal governments). For example, a species listed as threatened or endangered at the state or province level generally has no special standing elsewhere (except for basic protections under the Migratory Bird Treaty Act). This creates potential difficulties for management of a state-listed species if a limiting factor exerts significant influence during migration through a state or province where the species (does not breed and) is not listed. States tend to list only those species that have breeding populations within state boundaries and generally focus on determining a species' status within the state. In short, it is currently difficult, if not impossible, for states (and likely provinces) to effectively enact legal protection for species for which there is local or regional, but not federal, concern.

MANAGEMENT RECOMMENDATIONS

These management recommendations are based on a combination of locally and regionally important conservation issues. The following sections contain a spectrum of management recommendations that land owners, resource managers, and others can use to reduce impacts to shorebirds or to improve shorebird habitats. These recommendations address regional or large scale conservation issues, as well as site-specific actions that may be

meaningful to local sub-populations. Some of these recommendations can be implemented by landowners and local governments, while others are more policy oriented, and need to be addressed by state and federal agencies, and conservation organizations. Because of the broad range of shorebird distributions and their dynamic life history characteristics, it is important to understand these management issues at various spatial and temporal scales.

Habitat Identification and Preservation

Identify important local and regional sites - One of the first tasks required to protect shorebird habitat is to identify important local and regional sites. British workers have developed a system to evaluate site populations by comparing them to national, international and flyway populations (Prater 1981). Field work to identify locally and regionally important sites is ongoing in much of western North America (Page and Gill 1994; G. Page, personal communication), and many important sites in western Washington have been identified (Buchanan and Evenson 1997, Evenson and Buchanan 1997). Additional work is needed for the migration periods in eastern Washington, the fall migration period in western Washington, and for the group of rocky shoreline species along the Washington coast.

Wetland habitats of all sizes support shorebird populations in Washington. In North America, standards set forth by the Western Hemisphere Shorebird Reserve Network specify that sites which support at least 20,000 shorebirds or at least 5% of the flyway population are of regional importance (Myers et al. 1987a; Harrington and Perry 1995; I. Davidson, personal communication). This strategy appears to effectively identify several of the major estuarine sites in Washington. However, recent research in Puget Sound indicates that numerous sites support populations of <5,000 shorebirds, and that cumulatively these sites may account for as much as 20-50% of the Puget Sound shorebird population (Evenson and Buchanan 1995, 1997), indicating a need to recognize the importance of assemblages of smaller sites. This may also be particularly important for some shorebirds that migrate through the Columbia Basin (Robinson and Warnock 1996, Skagen 1997).

Preserve remaining wetland habitat - Preservation of remaining wetland habitat should be a priority for shorebird conservation programs. Locally and regionally important sites should be purchased to reduce the loss or degradation of habitat important for shorebirds and other wildlife. Following an assessment of water needs and a determination of salinization significance, efforts should be made to insure the availability of high-quality water for important wetlands and wetland complexes in the Columbia Basin. In a review of coastal wetland conservation strategies, Bildstein et al. (1991) recommended the development of new protective and regulatory legislation, and more effective enforcement of existing laws concerning wetland use.

Land Use Assessment

Assess livestock grazing in habitats used by shorebirds for potential impacts - Research indicates a number of direct and indirect impacts on shorebirds or their habitats due to grazing livestock (Powers and Glimp 1996). Negative impacts described elsewhere include the destruction of eggs or nests (Rohwer et al. 1979, Guldemond et al. 1993), abandonment of disturbed nests (Delehanty and Oring 1993), and adult birds spending an increased time away from their nests (Graul 1975), which likely results in increased exposure of eggs.

Assess commercial sand and gravel extraction from beach and riverine areas for potential impacts to shorebirds - Certain beach and riverine areas are important foraging, roosting, or nesting areas for shorebirds (Buchanan 1992, Paulson 1993). The development of a review process for these activities would help ensure that shorebirds are considered as part of the permitting process.

Utility Lines and Wind Turbines

Assess impacts associated with placement of new utility towers and lines - New towers and utility lines should not be placed in known or suspected flight corridors or near wetland areas used by shorebirds. New lines should be placed below ground if possible. In areas where placement of towers and lines have been proposed, an effort should be made to determine whether flight corridors or wetlands occur nearby so that more appropriate alternate strategies may be developed and implemented.

Mark existing utility lines to make them more visible - Where possible, existing utility lines should be marked or treated to make them more detectable by birds in areas where collisions involving shorebirds have occurred or are likely to occur. Techniques include: coating or painting wires, marking wires with mobile (i.e., non-stationary) spirals or strips of fiberglass or plastic, warning lights, and placement of predator silhouettes or acoustical devices to scare birds (Bevanger 1994). Recent research indicates that static wire-marking may effectively reduce the number of collisions birds have with power lines (Janss and Ferrer 1998); the wire markings used in that study included white spirals (30 cm diameter x 100 cm length) looped around the static wire and black crossed bands (two 35 cm bands attached side-by-side at their mid point) on conductors. Similarly, collision mortality (of cranes and waterfowl) was reduced in sections of transmission and distribution lines marked with dampers (112-125 cm [1.27 cm diameter] polyvinyl chloride plastic lengths twisted around the transmission lines and placed at 3.3 m intervals on the uppermost static wire) or plates (30.5 x 30.5 cm yellow fiberglass squares with a contrasting black diagonal stripe 5 cm in width and placed at 23-32 m intervals on static wires or center conductors) (Brown and Drewien 1995). Also, yellow marking devices may be more visible to birds and should be used in areas characterized by dark or cloudy conditions, whereas a combination of colors (red markers may be best in bright sunlight) would suffice for variable conditions (Raevel and Tombal 1991, Brown and Drewien 1995).

Some strategies may be more effective for certain species groups than others due to species differences in sound or color perception. Research should be conducted to evaluate the effectiveness of these and other techniques designed to reduce collisions (Bevanger 1994, English 1996). Evaluations of potential techniques should consider the type of behavior that places birds at risk. For example, the first 3 approaches listed above may be less effective in areas where shorebirds make significant nocturnal flights between foraging and roosting locations.

Other strategies to reduce the incidence of bird collisions with utility lines involve line configuration. Grouping multiple lines might make them more visible to birds, and the lines will occupy a smaller area of flight space, thus reducing the likelihood of collisions Bevanger (1994). In addition, the lines should be arranged side by side rather than in a vertical stacked formation (Bevanger 1994).

Assess impacts associated with placement of wind turbines - Wind turbines should not be placed in known or suspected flight corridors, near known concentrations of birds, or near wetland areas used by shorebirds. In areas where wind turbine placement has been proposed, an effort should be made to determine whether flight corridors, important wetlands, or other habitats occur nearby so that alternate strategies may be used.

Oil Spills

In the event of an oil spill, limit public access to beach or estuarine spill sites - Oiled birds typically spend a considerable amount of time attempting to clean their plumage and spend less time foraging (Burger 1997). This results in an increase in energetic costs. Consequently, the impacts of an oil spill can be exacerbated by disturbances caused by human recreation (e.g., beach walking), except in some circumstances where intentional disturbance is used to exclude shorebirds and other wildlife from oiled beaches. For this reason, public access to the vicinity of spill sites or areas where oiled birds occur should be limited as much as necessary or possible until shorebird roosting, foraging, and preening behavior returns to a baseline level.

Assess and enhance navigational assistance procedures for commercial marine vessels - An assessment of the causes of oil spills should be conducted to determine how navigational aids might reduce the incidence of these events. Although determining the specific enhancements is beyond the scope of this document, they might include better navigational charts or training, and increased tug boat availability to assist larger vessels that enter Strait of Juan de Fuca and Puget Sound waters.

Continue the development and refinement of oil trajectory models - A number of oil trajectory models have been developed for spill response management. These models typically incorporate factors such as characteristics of the oil; wave action and other physical processes; and oceanographic and meteorological factors such as tidal cycle, currents and weather (ASCE Task Committee 1996, Galt 1994, Galt et al. 1996). These models are used to respond to actual spills and to identify high risk sites (Begg et al. 1997). Because of the complex functioning of currents and tides within the Puget Sound region, however, researchers are attempting to develop new models to improve site protection and spill response. These important efforts should be continued and supported (Begg et al. 1997).

Develop baseline information needed to assess impacts of oil spills - Baseline information on shorebird abundance and habitat use is lacking for a number of species and should be updated periodically for all potentially vulnerable species. This information will be important for efforts to: 1) assess impacts of oil spills (Parsons 1996), 2) develop appropriate remediation for spill damages (Parsons 1996), and 3) improve protection and response strategies (Begg et al. 1997).

Plastics in the Marine Environment

Develop procedures for controlling spills of plastics into the marine environment - Small plastic particles injure surface feeding marine birds that intentionally or inadvertently ingest them. A strategy to control the amount of plastic that enters the marine environment will be complex because plastic waste originates from land and at-sea sources, it is virtually impossible to identify the origin of most debris (Ribic et al. 1997), and compliance is difficult to enforce (offenders are rarely caught; Laska 1997, Sutinen 1997). Local waste management programs are generally ineffective because the mobility of plastic makes this form of pollution a global management issue (Ninaber 1997).

Much of the land-based plastic pollution appears to enter the marine environment from storm water runoff. Moreover, plastic pellets are transported to marine waters from locations at any sector of the plastics industry (Redford et al. 1997), indicating that better containment is needed in all phases of pellet manufacture, packaging, transport, and use. Strategies to limit land-based sources of marine debris should involve development and implementation of regulatory and administrative measures, use of education to identify problems and solutions, creation of solid waste management infrastructure, use of new technologies, political commitment, and assessment and monitoring programs (Redford et al. 1997).

Support changes to marine pollution regulations that result in global control of marine plastic pollution. Annex V of the International Convention for the Protection of Pollution from Ships, known as MARPOL (73/78), was enacted in 1988 to reduce at-sea marine pollution. MARPOL is a product of the International Maritime Organization. Some authorities believe the provisions of MARPOL must be enhanced to be truly effective (Ninaber 1997). Improvements to MARPOL and other marine pollution regulations are needed and should consist of the following elements at the very least: 1) technological innovations that reduce the amount of plastic materials used on ships or that allow for at-sea processing, 2) organizational and operational changes within the shipping and marine recreation industries to facilitate policy development that addresses waste management, 3) educational communication that is designed to promote an environmental ethic and which targets specific marine 'user' groups, 4) government and private regulation and enforcement efforts that require development of waste management plans for ocean-going vessels and that extend authority to state or municipal authorities to levy fines for illegal dumping, and 5) creation of economic incentives by promoting development and use of recyclable products and development of on-board waste-processing equipment (Laska 1997). Finally, because waste management in the marine environment is a global issue, a standardized approach that facilitates participation by vessels and ports world-wide is needed. Incompatible vessel and port waste management programs (e.g. removal and handling of recyclable waste) will result in failure to control marine plastic pollution. For additional recommendations regarding plastic particle pollution, see Koss (1997), Laska (1997), Liffmann et al. (1997), Ninaber (1997), Sutinen (1997), and Wallace (1997).

Pesticides and Other Chemicals

Use extreme caution when applying chemicals near habitats used by shorebirds - Some pesticides (including insecticides, fungicides, rodenticides, herbicides) and fertilizers (including animal waste) can directly kill fish and wildlife and indirectly affect habitat quality when used inappropriately. Because information on the toxicity and effects of specific chemical treatments to fish and wildlife is scarce or lacking for many chemical compounds, a conservative approach to chemical treatments is recommended and alternatives to chemical use are encouraged (Odum 1987). Appendix A (of this volume) lists contacts useful in assessing pesticides, herbicides, and their alternatives.

Use current information to establish buffer zones when applying chemicals - Buffer zones should be implemented around shorebird and waterfowl nesting habitat in agricultural landscapes to minimize the impacts of spray drift (e.g., Payne et al. 1988), particularly when the effects of drift are negative or unknown. These buffer zones should be specific to the types of chemicals used and their methods of application. Creation of adequate buffer zones

requires up-to-date information about the potentially adverse effects of various compounds on estuarine and wetland ecosystems and the wildlife that use these habitats.

Promote public education about chemical use and wetland functions through natural-resource agencies, local governments, conservation groups, and others - There is a need for a general understanding by the public that actions near or within wetlands affect the proper functioning of the ecosystem (Grue et al. 1986). Efforts to provide important information to the public will likely require elements of research, monitoring, and education. Implementation of an integrated training and certification program for landowners and commercial pesticide applicators has been recommended as a means to provide pesticide users with important biological information and training (Grue et al. 1989).

Human Disturbance

Control public access and human activities in areas important to shorebirds - This may consist of directing foot traffic away from roosting or foraging sites that should not be disturbed by human visitors. Similar efforts to control areas open to the public at Grays Harbor during spring migration appear to have been successful although an ecological assessment of human disturbance on shorebirds there has not been done. Similarly, Pfister et al. (1992) recommended identifying important beach areas and establishing vehicle restriction zones during critical roosting periods to reduce disturbance to shorebirds.

Develop site-specific strategies to manage human disturbance - Important wintering and migratory staging sites should be identified so that site-specific strategies can be developed, as necessary, to manage human disturbance. Potential strategies include developing informational signs that identify or describe important foraging or roosting areas. Groups of volunteers ("beach patrols") at the Dee estuary in Europe have successfully educated the public about shorebird ecology by distributing leaflets and leading organized birdwatching trips to roost sites (Kirby et al. 1993). It may be possible to coordinate similar groups of volunteers in Washington if future site disturbance warrants such action.

Post informational signs to reduce human disturbance - Informing the public about the sensitivity of large concentrations of roosting or foraging birds may reduce disturbance at such sites. One means to accomplish this would be to post informational signs at beach access points, public boat launches, or other marine access points.

Address the effects of disturbance in refuge management plans - Management plans for existing or proposed refuge or wildlife management areas should address the potential impacts of hunting and other human disturbances. Fox and Madsen (1997) assert that many refuge/wildlife management areas are linear in shape and as a consequence have few disturbance-free areas. They propose that refuges should be designed to provide disturbance-free areas and adequate buffer zones, and that refuge design must take into account the ecology of the species expected to use the area. For shorebirds, this means identifying important foraging and roosting areas and accounting for typical spatial and temporal patterns of use. For example, it would be important to determine whether shorebirds exhibited differential use of diurnal and nocturnal roost sites, and whether there was age-, sex- or species-related segregation in habitat use (Meltofte et al. 1994). In addition, it has been recommended that complexes of disturbance-free roosting sites should be situated such that the distance among roosts is equal to normal intra-roost flight distances of the species that typically move the shortest distances within a single estuary (Rehfishch et al. 1996). Obviously, a substantial amount of information is needed to examine the issue of disturbance and to develop scientifically-based management guidelines as needed (Hill et al. 1997).

Assess the level of unintentional shorebird mortality due to hunting - The level of unintentional mortality of shorebirds due to hunting is likely very low. An evaluation of this source of mortality would provide an indication as to whether a new identification/information guide for shorebirds should be developed for inclusion in a waterfowl hunting pamphlet. Such an assessment may allow for more effective refuge design or area access considerations.

Implement educational programs that inform the public about the ecology and behavior of shorebirds through natural-resource agencies, local governments, conservation groups, and others - This may reduce harassment of shorebirds in areas of high use by humans (Kirby et al. 1993). In addition, public education programs should emphasize the international scope of shorebird conservation (Bucher 1995, Finney 1995); such an effort should greatly improve conservation efforts throughout the western hemisphere (Castro 1993). Finally, resource

management agencies and wildlife interest groups must work together to improve regional involvement in international conservation efforts. Such efforts require improved information on the basic ecology of flyway species, identification of significant threats or potential impacts, and development of real conservation measures (Davidson et al. 1995).

Control of Exotic Species

Continue efforts to control the establishment and growth of cordgrass, purple loosestrife, and other noxious weeds- A substantial effort is underway to implement an integrated weed management program in Puget Sound and Willapa Bay following guidelines set forth in an environmental impact statement on noxious emergent plant control (Washington Department of Agriculture et al. 1993). Potential methods to eradicate noxious weeds include biological control, repeated mowing, hand pulling of seedlings, and chemical treatment (Washington Department of Agriculture et al. 1993). Some of these methods are currently being used (Kilbride et al. 1995, Washington Department of Fish and Wildlife 1995c). A monitoring and assessment strategy is essential to determine the efficacy of the methods and to safeguard against unanticipated impacts (e.g., those resulting from chemical application). Appendix A lists useful contacts for assessing pesticides, herbicides, and their alternatives.

Develop guidelines or regulations to control the transport of exotic invertebrates in marine waters - A large number of exotic invertebrate species are transported in ship ballast and discharged in estuarine or portside waters around the world (Carlton 1985). Ballast occasionally is discharged in "technically restricted places" if it is felt that petroleum products are not contained in the ballast (Carlton 1985), making current controls on ballast uptake and discharge limited or ineffective. Due to the potentially deleterious effects of exotic marine invertebrates on native marine assemblages and the apparent lack of meaningful controls on ballast management, policy makers and resource management agencies should work with marine transport organizations to develop meaningful procedures for uptake and discharge of ballast.

Restoration/Creation of Habitat

The restoration or creation of tidal and nontidal areas for overwintering shorebirds is a possible means to mitigate environmental impacts. There is potential risk associated with this approach, however, because shorebirds do not settle in their winter quarters in a random manner, but rather return to areas used in previous years. Little information is available to assess the potential effectiveness of such restoration efforts (Wilcox 1986, Rehfish 1994), and it is stressed that restoration is not an adequate substitute for safeguarding existing wetlands. Mitigation efforts at wintering grounds must recognize that habitat loss will most likely result in density-dependent competition at other sites in the region (see below).

Restoration of habitats used during breeding and migration seasons is also an important consideration. Substantial efforts are currently underway in the intermountain west to manage and restore wetland habitats (Inter-mountain West Joint Venture; Ratti and Kadlec 1992). These efforts should be supported.

There are many risks, often unforeseen, associated with restoration/creation projects. For example, restoration projects that reduce shore width typically result in the covering of adjacent high-level sandy tide flats with fine silt (Hill and Randerson 1986); the resulting change in substrate may not support species that formerly used the site (Burton et al. 1996).

Develop site-specific strategies for restoration projects - Information on local water, soil, and vegetation conditions and requirements (freshwater environments; Hammer 1997) or tidal, wind pattern, sea swell, and substrate conditions (marine environments; see below) needs to be incorporated.

Create new sites at least five years prior to modification of natural habitat - Artificially created sites should provide for all displaced birds and should address this need at least 5 years prior to the modification of natural habitat to allow an assessment of its success (Davidson and Evans 1987). Specifically, this 5-year period is needed to: 1) identify suitable sites; 2) acquire, design, and construct the mitigation features at sites; 3) allow settlement and stabilization of suitable sediments; and 4) allow colonization of sufficient densities of invertebrate prey species (Davidson and Evans 1987).

Address population dynamics at long-term and regional scales through mitigation - Mitigation studies should model population dynamics in a variety of local habitats over wide spatial (e.g. coastal, Puget Sound, and interior) and temporal (e.g., at least 5 years) scales. This is important because 1) shorebirds may use a variety of habitats (e.g., intertidal mudflats, beach, salt marsh) in an area (Burger et al. 1997); 2) changes in shorebird populations at a site during the nonbreeding season may also reflect responses to factors at other sites within the estuary, at other estuaries, or even at breeding areas (Goss-Custard and Durell 1990, Goss-Custard and Yates 1992); and 3) impacts to a site may influence shorebird populations at other sites.

Evaluate shorebird use of artificial impoundments - Artificially created sites may be very important to shorebirds, particularly in the Columbia Basin. Artificial drawdown sites may provide more nesting opportunities for certain species depending on the type of shoreline or the availability of nesting substrate (Paton and Bachman 1996). Care must be taken, however, to determine whether the spatial extent of the shoreline area created by the drawdown concentrates predator search effort and leads to high predation rates (Rönkä and Koivula 1997). In addition, efforts to modify such sites should be evaluated in the same manner as undisturbed sites (Warnock and Takekawa 1995).

Create adequate roost sites - Roost sites are an important habitat resource used by shorebirds during the nonbreeding season. Although most shorebirds appear to prefer salt marshes and beaches as roost sites, they also use dredge-spoil islands and other human-created areas. Shorebirds will likely use artificial sites if they are properly designed. A primary consideration in creating a roost site is that it must be designed to address the needs of the species that will use the site. Island roosts should provide shelter from strong winds or sea swell if these are significant environmental conditions in the particular area (Burton et al. 1996). In addition, Burton et al. (1996) recommended that island roosts should be open, with flat tops and gently sloping sides so that the birds can effectively scan for predators (Metcalf 1984).

Manage artificial (freshwater) sites for breeding season use - Shorebirds will nest in artificial wetlands and impoundment drawdowns when certain conditions are met (Green 1988, Paton and Bachman 1996). The first consideration required when managing habitats for breeding birds is to determine the focal species that will use the site. Nesting requirements are quite different for species like the killdeer and American avocet. Other considerations include the depth of water in impoundments and the availability of invertebrate prey (see sections below).

Manage artificial (freshwater) sites during fall migration - During fall migration, shorebirds are attracted to drawdowns in reservoirs and other artificial impoundments, flooded agricultural lands, and artificial fish ponds (Rundle and Fredrickson 1981, Hands et al. 1991, Smith et al. 1991). Gradual draw-downs in impoundments are recommended because this more effectively facilitates the extended-use period of shorebirds during fall migration and assures availability of resource alternatives as local conditions change (Rundle and Fredrickson 1981, Skagen and Knopf 1994). Rundle and Fredrickson (1981) further recommended that shallow [0-5 cm (0-2 in) deep] flood pools be interspersed with exposed saturated soils to enhance shorebird use; shorebirds also used areas disked prior to flooding. It is important to maintain drawdown and flooded lands habitat for the duration of fall migration to provide habitat conditions favorable for late-season movements of juveniles (Morrison 1984, Hands et al. 1991). Shorebirds are attracted to these artificially created areas during spring migration, but seem to use them less than during fall (Rundle and Fredrickson 1981, Hands et al. 1991), although data from sites in the Pacific Northwest are lacking.

Maximize invertebrate production at artificial (freshwater) sites - Artificial impoundments will be most effective if the site contains features that maximize invertebrate production and foraging efficiency by shorebirds (Rehfisch 1994). The enhancement or creation of artificial sites will require local knowledge of the potential for a specific site to support desired populations of invertebrates. Some recommendations for the management of artificial impoundments are provided in Table 2.

Table 2. Features of pastures, fields, and artificial impoundments that maximize benefits for nesting or migrating shorebirds.

Site feature	Recommended condition or action	References
Water depth	<ul style="list-style-type: none"> • Less than 5 cm (2 in) for sandpipers. • Less than 10-15 cm (4-6 in) for larger species (e.g., yellowlegs, avocets). Areas of slightly deeper water may be suitable for phalaropes. • Particularly at sites with a permanent or long-term management emphasis, areas of deeper water [>30 cm (12 in)] should be maintained in the center of impoundments to minimize winter mortality of invertebrates. Also, the deeper area(s) should not be allowed to dry out and would thus act as a source from which invertebrates might colonize areas flooded during migration periods. 	<p>Hands et al. (1991), and Rundle and Fredrickson (1981)</p> <p>Rehfisch (1994)</p>
Seasonal availability	<ul style="list-style-type: none"> • Impoundments and managed drawdowns may be most important during autumn migration. Where possible, maintain a number of units (e.g., 6) during peak periods of anticipated use to ensure the availability of suitable conditions; the most important period in eastern Washington is probably August-September. • Gradual drawdowns create suitable conditions over a longer time period. 	<p>Hands et al. (1991), Rundle and Fredrickson (1981)</p>
Vegetation	<ul style="list-style-type: none"> • In impoundments generated by spring precipitation or runoff, greater water depths may be needed to inhibit growth of undesirable aquatic vegetation. Short drying periods may also be required to control invasive plant species. • Dense shoreline vegetation may impede use by shorebirds. • Use of pastures by small and medium-sized shorebirds increases when vegetation is <20 cm (8 in) tall; shorebirds appear to prefer sites with vegetation <10 cm (4 in) tall. 	<p>Rundle and Fredrickson (1981) and Rehfisch (1994)</p> <p>Rundle and Fredrickson (1981)</p> <p>Colwell and Dodd (1997)</p>
Special methods of site preparation	<ul style="list-style-type: none"> • Disking prior to flooding may improve site conditions. 	<p>Rundle and Fredrickson (1981)</p>
Arrangement of units	<ul style="list-style-type: none"> • Where possible, maintain a number of sites (e.g., 6) during peak periods of anticipated use to ensure the availability of suitable conditions. • Create mosaic of shallow water areas interspersed with areas of exposed, saturated soil. 	<p>Hands et al. (1991) and Reid et al. (1983)</p> <p>Rundle and Fredrickson (1981)</p>

Maintain agricultural areas and pasturelands near sites used by shorebirds - Colwell and Dodd (1995, 1997) recommended that a mosaic of pasture lands with various vegetation heights and flooding conditions be maintained in coastal areas near estuaries. They felt that it might be possible to manage for appropriate vegetation height through cattle grazing. They added, however, that the information needed to make specific recommendations about grazing intensity and timing was not currently available. Similarly, Rottenborn (1996) stated that the greatest use by shorebirds of agricultural lands in Virginia was in areas of flooded, bare (plowed) earth. He believed that the potential value of staging areas might be enhanced by managing adjacent pasture and agricultural lands for the open conditions most often used by shorebirds. Prescribed fire may be a potential method to create or enhance shorebird habitat in certain upland areas (Stone 1994).

Effectively manage artificial sites - There are several additional practical issues that should be addressed by those interested in creating or maintaining artificial habitats (Engilis and Reid 1996). First, in areas where flooding or erosion are important issues, it will be necessary to design and use spillways properly to prevent damage. Second, exotic species such as carp and purple loosestrife must be controlled and their potential reinvasion routes managed to prevent the reestablishment of these species. Third, in areas with a controlled water source it is important to maintain water flow, provide adequate draining, and use adequate spacing between inflow and outflow points to minimize stagnant water and reduce the likelihood of outbreaks of avian cholera and botulism Type C (Kadlec and Smith 1989). Fourth, an assessment of soil conditions is necessary to determine whether the site will effectively hold water (e.g., prevention of drainage to the water table, or seepage through dikes). The capacity of a site to contain water may be accomplished with as little as 10% clay content although 30% clay content is more desirable

(Engilis and Reid 1996). Finally, artificially constructed islands designed as shorebird nest sites must have a gently sloping shoreline (a minimum 5:1 ratio to a height 30-60 cm above water level is recommended; Engilis and Reid 1996) and be large enough to enable shorebirds to effectively use predator avoidance behavior to protect eggs or fledglings. Resource managers should consult Engilis and Reid (1996) and Hammer (1997) for more details about wetland habitats and restoration.

Consider other recommendations - Evans (1991) made a number of additional recommendations that should be considered in any restoration or mitigation project. These recommendations are based on shorebird ecological studies and do not reflect results of actual mitigation assessments, which are largely lacking. First, many wintering shorebirds forage in protected areas during periods of strong winds. In areas where strong winds are known to occur, it may be important to provide sheltered, yet open feeding areas. This might be accomplished by excavating channels through mitigation tideflats. Second, it may be possible to increase the availability of invertebrate prey at wintering sites by discharging clean cooling water from industrial processes. Evans (1991) suggests that increases in prey availability may occur if such discharges increase water and mud temperatures. However, it is recommended that such action be done experimentally and evaluated for its potential impacts to plankton and invertebrate communities prior to more widespread use. Finally, creation of adjacent wetlands may be beneficial in some situations where reclamation eliminates habitat and effectively reduces the amount of time that shorebirds can spend foraging at a site. This may be particularly important for smaller shorebirds that face a competitive disadvantage to larger species for spatially or temporally limited resources (Davidson and Evans 1986). [Shorebird conservation planning documents were prepared after this PHS document was completed; see Brown et al. (2000) and Drut and Buchanan (2000)].

Conservation Planning

Develop a comprehensive planning process within state and federal natural resource agencies - Managing for shorebird populations in Washington requires development of comprehensive conservation objectives for the various shorebird species and the habitats they use. This must be done in the context of a landscape scale that incorporates the full range of species occurrences and community interactions in the habitats involved (Skagen 1997). Accomplishing this will likely facilitate more effective implementation of the recommendations described above and will likely provide greater opportunities to address the conservation needs of other species associated with the habitats used by shorebirds (Dickson and McKeating 1993, Laubhan and Fredrickson 1993, Streeter et al. 1993, Fredrickson and Laubhan 1994) [Shorebird conservation planning documents were prepared after this PHS document was completed; see Brown et al. (2000) and Drut and Buchanan (2000)].

Broaden the geopolitical scale of conservation planning - Due to the migratory status of most shorebirds and the potential difficulties associated with their management as described above, there is a need for comprehensive conservation planning at the flyway level. Strong partnerships and governmental commitments developed at this geopolitical scale may result in:

1) better understanding of limiting factors and population health of various species, 2) more effective management of refuges and other important areas used by shorebirds, and 3) opportunities to efficiently protect shorebirds and a large number of other species through the development of regional or flyway-level plans that emphasize specific needs and solutions. The current effort to develop a National Shorebird Conservation Plan may address these issues and should be supported. In addition, as part of a comprehensive planning and coordination process, cooperative agreements should be established whereby listing a species as threatened or endangered in a flyway state or province would prompt other flyway states or provinces to evaluate that species' status. The evaluation would determine 1) whether factors in the other states or provinces may have influenced the initial listing or are significant for recovery planning, and 2) whether the species should be listed in other states or on a flyway basis. This second concept requires that regional or flyway standards for listing be developed.

RESEARCH NEEDS

Many authors have commented on the importance of research for conserving wildlife resources (Bildstein et al. 1991, Morrison 1991). Essential research should investigate shorebird distribution, population trends, and annual survival or mortality estimates, as well as energetic and eco-physiological relationships. In addition, shorebird ecology and habitat relationships in Washington need to be studied, including threats to shorebird habitats and their

Table 3. Summary of research and information gaps relating to shorebird species in Washington that are addressed in this document. An asterisks (*) represents areas of information developed from Washington, pound sign (#) represents areas of information from elsewhere within the species range that is pertinent to Washington.

Species	Important sites identified ^a	Population trends monitor ^d	Food habits ^b	Physiolog/mortality factors	Recent contaminant studies ^c	Effects of disturbance ^d	Effects of habitat degradation	References ^e
Black-bellied plover	*				*	#	#	7,8,9,15,16
American golden-plover	*							14
Pacific golden-plover	*							14
Semipalmated plover	*					#		14
Killdeer	*					#		9,14
Black oyster-catcher	*		*			#		11,13,17
Black-necked stilt	*					#		14
American avocet	*							14
Greater yellowlegs	*					#		3,7,9
Lesser yellowlegs						#		
Solitary sandpiper								
Wandering tattler							#	1
Spotted sandpiper							#	1
Whimbrel							#	1
Marbled godwit	*							14
Ruddy turnstone							#	1
Black turnstone							#	1
Surfbird								
Red knot	*					#		14
Sanderling	*				*	#		4,15
Western sandpiper	*				*	#		7,9,15
Least sandpiper						#		
Baird's sandpiper								
Pectoral sandpiper	*							5
Rock sandpiper		*						6,14
Dunlin	*		*		*	#		2,4,9,15
Short-billed dowitcher	*					#		7,10,14
Long-billed dowitcher	*							7,10,14

Species	Important sites identified ^a	Population trends monitor ^d	Food habits ^b	Physiology/mortality factors	Recent contaminant studies ^c	Effects of disturbance ^d	Effects of habitat degradation	References ^c
Common snipe	*							14
Wilson's phalarope	*							14
Red-necked phalarope	*		*					12,14
Red phalarope	*							14

^aVarious species that migrate through eastern Washington use habitats whose availability is seasonally or annually unpredictable due to changes in water levels; important habitats for many species (for example, lesser yellowlegs, solitary sandpiper, spotted sandpiper, and least sandpiper) can likely be predicted seasonally or annually based on availability of suitable conditions; ^bOnly the food habits studies conducted in Washington, Oregon, or southern British Columbia are included because of substantial regional differences in energetic demands, prey availability, and prey use; ^cIncludes chemical, industrial, heavy metal, plastic, and oil pollution; ^dSee table 4 for details and references; ^eReferences are as follows: 1 = Bradley and Bradley 1993, 2 = Brennan et al. 1990, 3 = Buchanan 1988, 4 = Buchanan 1992, 5 = Buchanan (in prep - a), 6 = Buchanan (in prep - b), 7 = Buchanan and Evenson 1997, 8 = Custer and Myers 1990, 9 = Evenson and Buchanan 1995, 10 = Evenson and Buchanan 1997, 11 = Frank 1982, 12 = Jehl 1986, 13 = Nysewander 1977, 14 = Paulson 1993, 15 = Schick et al. 1987, 16 = Sutherland and Goss-Custard 1991, 17 = Vermeer et al. 1989.

use of artificial wetlands. Research on environmental contaminants and shorebird toxicology is needed in Washington (Morrison 1991). Additional research needs are presented below. Many of these and other research topics have not been addressed for shorebird species in Washington (Table 3).

Evaluate the potential impacts of commercial shellfish management may have on shorebird populations - There is currently a dearth of information on the response of shorebirds to management of bivalves in intertidal areas in the Pacific Northwest. Due to this lack of information, research should be conducted to evaluate whether various aspects of commercial bivalve production influence site quality for shorebirds.

Determine the relationship between livestock grazing and shorebird habitat quality - Information on the effects livestock trampling may have on shorebirds is needed for the intermountain west. Negative effects noted elsewhere include eggs or nest destruction (Rohwer et al. 1979, Guldemon et al. 1993), nest abandonment (Delehanty and Oring 1993), and adult birds spending an increased time away from their nests (Graul 1975), which likely results in increased exposure of eggs. Vegetation control is one potential positive effect. An effort is needed to identify these relationships, particularly in the Columbia Basin, and determine the conditions under which grazing activities and shorebird habitat management might be compatible.

Develop a better understanding of the ecology and population status of the common snipe - The common snipe is a state game species. The effects of hunting mortality on common snipe populations need to be investigated to ensure appropriate management.

Evaluate the effects of various types of human disturbance on shorebirds - Studies have shown that many types of human activities disturb shorebirds. Research on disturbance effects should focus on 1) vehicle and pedestrian traffic on beaches, 2) watercraft disturbance on lakes and bays, and 3) tourist/birdwatcher disturbance at migratory stopover sites.

Determine the effects of water salinization on shorebirds and other wildlife - The relationship between increasing water salinization within the Columbia Basin and the shorebirds that migrate through or nest in that region needs to be investigated. Understanding this relationship will be required to better control the potentially harmful effects of increasing salinization on shorebirds and other wildlife, and for effective management of vegetation.

Use new technology to improve our understanding of shorebird ecology - Satellite imagery has been used to assess habitat suitability and availability (Yates et al. 1993a,b), as well as to predict presence or abundance of birds (Lavers and Haines-Young 1997). Development of this and other tools, including Geographic Information Systems, should greatly increase our ability to address management issues of concern.

Table 4. Summary of responses by shorebirds to human disturbances.

Species	Response behavior and type of disturbance	Reference
Killdeer	<ul style="list-style-type: none"> Moved to areas beyond 60 m (197 ft) from trail¹ when visitation level exceeded 301-450 visitors/4 hr time period. Did not appear to be as sensitive to vehicle traffic. 	Klein et al. (1995)
Black-bellied plover	<ul style="list-style-type: none"> Generally found far [81-100 m (266-328 ft)] from roads, and moved to areas beyond 100 m (328 ft) when traffic level exceeded 601-750 vehicles/4 hr time period. In northern Europe, mean flush distance in response to people walking on tidal flats was 124 m (407 ft). 	Klein et al. (1995), Smit and Visser (1993)
Semipalmated plover	<ul style="list-style-type: none"> Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. In northern Europe, the mean flush distance in response to people walking on tide flats by the closely related ringed plover (<i>Charadrius semipalmatus</i>) was 121 m (397 ft). 	Klein et al. (1995), Smit and Visser (1993)
Willet	<ul style="list-style-type: none"> Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. Moved to areas beyond 40 m (131 ft) from trail when visitation level exceeded 151-300 visitors/4 hr time period. 	Klein et al. (1995)
Sanderling	<ul style="list-style-type: none"> Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. Moved to areas beyond 60 m (197 ft) from trail when visitation level exceeded 301-451 visitors/4 hr time period. Median flush response distance on a New England beach was 12 m (39 ft). More sensitive to disturbance (humans, dogs, etc.) on beaches at dusk [flush response distance = 8.3 m (27.2 ft)] than during day [flush response distance = 5.0 m (16.4)]. Concentrated on sections of beach with fewer people. At high disturbance levels (vehicle count >100/day), used back beach much more than front beach, compared to periods of lower disturbance (vehicle count <20/day). 	Klein et al. (1995), Roberts and Evans (1993) Burger and Gochfeld (1991) Pfister et al. (1992)
Dunlin	<ul style="list-style-type: none"> Generally found far [81-100 m (266-328 ft)] from roads, and moved to areas beyond 100 m (328 ft) when traffic level exceeded 301-450 vehicles/4 hr time period. In northern Europe, mean flush distance in response to people walking on tidal flats was 71-163 m (233-535 ft). 	Klein et al. (1995), Smit and Visser (1993)
Western/least sandpiper	<ul style="list-style-type: none"> Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. 	Klein et al. (1995)

Species	Response behavior and type of disturbance	Reference
Greater yellowlegs	<ul style="list-style-type: none"> Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most greater yellowlegs used areas >20 m (66 ft) from the road. 	Klein et al. (1995)
Lesser yellowlegs	<ul style="list-style-type: none"> Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most lesser yellowlegs used areas >20 m (66 ft) from the road. 	Klein et al. (1995)
Red Knot	<ul style="list-style-type: none"> Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most red knots used areas >90 m (295 ft) from the road. In northern Europe, mean flight distance in response to person in kayak was about 250 m (820 ft) Mean flight distance in response to wind surfer was about 200 m (656 ft). In northern Europe, birds less approachable on days with aircraft activity. Incidence of restlessness greater on days with aircraft activity. 	Klein et al. (1995) Smit and Visser (1993), Koolhaas et al. (1993)
Short-billed dowitcher	<ul style="list-style-type: none"> Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Dowitchers were more common at >90 m (295 ft) than at any distances closer to road. Abundance on front beach declined sharply when level of disturbance exceeded 10-40 vehicles/day. 	Klein et al. (1995) Pfister et al. (1992)
Black-necked stilt	<ul style="list-style-type: none"> Avoided habitats within 20 m (66 ft) of road. 	Klein et al. (1995)
Eurasian oystercatcher (<i>Haematopus ostralegus</i>)	<ul style="list-style-type: none"> In northern Europe, took to flight when walking person within 250 m (820 ft) 57% of time. In northern Africa, flocks were flushed by a walking person at 400-500 m (1,312-1,640 ft). Mean flight distance in response to walking person ranged from 85-138 m (279-453 ft). Mean flight distance in response to person in kayak was about 40 m (131 ft). Mean flight distance in response to wind surfer was about 125 m (410 ft). 	Smit and Visser (1993)
Redshank <i>Tringa totanus</i>	<ul style="list-style-type: none"> Mean flight distance in response to person in kayak was about 195 m (640 ft). Mean flight distance in response to wind surfer was about 285 m (935 ft). 	Smit and Visser (1993)

Species	Response behavior and type of disturbance	Reference
Bar-tailed godwit	<ul style="list-style-type: none"> • Mean flight distance in response to person in kayak was about 200 m (656 ft). • Mean flight distance in response to wind surfer was about 240 m (787 ft). • Mean flight distance in response to walking person ranged from 101-219 m (331-718 ft). • At least 20% of birds in flock flushed when jet flew within 400-500 m (1,312-1,640 ft). • At least 55% of birds in flock flushed when helicopter flew within 900-1,000 m (2,953-3,281 ft). 	Smit and Visser (1993)
Eurasian Curlew <i>Numenius arquata</i>	<ul style="list-style-type: none"> • Mean flight distance in response to person in kayak was about 230 m (755 ft). • Mean flight distance in response to wind surfer was about 400 m (1,312 ft). • Mean flight distance in response to walking person ranged from 101-339 m (331-1,112 ft). 	Smit and Visser (1993)
Black turnstone	<ul style="list-style-type: none"> • In northern Europe, mean flush distance in response to people walking on tidal flats was 47 m (154 ft). 	Smit and Visser (1993)
Primarily 8 species, including: semipalmated sandpiper, ruddy turnstone, sanderling, both dowitchers, red knot, dunlin, and greater yellowlegs	<ul style="list-style-type: none"> • In two New Jersey bays, factors influencing whether shorebirds flew but returned as a result of disturbances included duration of disturbance (short disturbances causes more flights), number of disturbances, distance between birds and source of disturbance, number of children at the site, number of people walking, and number of dogs. Factors influencing whether shorebirds flew away and did not return included duration of disturbance, the number of boats, and the number of children at the site. 	Burger (1986)

¹Trail or road traffic in various studies refers to responses of shorebirds to pedestrian or vehicular activity on trails or roads adjacent to intertidal areas within a refuge, unless otherwise noted.

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KEY POINTS

Habitat Requirements

Coastal Environments

- The primary habitat requirements of migrant or winter resident shorebirds relate to the availability of adequate foraging and roosting areas.
- Most species in western Washington are associated with silt or silt/sand intertidal areas and adjacent beaches or salt marshes. Pastures and agricultural land are also used by roosting and foraging shorebirds in western Washington.
- Shorebirds are adapted to forage in a narrow range of microhabitat conditions, from exposed tide flats or beaches to shallow water, salt marshes, and even open water.
- The foraging requirements of many shorebirds are met primarily in estuarine ecosystems, where tidal mud flats provide foraging substrates. Black-bellied plover, dunlin, western sandpiper, and dowitchers forage on mud flats with high levels of silt, whereas semipalmated plovers and sanderlings forage in sandy or silt/sand areas. Other species, such as rock sandpiper, surfbird, and wandering tattler are found almost exclusively along rocky intertidal shores.
- Shorebirds often roost in salt marshes adjacent to intertidal feeding areas, but will use a variety of habitats. Shorebirds at Grays Harbor and Willapa Bay often roost in large flocks on Pacific beaches, occasionally concentrating near the mouths of small creeks. In some areas, shorebirds roost on naturally-occurring and dredge-spoil islands and on higher elevation sand beaches. Some species may also roost in fields near intertidal foraging areas; foraging occurs at these or other roost sites if suitable prey are present. Shorebirds occasionally roost on log rafts, floating docks, and other floating structures when natural roost sites are limited.

- Use of artificial wetlands by shorebirds has not been documented in Washington. However, many species of shorebirds, including at least 12 species that occur in western Washington, use artificial or managed coastal wetlands in other parts of the United States and the world. Artificial wetlands could potentially provide important shorebird habitat in Washington.
- Shorebirds are generally site-faithful to specific wintering areas. This fidelity to particular sites has important ramifications for conservation management and mitigation.

Freshwater Environments

- Many species in eastern Washington use wet meadows, flooded fields and other areas of shallow water.
- Most shorebirds that forage in freshwater areas require ponds and pools that have exposed shorelines or that are shallow enough to allow foraging by wading birds. As with estuarine sites, the availability of appropriate invertebrate prey and roost sites are important habitat requirements.
- Habitats used by shorebirds in nonestuarine regions include marshes, pastures, flooded fields, reservoirs, impoundment drawdowns, stormwater wetlands, and other artificial wetlands.

Management Recommendations

Habitat Protection

- Identify and preserve wetland habitats important to shorebirds. Assemblages of smaller sites, as well as major estuaries provide critical habitat to shorebirds in Washington.
- Where livestock grazing occurs in pastures used by shorebirds, assess for potential trampling or disturbance of nesting birds.
- Assess commercial sand and gravel extraction from beach and riverine areas for potential impacts to shorebirds. The development of a review process for these activities would help ensure that shorebirds are considered as part of the permitting process.
- Avoid placement of new utility towers and lines in flight corridors or near wetland areas used by shorebirds. New lines should be placed below ground if possible.
- Where possible, treat existing utility lines to make them more detectable by birds in areas where collisions with shorebirds have occurred or are likely to occur. Techniques include coating or painting wires, marking of wires with mobile spirals or strips of fiberglass or plastic, placement of predator silhouettes, warning lights, and acoustical devices to scare birds. Static wire-marking may effectively reduce the number of collisions with power lines. Grouping multiple lines may make them more visible to birds and will occupy a smaller area of flight space. In addition, it is suggested that the lines be arranged side by side rather than in a vertical stacked formation.
- Address shorebirds and their flight corridors in wind turbine and cellular tower proposals.
- In the event of an oil spill, limit public access to beach or estuarine spill sites. The impacts of an oil spill can be exacerbated by disturbances caused by human recreation (e.g., beach walking).
- Control the entry of plastic litter into the marine environment. Small plastic particles injure surface feeding marine birds that inadvertently ingest them.
- Continue efforts to control the establishment and growth of cordgrass, purple loosestrife, and other noxious weeds. Potential methods to eradicate noxious weeds include biological control, repeated mowing, hand pulling of seedlings, and chemical treatment.
- Use extreme caution when applying chemicals near habitats used by shorebirds. Encourage alternatives to chemical use. Appendix A (of this volume) lists contacts useful in assessing pesticides, herbicides, and their alternatives.
- Use current information to establish buffer zones when applying chemicals. Implement buffer zones around shorebird and waterfowl nesting habitat in agricultural landscapes to minimize the impacts of spray drift.
- Assess whether or not public access and human activities should be controlled at areas important to shorebirds. If needed, potential solutions may include erecting cordons to restrict foot traffic from roosting or foraging sites, and establishing vehicle restriction zones during critical roosting periods.

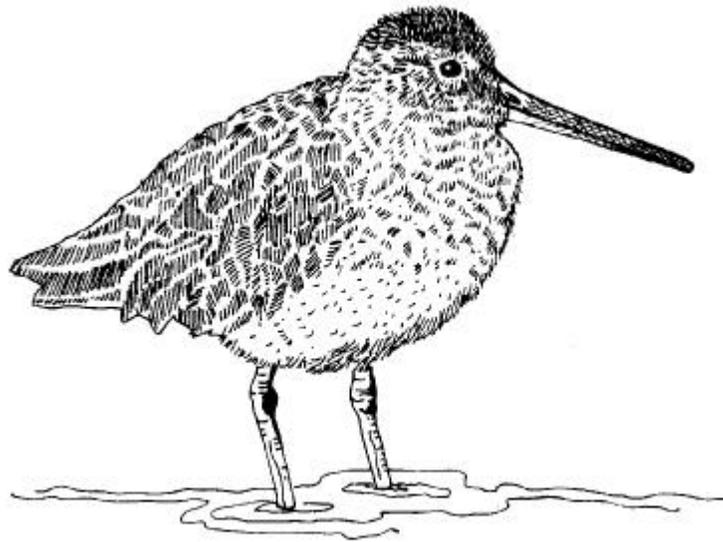
Restoration/Creation of Habitat

- Develop a site-specific strategy for any restoration project affecting shorebirds. Information on local water, soil, and vegetation conditions and requirements (freshwater environments) or tidal, wind pattern, sea swell, and substrate conditions (marine environments) needs to be incorporated.
- Create new sites at least five years prior to modification of natural habitat. Artificially created sites should provide for all displaced birds and should address this need at least 5 years prior to the modification of natural habitat to allow an assessment of its success. This 5-year period is needed to 1) identify suitable sites; 2) acquire, design, and construct the mitigation features at sites; 3) allow settlement and stabilization of suitable sediments; and 4) allow colonization of sufficient densities of invertebrate prey species.
- When conducting mitigation studies, model population dynamics in a variety of local habitats over wide spatial (e.g. coastal, Puget Sound, and interior) and temporal (e.g., at least 5 years) scales.
- Evaluate shorebird use of artificial impoundments. Artificially-created sites may be very important to shorebirds, particularly in the Columbia Basin. Artificial drawdown sites may provide more nesting opportunities for certain species depending on the type of shoreline or the availability of nesting substrate. In addition, efforts to modify such sites should be evaluated in the same manner as undisturbed sites.
- Create adequate roost sites. A primary consideration in creating a roost site is that it must be designed to address the needs of the species that will use the site. Island roosts should provide shelter from strong winds or sea swell if these are significant environmental conditions in the particular area. Island roosts should also be open, with flat tops and gently sloping sides so that the birds can effectively scan for predators.
- Manage artificial (freshwater) sites for breeding season use as well as fall migration.
- Maximize invertebrate production at artificial (freshwater) sites.
- Maintain agricultural areas and pasturelands near sites used by shorebirds.
- Practical considerations regarding management of artificial sites include:
 - proper design and use of spillways in areas prone to flooding and erosion,
 - control of exotic species such as carp and purple loosestrife,
 - water flow maintenance that minimizes stagnant water and reduces the likelihood of outbreaks of avian cholera and botulism Type C,
 - an assessment of soil conditions to determine whether a site will effectively hold water (e.g., prevention of drainage to the water table, or seepage through dikes).

Policy needs and considerations for government agencies and conservation organizations

- Initiate and design conservation planning efforts to address the following:
 - comprehensive, multi-species, landscape-level or ecosystem plans that address many species, habitats, as well as factors such as community dynamics.
 - flyway-level biological and policy coordination among states and provinces to improve regional management and enhance opportunities to protect shorebird populations.
- Identify important local and regional sites.
- Preserve remaining wetland habitat. Locally or regionally important sites should be purchased to reduce the risk of loss or degradation of habitat important for shorebirds and other wildlife. New protective and regulatory legislation needs development, and existing laws concerning wetland use need more effective enforcement.
- Promote public education about chemical use and wetland functions. Implementation of an integrated training and certification program for landowners and commercial pesticide applicators has been recommended as a means to provide pesticide users with important biological information and training.
- Continue the development and refinement of oil trajectory models.
- Develop site-specific strategies to manage human disturbance. Potential strategies include developing informational signs that identify or describe important foraging or roosting areas and organizing groups of volunteers (“beach patrols”) to educate the public about shorebird ecology.
- Post informational signs at boat docks, moorage areas, and beach access points to explain the impacts of disturbances caused by boats, personal watercraft, unleashed dogs, and other human activities.

- Address the effects of human disturbance in refuge management plans. Refuges should be designed to provide disturbance-free areas and should take into account the ecology of the species expected to use the area.
- Assess the level of unintentional mortality due to hunting. An evaluation of this source of mortality would provide an indication as to whether a new identification/information guide for shorebirds should be developed for inclusion in a waterfowl hunting pamphlet.
- Implement educational programs to inform the public about the ecology and behavior of shorebirds. Public education programs should emphasize the regional and international scope of shorebird conservation. Such efforts require improved information on the basic ecology of flyway species, identification of significant threats or potential impacts, and development of real conservation measures.
- Undertake comprehensive efforts to control the spread of exotic invertebrates in marine waters.



Common Murre removed from Priority Habitat and Species list in 2018



Common Murre

Uria aalge

Last updated: 2003

Written by Kenneth I. Warheit and Christopher Thompson

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The common murre is a gregarious, colonially nesting, and circumpolar seabird with a boreal, low Arctic, and northern temperate distribution (American Ornithologists' Union 1983, Nettleship and Evans 1985, Gaston and Jones 1998, Ainley et al. 2002). Based mostly on morphological differences, there have been up to eight subspecies or races described for the common murre (Storer 1952, Tuck 1961, Bédard 1985, Gaston and Jones 1998, Ainley et al. 2002), with three to six occurring in the Atlantic Ocean and two in the Pacific Ocean (*Uria aalge inornata*, *U. a. californica*).

In the Atlantic Ocean there are roughly 2,000,000 (Nettleship and Evans 1985) to as many as 9,000,000 (Gaston and Jones 1998) adult common murres breeding from the Labrador and Newfoundland coast in Canada, north to southern Greenland, Iceland, northern Norway and Spitsbergen, and south to Great Britain and the coast of Europe to Portugal (Harrison 1983, Gaston and Jones 1998, Ainley et al. 2002). In the Pacific and Arctic Oceans, common murres range from Cape Lisburne, Chukchi Sea, Siberian and Alaskan coasts of the Bering Sea, and south along the eastern and western north Pacific to Hokkaido, Japan, and Hurricane Point, central California, respectively (Sowls et al. 1978, American Ornithologists' Union 1983, Harrison 1983, Gaston and Jones 1998, Ainley et al. 2002). In the northern parts of the Pacific Ocean and throughout the Arctic Ocean, the common murre and the closely related thick-billed murre (*Uria lomvia*) may nest together in mixed colonies, making it difficult to estimate the total population of either species (Gaston and Jones 1998). Based on the work of Carter et al. (2001), U.S. Fish and Wildlife Service [USFWS] (2001), and others (e.g., Takekawa et al. 1990, Lowe and Pitkin 1996), Ainley et al. (2002) recorded nearly 5,000,000 common murres and 4,500,000 unidentified murres from California through Alaska, and Gaston and Jones (1998) added an additional 2,700,000 common murres from the Siberian Bering Sea and Kuril Island in the western Pacific Ocean.

Although common murres move away from breeding colonies after the breeding season, their winter range is essentially the same as their breeding range, but extends further south where murres are regularly found in southern California in the Pacific and Maine in the Atlantic (American Ornithologists' Union 1983). Some populations of common murres may remain resident near breeding colonies throughout the year (e.g., common murres nesting in central California; Boekelheide et al. 1990, Sydeman 1993).

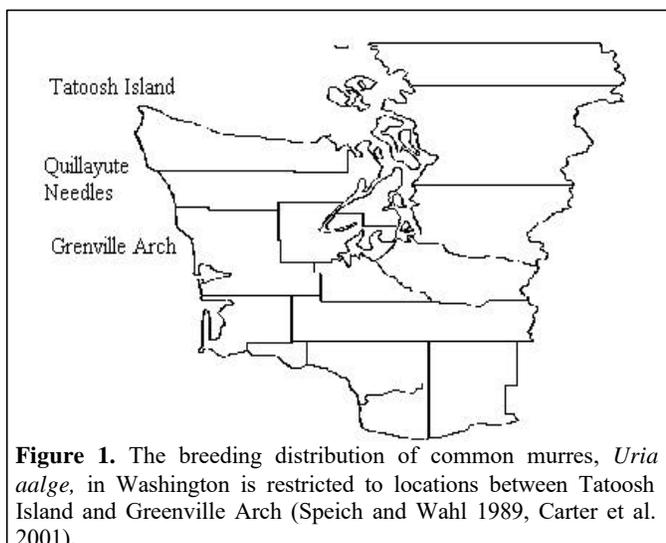


Figure 1. The breeding distribution of common murres, *Uria aalge*, in Washington is restricted to locations between Tatoosh Island and Grenville Arch (Speich and Wahl 1989, Carter et al. 2001).

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Washington Colony Distribution, Attendance, and Trends

Distribution: The breeding distribution for common murres in Washington State is restricted to the outer coast from Grenville Arch (47° 18' N, 124° 17' W) to Tatoosh Island (48° 24' N, 124° 44' W) and include at least five groups of colonies or “complexes”: Point Grenville, Split-Willoughby, Quillayute Needles, Carroll-Jagged, and Tatoosh (see Figure 1; Speich and Wahl 1989, Carter et al. 2001). All colonies, except that on Tatoosh Island, are part of the USFWS National Wildlife Refuge (NWR) system (North to South: Flattery Rocks, Quillayute Needles, and Copalis NWRs) and have been aerially surveyed each year since 1979 (Wilson 1991, Carter et al. 2001). Tatoosh Island is owned by the Makah Tribe and regular ground and boat surveys of breeding common murres on the island began in 1990 (Parrish 1995), although some data on murre status were collected on the island in the 1980s (Paine et al. 1990).

Attendance¹: Data on the attendance of common murres in Washington have been recorded continuously by USFWS since 1979, when more than 31,000 birds were recorded from 12 localities (Speich and Wahl 1989, Carter et al. 2001). USFWS surveys did not include Tatoosh Island until 1994 (Carter et al. 2001), although work by University of Washington researchers estimated attendance at Tatoosh Island in 1979 to be less than 500-1000 birds (Paine et al. 1990, Parrish et al. 2001). In 2002 there were between 5,785 and 5,925 common murres in attendance at 15 NWR colonies (Wilson 2003), plus an additional 4,466 murres at Tatoosh Island (Thompson et al. 2003), for a total of over 10,000 birds. The largest colony in the state is Tatoosh Island, followed by Cake Island (Wilson 2003), both of which are in the northern part of Washington’s common murre range.

Trends: In order to better understand the population dynamics of murres in Washington through 2002, we added to the analyses of Wilson (1991) and Carter et al. (2001), and included additional data for the refuge islands (Wilson 1996, 1999, 2002, and 2003) and for Tatoosh Island (Paine et al. 1990, Thompson et al. 2003). This new dataset provides nearly continuous data for common murres in Washington from 1979 through 2002, with the following exceptions: (1) refuge colony-specific data for 1999 and 2000 were not available, although total counts were obtained from Figure 1 in Wilson (2003); and (2) continuous attendance data from Tatoosh Island were only available from 1991 through 2002 (Thompson et al. 2003), although Paine et al. (1990) plotted murre attendance for 1978, 1979, 1986, and 1988). In order to fill in the gaps, we used the plotted attendance figures for these years and extrapolated from these figures using linear regression to obtain attendance estimates at Tatoosh Island for 1987 and 1989-1990 (Figures 2, 3). Our analysis is similar to that of Wilson (2003), except we include data for Tatoosh Island, and we do not focus attention on a time period dictated by the *Tenyo Maru* oil spill. When multiple aerial surveys were conducted in a given year, we chose the median values in our analysis. Our results indicate that the common murre population in Washington appears stable over the past decade.

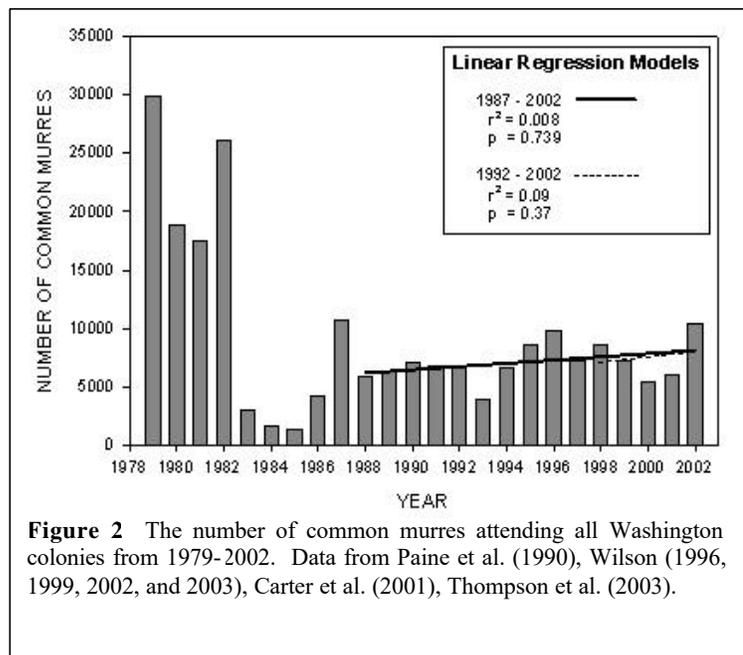


Figure 2 The number of common murres attending all Washington colonies from 1979-2002. Data from Paine et al. (1990), Wilson (1996, 1999, 2002, and 2003), Carter et al. (2001), Thompson et al. (2003).

¹ Attendance is the number of individuals counted during a colony census, and represents breeding and non-breeding birds. At the time of these censuses, the breeding population at the colony was composed of breeding birds (i.e., adults) that were at the colony and were therefore counted. Adult birds (generally the mates of the birds present at the colony) that were at-sea were not counted. The total population was composed of all juvenile, subadult, and adult birds that would or potentially would breed at the colony.

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Figure 2 shows the total attendance at murre colonies from 1979 through 2002. The dramatic decline in murre attendance in 1983, as initially documented by Wilson (1991), is clearly evident. Murre numbers stayed low from 1983-1985 and began to increase through 1987. After 1987, murre numbers remained stable through 2002. If murre numbers in Washington are at “carrying capacity²” (Wilson 2003:2), this capacity is remarkably lower than that in the late 1970s and early 1980s (see below, and Parrish and Zador 2003 for discussion of common murre carrying capacity in Washington).

Carter et al. (2001) divided the murre colonies into a southern (Gray’s Harbor County, including Point Grenville and Split-Willoughby Complexes) and a northern component (Jefferson and Clallam Counties, including the Quillayute Needles, Carroll-Jagged, and Tatoosh Complexes). From 1979 through 1982, common murre attendance at Washington colonies in the southern areas averaged 92% of the total Washington population (Figure 3). In 1988, the dominance of the southern areas ended and by the mid 1990s the Washington murre population had shifted to the northern colonies (Figure 3). In 2002, 81% of common murre attendance in Washington were nesting in the northern areas, with 44% at Tatoosh Island and 35% at the Quillayute Needles Complex.

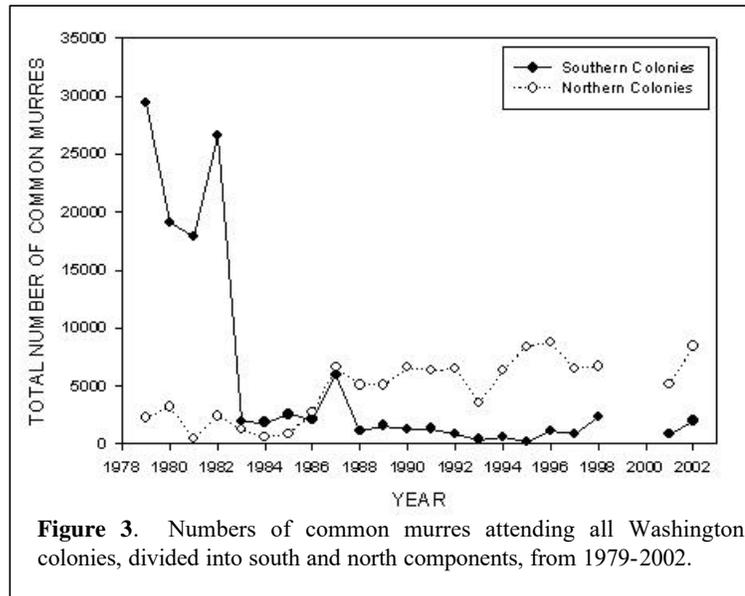


Figure 3. Numbers of common murre attending all Washington colonies, divided into south and north components, from 1979-2002.

Although murre attendance summed across all colonies (as presented in Figure 2) has been relatively stable for 15 years, attendance at individual rocks has varied (Carter et al. 2001). This is especially true at the Quillayute Needles and Carroll-Jagged Complexes, in particular Cake Rock and Carroll, Huntington, and Petrel Islands (Figure 4; see also Carter et al.

2001:Figure 2.11). In the early 1980s, Petrel Island was the predominant murre colony in the area, followed by Huntington Island from the mid 1980s through the early 1990s. The murre population at Carroll Island increased dramatically following the 1994 breeding season, but has been replaced by Cake Rock (Figure 4) as the main murre colony in the area.

Understanding trends in common murre colony attendance in Washington over the past two decades is confounded by at least two basic issues. First, as discussed above, there does not appear to be a uniform trend in colony attendance among colonies from the Quillayute Needles and Carroll-Jagged Complexes. The fact that all Washington murre colonies are within a range of 127 km (79 mi) makes these data even more perplexing. Second, counts at particular colonies generally have not been replicated in any given year, and census methods used by different researchers may differ and may not be directly comparable. Counts at common murre refuge colonies have been conducted only once per year from 1979 through 1993 (Carter et al. 2001), and single yearly counts can result in poor estimates of breeding attendance (Hatch and Hatch 1989). Censuses by other researchers often resulted in different population estimates. For example, Wilson (in Carter et al. 2001:Appendix F) estimated that only 50 common murre were in attendance on Grenville Arch during an aerial survey on June 26, 1985. However, Speich et al. (1987) provided a maximum count of 8,000 common murre on Grenville Arch for the week that included June 26, 1985, based on a combination of shore- and boat-based counts. Land, boat, and aerial surveys have the potential of sampling different parts of a colony, and therefore they may produce different results. In addition, there may be inherent hourly or daily variability in attendance at Washington colonies (Parrish 1996a, b), and censuses taken on two different days (or at two different times during the same day) may differ as a result of this variability.

² The number of individuals that the resources of a habitat can support.

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At-sea Distribution

Although common murre breeding in Washington is restricted to cliffs, rocks, and islands on the outer coast, murre are found throughout the year in all marine waters of the state, including Puget Sound (Wahl et al. 1981, Briggs et al. 1992, Thompson 1997, 1999, Nysewander et al. 2001, Thompson et al. 2002, 2003). In Puget Sound, murre densities are positively correlated with distance from the shore and water depth (D. Nysewander, personal communication; Wahl et al. 1981); however, this relationship does not exist along the outer coast and in the western portions of the Strait of Juan de Fuca (Thompson 1997, 1999). The temporal and spatial patterns for the abundance and distribution of common murre in Puget Sound are highly variable (Thompson 1997, 1999, Nysewander et al. 2001). For example, population indices for common murre in the Puget Sound in July were 48,423; 9,915; 5,271; and 30,660 for 1993 through 1996, respectively (D. Nysewander, personal communication). The reason for this variability is unclear, although the timing of post-breeding dispersal of adult murre from coastal colonies is most likely an important variable. The at-sea density of common murre is highest in the fall (i.e., post-breeding, beginning late July/early August) on the outer coast (Briggs et al. 1992, Thompson 1997, 1999, unpublished data) and in Puget Sound (D. Nysewander, personal communication). The increase of murre in Washington waters following the breeding season is, in part, a result of post-breeding dispersal from colonies in Oregon (Warheit 1996, Thompson 1997, 1999), possibly California, and to a lesser extent, British Columbia and Alaska. Although murre distribution and abundance also varies substantially in time and location on the outer coast, total at-sea population estimates of murre on the outer coast were consistent in 2001 and 2002 ([mean, 95% CI] 2001: 72,840; 48,816 – 91,124; 2002: 74,011; 35,803 – 103,048; Thompson, unpublished data).

RATIONALE

The common murre is a State Candidate species. Carter et al. (2001) concluded that the common murre population dropped dramatically from approximately 26,000 in 1982 to 3,000 in 1983, coinciding with a severe El Niño-Southern Oscillation (ENSO) (Wilson 1991). This decline was mirrored at common murre colonies in California (Boekelheide et al. 1990) and Oregon (Hodder and Graybill 1985). However, unlike colonies in California and Oregon total attendance at Washington refuge colonies has not recovered to pre-1983 ENSO levels and has not exceeded 11,000 since that event. Wilson (1991) and Carter et al. (2001) suggested that the lack of recovery to pre-1983 numbers and low attendance within the NWRs may be the result of a combination of ENSOs, oil spills, gillnet mortality, and Naval disturbances at breeding colonies.

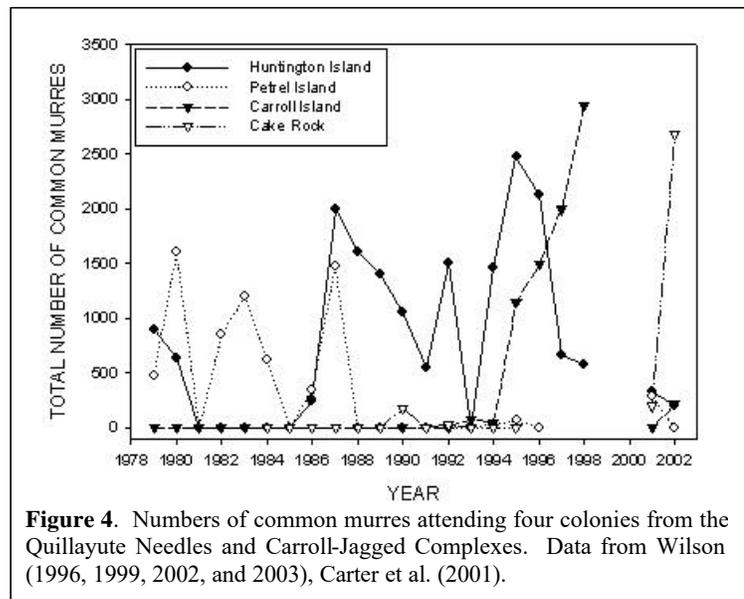


Figure 4. Numbers of common murre attending four colonies from the Quillayute Needles and Carroll-Jagged Complexes. Data from Wilson (1996, 1999, 2002, and 2003), Carter et al. (2001).

HABITAT REQUIREMENTS

Common murre require coastal cliff ledges or elevated marine terraces on islands or rocky headlands for breeding (Ainley et al. 2002). The habitat must be above the splash zone, inaccessible to terrestrial predators or pests (such as cats, rats, foxes, or raccoons), sufficiently windswept or elevated to permit takeoff and landing (Tuck 1961), and in “full ocean view” (Ainley et al. 2002:5). Common murre do not build nests, and each pair lays a single egg directly on the substrate, usually on bare rock, although on Tatoosh Island a subcolony of murre nested on soil near vegetation (salmonberry [*Rubus spectabilis*]; Parrish 1995, Parrish and Paine 1996). Common murre also require marine habitats with relatively abundant prey. Prey include Pacific herring (*Clupea harengus*), Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), rockfish (*Sebastes* spp.), salmon (*Oncorhynchus*

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spp.), squid, and euphasids (Vermeer et al. 1987, Boekelheide et al. 1990, Ainley et al. 2002). Common murrens require that breeding habitat be sufficiently close to productive foraging areas (e.g., oceanographic fronts, tidal sheers, upwelling plumes, shelf-break fronts, and runoff plumes; Ainley et al. 2002) so that repeated trips between the colony and prey sources can be made within a single day (foraging radius for common murrens is approximately 60 km [37 mi]; see Ainley et al. 1991). Following the breeding season, common murrens require only suitable marine habitat for foraging and resting, although murrens may return to colony rocks prior to the breeding season. During this time murrens are frequently seen close to shore (Ainley et al. 2002).

Diet

There have been only two detailed studies of the diet of common murrens in Washington. The first study is based on the contents of the gastrointestinal tracts of common murrens collected from salmon drift gill nets in the late summer and fall from 1993 through 1996 (Wilson 1998, Wilson and Thompson 1998, Lance and Thompson, in press). In this geographically limited study, common murrens fed on Pacific herring (74.2 % frequency of occurrence), Pacific sandlance (45.8%), and salmonid species (21.9%). The proportion of these prey species in the diet of murrens did not differ significantly between murre age classes (adult vs. subadult), gender, or among years. The mean lengths of Pacific herring and Pacific sandlance were not significantly different in the murre diet. Diet diversity within individual murrens was low with most gastrointestinal tracts containing only one or two prey species. Based on the time of day in which Pacific herring and Pacific sandlance were present in murre esophagi and/or proventriculi, Wilson and Thompson (1998) and Lance and Thompson (in press) determined that murrens fed most frequently on these two species at dusk (2100-2259 PST).

The second study included only the diet of chicks fed by adults at nest sites on Tatoosh Island (Parrish 1996 a, b, Parrish and Zador 2003, Thompson et al. 2003). The primary prey items fed to chicks were surf smelt (*Hypomesus pretiosus*), Pacific herring, Pacific sandlance, and eulachon (*Thaleichthys pacificus*) (Parrish and Zador 2003, Thompson et al. 2003).

LIMITING FACTORS

A variety of natural and human-induced factors can affect common murre populations. Colony attendance and reproductive success for murre populations along the west coast of North America have been affected by ENSO events (Hodder and Graybill 1985, Ainley and Boekelheide 1990, Wilson 1991). Additional natural factors that may affect murre abundance, distribution, and reproductive success include food availability, predation pressure, and the distribution of specific marine habitats (Briggs et al. 1987, 1992; Speich et al. 1987; Ainley and Boekelheide 1990; Allen 1994; Ainley et al. 1995; Parrish 1996a; Parrish and Paine 1996; Thompson 1997). Disturbance caused by aerial predators such as the bald eagle (*Haliaeetus leucocephalus*) can also negatively affect the reproductive success of breeding murrens (Speich et al. 1987, Parrish 1995, 1996a, b; Parrish et al. 2001, Thompson et al. 2003; R. Lowe, personal communications).

Common murrens are also vulnerable to drowning in fish-nets or becoming oiled during spills because they are gregarious on land and at sea (Burger and Fry 1993, DeGange et al. 1993, Warheit et al. 1997). In the last 10-20 years, there have been several oil spills in California, Oregon, and Washington, with two major spills in Washington resulting in substantial mortality to common murrens. Murrens were the most numerous seabirds affected in the *Tenyo Maru* and *Nestucca* oil spills off the coast of Washington (Ford et al. 1991, Momot 1995, *Tenyo Maru* Oil Spill Natural Resources Trustees 2000). Seabird mortality associated with gillnets in Washington and central California have shown a bias toward common murrens (Takekawa et al. 1990, Erstad et al. 1994, Pierce et al. 1994, Thompson et al. 1998). Overall, in Washington, it is estimated that thousands of common murrens have been killed in salmon gillnets and by oil spills (Ford et al. 1991, Momot 1995, Melvin and Conquest 1996; Warheit 1996; Melvin et al. 1997). Recreational fishing does not appear to be a threat to common murrens in Washington (C. MacDonald and W. Beeghley, unpublished data); however, more research is necessary before any conclusions can be reached. The degree to which these factors affect the long-term stability of the population(s) of common murrens in Washington is unknown.

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Population Regulation

Population responses of a common murre colony to natural or human-induced environmental changes may depend on how that colony is reproductively linked to other colonies and how the overall population is geographically structured. There have been three studies particularly relevant to the geographic structure of common murres occurring from British Columbia south to California. First, Warheit (1996) estimated that 55–58% of common murres killed during the *Tenyo Maru* oil spill were from Washington (the remaining birds were from Oregon). These results indicate that at certain times of the year the Washington “population” of common murres is simply an association of birds from different geographic areas, and not necessarily an integrated breeding nexus. Second, Warheit (1999) stated that based on preliminary genetic analysis, there is little to no geographic structure to common murre populations from British Columbia to California, although there is a slight north-south gradient in allelic frequencies. These tentative conclusions also indicate that there is no evidence for a distinct Washington “population.” Finally, Drovetski et al. (submitted) found a lack of geographic structure to mitochondrial DNA variation among common murres from Japan, Russia, Alaska, and California, and that the history of common murres in the Pacific is highlighted by local population declines and recovery through high migration and gene flow.

The results from the two genetic analyses suggest that common murres in Washington are part of a large and integrated metapopulation that includes, at a minimum, birds from Oregon and British Columbia. However, because both studies limited the Washington samples from one locality (near Tatoosh Island), neither contributes to our understanding of the geographic structure and demographics of common murres within Washington.

There are few data available to help determine what factors (natural or human-induced) are actually “regulating” common murre populations in Washington. Common murre abundance and distribution may be determined by factors such as migration from outside Washington (as the genetic data suggests), food distribution, or bald eagle predation or disturbance. Wilson (2003) has suggested that common murres in Washington are at their carrying capacity and that growth of this population is being limited by food. Parrish and Zador (2003) looked for correlations between a series of mechanisms and several measures of murre demographics and foraging behaviors. They concluded that although a central Oregon colony of murres (Yaquina Head) may be near carrying capacity, Washington colonies “probably exist well below carrying capacity,” and at Tatoosh Island eagle predatory pressure is affecting several demographic parameters (Parrish and Zador 2003:1054). Without additional data on potential regulating factors, it is impossible to predict how a particular colony or population will be affected by events such as gillnet or oil spill mortality. In addition, without more inclusive data on common murre demographic parameters throughout Washington (such as survival, reproductive success, or dispersal from colonies in addition to Tatoosh Island) or information about common murre food habits and potential effects of climate change on prey distribution and abundance, it is difficult to design a comprehensive management or restoration plan for common murres in Washington.

MANAGEMENT RECOMMENDATIONS

To successfully manage the population(s) of common murres in Washington, additional baseline data are needed. Therefore, the following management recommendations consist of two parts. First, we will outline the priority research recommendations. Second, we list direct management activities that should be or have been implemented for the conservation of the breeding and at-sea populations of common murres in Washington.

Research and Monitoring Recommendations

- 1) *Breeding distribution and phenology, and reproductive success*: Tatoosh Island, and to a lesser extent Point Grenville (Thompson et al. 2003) are the only areas in Washington where definitive data have been collected on the basic reproductive parameters of common murres. Therefore, there are no extensive data on breeding phenology, reproductive success, or factors affecting reproductive success (e.g., food availability) available from murre colonies south of Tatoosh Island. This information is important to understanding the demographics of common murres in Washington and for implementing effective management programs.

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- 2) *Geographic structure of population*: There are at least two aspects of the geographic structure of common murre populations in Washington that are important in designing management plans.
 - a) Dispersal: The connectivity among colonies is based on the degree to which birds hatched in an area disperse to another area. If the dispersal rate among several areas is high, these areas function as one population, and natural recovery following a disturbance may be relatively quick due to the influx of immigrants. In these cases, management activities need to be directed at the population, rather than an individual colony. However, if a colony or area is isolated and few or no birds disperse to or from the colony, management activities need to be directed at the colony or area because recovery following disturbance must be through local recruitment and natal philopatry (i.e., birds that hatch at a colony and return to that colony to breed). Data on dispersal can be collected directly through the observation of banded birds and indirectly through genetic analyses of individuals from colonies throughout a particular geographic range. At this time our entire knowledge of the genetic structure of common murres from British Columbia to California is based on only four colonies.
 - b) Identification of origin of birds: If common murres are geographically structured either within Washington or between Washington and other regions along the west coast, particular morphological or genetic markers may exist that can identify a bird from a specific colony or region. If such markers exist, it may be possible to identify the areas of origin (e.g., Washington versus Oregon) for common murres killed in oil spills or fishing nets in Washington marine waters (e.g., Warheit 1996, Edwards et al. 2001).
- 3) *Survival rates*: Adult and juvenile survival are important parameters in understanding the demographics of common murre populations (Nur et al. 1994). Although there are data on the survival rates for common murres from both the Atlantic and Pacific oceans (Hudson 1985, Harris and Wanless 1988, 1995; Sydeman 1993), no data are currently available from any Washington colony. Obtaining data on survival rates requires banding individual birds.
- 4) *Sources of mortality*: Researchers (Parrish 1996a, b; Parrish and Paine 1996; Parrish et al. 2001) studied the effects of eagle disturbance on survival and reproductive success of common murres on Tatoosh Island. This type of study should be conducted at other murre colonies in Washington, as was attempted at Point Grenville (Thompson et al. 2003). To better understand the effects of fishing bycatch mortality and oil spills on common murres in Washington, more data are needed on the number of individuals killed each year in all types of fishing gear (including recreational fishing) and in oil spills (including small-scale but chronic spills). Systematic and wide-ranging beach bird surveys are essential to document baseline mortality rates for marine birds in Washington. The Coastal Observation and Seabird Survey Team initiated such a comprehensive coastwide program in 1999 (Hass and Parrish 2000).
- 5) *Fisheries bycatch mortality*: More research is required to further reduce the number of birds killed in all kinds of fishing gear.
 - a) Pingers: Melvin et al. (1997) conducted experiments on the use of audio devices (i.e., pingers) attached to gillnets as a method to reduce the rate by which seabirds become entangled. We recommend that new experiments be conducted on the use of pingers on 20 mesh nets.
 - b) Recreational fishery activities: Based on one year of data, it appears that bycatch of common murres in recreational fishing lines are minimal (C. MacDonald and W. Beeghley, personal communications). Nevertheless, a more comprehensive, multi-year, and systematic study needs to be implemented to effectively evaluate this potential problem.
 - c) Monitoring: Comprehensive monitoring of the at-sea distribution of common murres in Puget Sound, Strait of Juan de Fuca, the outer coast, and along the Oregon coast needs to be implemented and maintained; monitoring and surveying have been or are currently being conducted on Tatoosh Island (Paine et al. 1990, Parrish 1995) and on all colonies managed by USFWS (Speich et al. 1987, Wilson 1991, Briggs et al. 1992, Carter et al. 2001). These data should be used to determine seasonal murre abundance that might influence the regulation of a particular gillnet fishery. This information will also help determine potential injury from oil spills occurring in particular places at specific times of the year.
- 6) *Food habits*: Short- and long-term changes in food resources for common murres can result from factors such as ENSO events, Pacific Decadal Oscillation (Mantua et al. 1997, Minobe 1999), overfishing, and global climate change. Food shortages resulting from ENSO events have been documented to be associated with large die-offs of common murres in Washington (Good et al. 1999). Management plans must be designed that

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incorporate this information. Detailed analysis of food habits for common murres in Washington is limited for most sites. Comprehensive studies of common murre food habits and foraging ecology are needed and should combine information gathered both at sea and at breeding colonies. These studies need to be long-term, multiyear endeavors, and should include analyses on diet, adult foraging rates, chick diet at nest sites, and information about the marine food web (in particular, the abundance, distribution, and life history of the primary prey species, and how these prey species might be affected by climate change). This type of comprehensive analysis was initiated in 2001 (Thompson et al. 2003), but the *Tenyo Maru* Oil Spill Trustee Committee terminated funding for this project after two years.

- 7) *Spatial factors affecting murre distribution*: As described in the Trends Section above, common murres have shifted their Washington distribution to the north (Figure 3), and have experienced irregular attendance at the Quillayute Needles and Carroll-Jagged Complexes (Figure 4). These spatial patterns are unmistakable and may relate to differences in local terrestrial and marine environments. Differences in factors such as food availability, human and eagle disturbance, and rates of predation need to be examined.

Direct Management Actions and Recommendations

- 1) *Reduce bycatch of common murres in Washington drift gillnets*: A considerable amount of research has been conducted in Washington to determine the degree to which seabirds, in particular common murres, are caught in non-treaty salmon drift gillnets (Erstad et al. 1994, 1996; Pierce et al. 1994; Thompson et al. 1998). In addition, researchers (Melvin and Conquest 1996, Melvin et al. 1997) have developed procedures to reduce seabird bycatch in drift gillnets. Because thousands of murres are potentially killed by gillnets each year (Thompson et al. 1998), specific management activities to reduce this mortality are warranted. The Washington Fish and Wildlife Commission adopted procedures and commercial fishing regulations designed to reduce the bycatch of seabirds, particularly common murres and rhinoceros auklets, in gillnets (Washington Department of Fish and Wildlife 1997). These regulations set the following gillnet design standards and timing restrictions to reduce mortality associated with gillnets:
- Net design**: The monofilament line in the first 20 meshes below the corkline of nets must be replaced with #12 white twine which is more visible to diving birds. Melvin et al. (1997) showed that the 20 mesh nets (but with thicker #18 white twine) significantly reduced seabird bycatch without significantly reducing fishing efficiency.
 - Length of season**: The Department of Fish and Wildlife was authorized to end the 1997 sockeye and pink salmon gillnet fisheries in northern Puget Sound (Areas 7/7a) when the number of seabirds in the fishing area became abundant in order to eliminate common murre bycatch. This authority should be extended to future years.
 - Fishing hours**: The Commission eliminated early morning (change-of-light period) and most night fishing to reduce the time in which fishers would be unable to see and thereby avoid flocks of birds; the designated open fishery was from 1.5 hours after sunrise to midnight.
 - Educational programs**: Although the Commission's new regulations did not require the implementation of educational programs, the Commission's goals may be best met through programs designed to instruct the commercial fishing fleet in Washington on how best to avoid encountering seabirds.
- 2) *Reduce effects from oil spills*: Oil spills are usually accidents and as such are difficult to plan and manage. Nevertheless, activities can be employed to reduce the probability and negative effects of an oil spill. The Washington Departments of Ecology and Fish and Wildlife are addressing the following:
- Spill prevention through vessel and facility inspections
 - Coordinated spill response and injury assessment
 - Restoration planning and implementation
 - Oiled wildlife rescue capabilities
 - Industry and coast guard drills and geographic response plans to enhance spill response activities
- 3) *Reduce human disturbance at breeding colonies*: Human disturbance through activities such as kayaking, boating, or aircraft overflights can disturb nesting common murres and affect local recruitment and productivity (Speich et al. 1987, Parrish 1996b, Warheit et al. 1997). As provided in the *Nestucca* oil spill restoration plan (Momot 1995), the USFWS will inform citizens about the sensitivities of seabird breeding colonies at NWR sites in Washington through brochures and signs/posters displayed prominently at commercial, private, and

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public boat launches and marinas, and in refuges and parks. These brochures and signs will also inform the public that it is illegal to harass seabirds and to enter onto a NWR island without proper authorization. The *Tenyo Maru* Oil Spill Trustee Committee has implemented a similar program in Oregon and the Cape Flattery – Tatoosh Island area in Washington (*Tenyo Maru* Oil Spill Natural Resources Trustees 2000). Finally, although the use of brochures and signs promises to reduce disturbance at specific colonies, other factors such as aircraft ceiling violations over specific common murre colonies (e.g., Tatoosh Island; Parrish 1996b) need to be addressed through a combination of educational programs and enforcement of existing laws and regulations.

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Common Murre removed from Priority Habitat and Species list in 2018

KEY POINTS

Habitat Requirements

- Requires for breeding coastal cliff ledges or elevated marine terraces on islands or rocky headlands that are inaccessible to terrestrial predators.
- Lays a single egg directly on the substrate, usually on bare rock.
- Requires breeding habitat to be sufficiently close to productive foraging areas.
- In the eastern Pacific, preys upon Pacific herring, Pacific sandlance, northern anchovy, rockfish, salmon, squid, and euphasids.
- In Washington, chicks are fed surf smelt, Pacific herring, Pacific sandlance, and eulachon by adults at the nest site.
- Dietary diversity of individual murrelets tends to be low.
- Requires only suitable marine habitat for foraging and resting following the breeding season. However, murrelets may return to colony rocks prior to the breeding season.

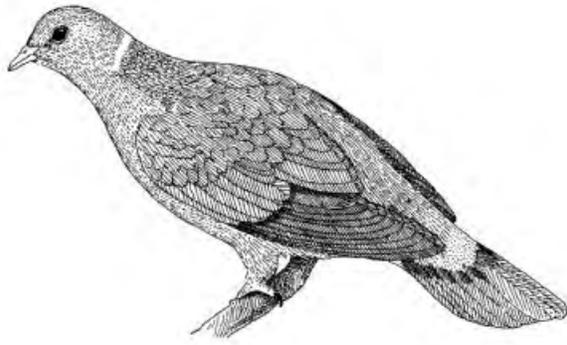
Management Recommendations

Research and Monitoring Recommendations

- Collect data on breeding phenology, reproductive success, and factors affecting reproductive success in Washington to support the implementation of more effective management programs.
- Gather comprehensive data to determine the rate of dispersal among colonies to better focus management efforts. Identification of genetic markers to track the origin of individual murrelets is also important.
- Collect survival data to more accurately understand murrelet demographics in Washington.
- Conduct comprehensive surveys to better understand the effects of various sources of mortality (e.g., natural mortality, bycatch, oil spills).
- Carry out additional research and monitoring efforts that will help identify ways to further reduce the number of birds killed in fishing gear.
- Develop and conduct comprehensive studies of murrelet food habits and foraging ecology. These studies should combine information gathered both at-sea and at breeding colonies.
- Examine spatial factors affecting murrelet distribution. Differences in factors such as food availability, human and eagle disturbance, and rates of predation need to be examined.

Direct Management Actions and Recommendations

- Replace the monofilament line in the first 20 meshes below the corkline of nets with #12 white twine which is more visible to diving birds. 20 mesh nets (but with thicker #18 white twine) significantly reduced seabird bycatch without significantly reducing fishing efficiency.
- Extend the Fish and Wildlife Commission's authority to end certain fishing seasons when the number of seabirds in a fishing area becomes abundant.
- Design programs to instruct commercial fishing fleets on how to best avoid seabird bycatch.
- Resource agencies should continuously improve their capabilities to reduce the effect of oil spills through various means (e.g., vessel and facility inspections, coordinated spill response and injury assessments, restoration, wildlife rescue).
- Reduce human disturbance at breeding colonies caused by activities such as kayaking, boating, or aircraft overflights.



Band-tailed Pigeon

Columba fasciata

Last updated: 2003

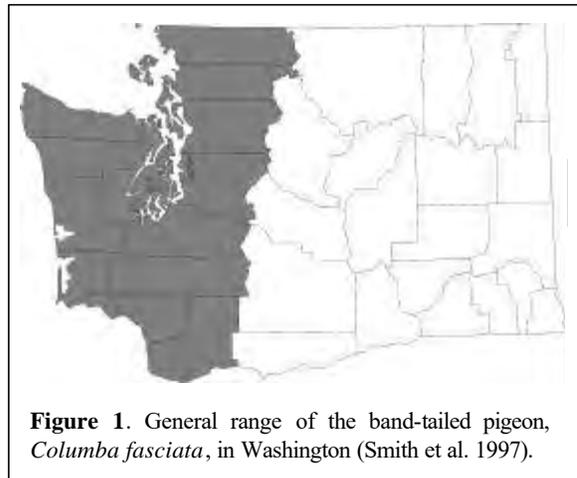
Written by Jeffrey C. Lewis, Michelle Tirhi, and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Band-tailed pigeons are primarily restricted to coniferous forest zones in mountainous areas of western North America (Jarvis and Passmore 1992). Braun (1994) recognized two races of band-tailed pigeons in North America. The interior race (*Columba fasciata fasciata*) breeds primarily in the Rocky Mountains south of Wyoming, whereas the Pacific Coast race (*Columba fasciata monilis*) breeds west of the Cascade and Sierra Nevada crests [up to 4,200 m (13,800 ft) elevation; Pacific Flyway Council 1983] from British Columbia and southeastern Alaska south to Baja California, Mexico.

The bulk of Pacific Coast population of band-tailed pigeons winters from south of Redding, California through Mexico (Schroeder and Braun 1993); however, year-round residents occur in the Pacific Northwest (Jarvis and Passmore 1992). Schroeder and Braun (1993) found that some interchange occurs between the Pacific coast and interior races.

Band-tailed pigeons reside mainly in western Washington (see Figure 1) and are typically located around mineral springs and seeps (Keppie and Braun 2000). The highest densities occur on the Olympic Peninsula and on Washington's southern coast (Grays Harbor, Pacific, and Wahkiakum counties). During the breeding season (April - September), most of the population is found below 305 m (1,000 ft) elevation (Jeffrey 1989). In late summer, band-tailed pigeons may move to higher elevations. By late September, most band-tailed pigeons leave Washington and migrate to their wintering grounds. However, year-round residents are known to occur in the Puget Sound as far north as Seattle (B. Tweit, personal communication).



RATIONALE

Band-tailed pigeons are listed as a State and Federal Game species. The hunting season in Washington underwent an emergency closure in 1991 due to a rapid decline in the population as determined from pigeon surveys (Braun 1994). Breeding Bird Survey data indicated the population of band-tailed pigeons in Washington declined significantly from 1968 to 1993 (Braun 1994, Keppie and Braun 2000). However, more recent data showed increases in population that allowed the reinstatement of a limited hunting season in 2002, after a 10-year restriction on hunting (Washington Department of Fish and Wildlife 2001, 2002).

Band-tailed pigeons require mineral springs close to a food source during the breeding and brood-rearing season (Jarvis and Passmore 1992). A scarcity of mineral sites combined with the alteration of available nesting habitat jeopardizes band-tailed

pigeon populations (Braun 1994). Intensive hunting pressure in the past has also been held responsible for declines in the population (Jarvis and Passmore 1992).

HABITAT REQUIREMENTS

In Washington, band-tailed pigeons are associated with Douglas-fir (*Pseudotsuga menziesii*), red alder (*Alnus rubra*), western hemlock (*Tsuga heterophylla*), red cedar (*Thuja plicata*), bigleaf maple (*Acer macrophyllum*), sitka spruce (*Picea sitchensis*), willow (*Salix* spp.), pine (*Pinus* spp.), cottonwood (*Populus* spp.), and Garry oak (*Quercus garryana*) (Jeffrey 1989, Braun 1994). Berry- and nut-producing trees and shrubs are also common in their range (Keppie and Braun 2000).

Breeding Season

During the breeding season (April - September), band-tailed pigeons are found in mixed conifer and hardwood forests interspersed with younger wooded areas or small fields (Jeffrey 1977, 1989). Abundant food and mineral sources are necessary during this time (Jarvis and Passmore 1992). Nesting habitat in western Oregon is dominated by closed-canopy, conifer forests (mostly Douglas-fir) in sapling-pole forest development stages (Leonard 1998). Nests are placed in conifers or broad-leafed trees, typically 4.5-12.0 m (15-40 ft) above the ground. Nests may be distributed in small groups or well-dispersed (Jeffrey 1977, Curtis and Braun 1983). In Oregon, average home range size during the nesting season was 11,121 ha. (Leonard, 1998).

Band-tailed pigeons seek sources of mineral salts (especially calcium) necessary for egg production and the production of "crop milk" for feeding young (March and Sadleir 1975, Jarvis and Passmore 1992, Braun 1994). Mineral salts are found in mineral springs and marine shorelines, and occasionally livestock salt blocks are used (Jeffrey 1977). Pigeons have been documented returning to mineral springs in subsequent years (Jarvis and Passmore 1977, 1992).

Food

During spring migration, this herbivorous bird feeds on acorns, buds, blossoms, young leaves and needles, fruits, and berries (Jeffrey 1977). Primary food sources include Cascara buckthorn (*Rhamnus purshiana*), elderberry (*Sambucus* spp.), wild cherry (*Prunus* spp.), huckleberry (*Gaylussacia* spp.), madrone (*Arbutus menziesii*), dogwood (*Cornus* spp.), and oak (*Quercus* spp.) in late spring and summer (Jeffrey 1977). Pacific red elderberry (*Sambucus callicarpa*), blue elderberry (*Sambucus cerulea*), and cascara buckthorn were determined to be important food items in the Northwest because of their high caloric, calcium and protein content (Jarvis and Passmore 1992, Keppie and Braun 2000, Sanders 2000). During the spring and summer, newly planted fields or stubble containing grains from the fall harvest are also preferred food sources (Jarvis and Passmore 1992, Braun 1994, Keppie and Braun 2000).

During fall and winter, band-tailed pigeons feed on acorns, nuts, berries, grains and fruits (Fry and Vaughn 1977, Jeffrey 1989). Pigeons often move to high elevation meadows in the fall prior to migration (Jeffrey 1989). In the Oregon coastal range, primary feeding sites for radio-marked band-tailed pigeons were located in riparian or moist bottomlands (Leonard 1998). Nestlings feed on "crop milk" which is later supplemented by other regurgitated crop contents from either parent (Keppie and Braun 2000).

LIMITING FACTORS

Land development and forest practices that degrade or destroy mineral springs and nesting habitat limit band-tailed pigeon populations (Pacific Flyway Council 1983). Although undocumented mineral sites likely occur, only a limited number of mineral sites actively used by pigeons are known to exist in western Washington (Gillum 1993). A lack of berry/mast-producing plants may also limit use of areas by band-tailed pigeons (D. Kraege, personal communication).

Band-tailed pigeons lay a single egg 1 to 3 times per year (Leonard 1998); thus, their productivity is considered low. Intensive hunting of band-tailed pigeons can be detrimental (Neff 1947; D. Kraege, personal communication), especially at mineral sites where breeding adults are more abundant than juveniles during the hunting season (Jarvis and Passmore 1992).

Outbreaks of the protozoan disease Trichomoniasis are suspected in periodic large-scale mortalities of band-tailed pigeons (Keppie and Braun 2000). Trichomoniasis is transmitted through contaminated feed at urban bird feeders and possibly through contaminated mineral springs (D. Kraege, personal communication).

MANAGEMENT RECOMMENDATIONS

To adequately conserve nesting habitat, mineral springs and other mineral sources used by band-tailed pigeons should be protected (Braun 1994). Trees surrounding mineral sites are important for perching (Pacific Flyway Council 2001), and their removal should be avoided. Mineral sources may be enhanced by removing dense vegetation that could limit bird access. Because mineral sites are uncommon, they should be a high priority for conservation-oriented acquisitions.

Large clearcuts should be discouraged in band-tailed pigeon habitat (Jeffrey 1977). Clearcuts should be replanted with a variety of species rather than a single tree species. Berry/mast-producing shrubs and trees are important food sources and should be maintained and enhanced, particularly those close to mineral sources and higher elevation areas used during migration (Braun 1994).

The use of herbicides that eliminate food producing shrubs and trees should be discouraged, particularly in stands containing the important food sources described by Jeffrey (1977). Modern silvicultural practices, including the use of herbicides to control deciduous shrubs and trees, have potentially reduced food-producing plants throughout the range of the band-tailed pigeon (Braun 1994). Landowners are encouraged to use integrated pest management strategies that target specific pests or weeds, use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). If pesticide or herbicide application is planned for areas used by band-tailed pigeons, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

People maintaining bird feeders should regularly clean feeders and report all sick and dying band-tailed pigeons to the nearest Washington Department of Fish and Wildlife regional office, the U.S. Fish and Wildlife Service regional headquarters, or to the USGS Wildlife Health Research Center at (608) 271-4640 (D. Kraege, personal communication).

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KEY POINTS

Habitat Requirements

- \$ Band-tailed pigeons are associated with Sitka spruce, red cedar, western hemlock, red alder, bigleaf maple, Douglas-fir, willow, pine, cottonwood, Garry oak, and other berry- and nut-producing trees and shrubs.
- \$ Mixed conifers and hardwoods with a good interspersed forest development stages and openings, abundant food resources, and mineral springs are necessary during the breeding and brood-rearing seasons.
- \$ Band-tailed pigeons feed on grains, acorns, nuts, buds, blossoms, young leaves, needles, and the fruits and berries of several trees and shrubs.

Management Recommendations

- \$ Protected and/or enhance mineral springs and other mineral sources used by band-tailed pigeons. These areas should be a high priority for conservation-oriented acquisition.
- \$ Avoid removal of trees surrounding mineral sites.
- \$ Avoid large clearcuts in band-tailed pigeon habitat.
- \$ Replant clearcuts with multiple tree species. Maintain and enhance berry-, fruit-, and nut-producing shrubs and trees in band-tailed pigeon habitat.
- \$ Avoid using herbicides that eliminate local food producing trees and shrubs and use integrated pest management within band-tailed pigeon habitats when possible. If pesticide or herbicide use is being considered for areas used by band-tailed pigeons, refer to Appendix A for a list of contacts to consult to assess pesticides, herbicides and their alternatives.
- \$ Report sick and dying band-tailed pigeons (indicating Trichomoniasis disease) to the nearest Washington Department of Fish and Wildlife regional office, the U.S. Fish and Wildlife Service regional headquarters, or to the USGS Wildlife Health Research Center at (608) 271-4640.
- \$ Avoid maintaining bird feeders in urban areas where Trichomoniasis outbreaks have been documented and regularly clean feeders.



Burrowing Owl

Athene cunicularia

Last updated: 2003

Written by Noelle Nordstrom

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The breeding range of the burrowing owl includes southern Canada from southern British Columbia eastward to south-central Manitoba, and extends as far south as Mexico (Haug et al. 1993). This species was extirpated from British Columbia but was reintroduced into the province in 1983. In Washington, burrowing owls typically occupy shrub-steppe habitat of the eastern part of the state during the breeding season (see Figure 1; Bryant 1990).

Burrowing owls winter mainly in the southern United States, central Mexico and Central America (Zarn 1974). Little information is available on the migration routes and times or wintering areas used by burrowing owls (Haug et al. 1993).

Recent banding data have shown that some owls overwinter in eastern Washington (Conway et al. 2002). Additionally, a resident owl was recently found with eggs that were produced in late February (C. Conway, personal communication). Most burrowing owls from Canada and the northern United States are believed to migrate south in September and October. The northern migration to the breeding grounds is thought to occur from March through the first week of May (James and Ethier 1989, James 1992, Haug et al. 1993).

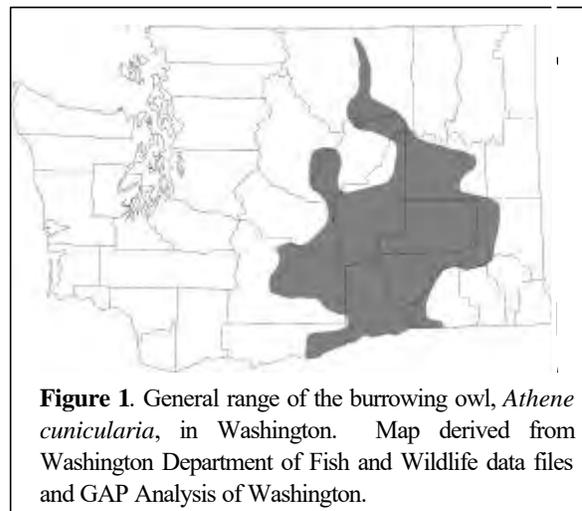


Figure 1. General range of the burrowing owl, *Athene cunicularia*, in Washington. Map derived from Washington Department of Fish and Wildlife data files and GAP Analysis of Washington.

RATIONALE

The burrowing owl is a State Candidate species and a Federal Species of Concern that was once widespread throughout steppe and prairie communities of North America. Currently, the burrowing owl is declining throughout much of its range in the western United States and Canada (Bent 1961, Holroyd and Wellicome 1997, Sheffield 1997). Breeding Bird Survey data for the Columbia Plateau indicate increasing populations, although this estimate is considered imprecise (Sauer et al. 2001).

HABITAT REQUIREMENTS

Burrowing owls inhabit open, dry areas in well-drained grasslands, shrub-steppe, prairies and deserts (Martin 1973). They also nest on agricultural lands and suburban areas (Haug et al. 1993). They use burrows for nesting, shelter, protection from predators and to reduce exposure to extreme temperatures (Zarn 1974, Winchell 1994). Although they are capable of digging, burrowing owls usually depend on abandoned burrows excavated by burrowing rodents such as prairie dogs (*Cynomys* spp.) and ground squirrels (*Citellus* spp.), or by larger mammals such as badgers (*Taxidea taxus*), foxes (*Vulpes* spp.) or coyotes (*Canis latrans*) (Mutafov 1992). In the Pacific Northwest, nesting burrowing owls often use unoccupied badger dens (Green and Anthony 1989).

The primary habitat characteristics preferred by burrowing owls include a complex of available burrows, short and/or sparse vegetation that provides good visibility, and adequate populations of prey species (Haug et al. 1993). Soil type affects the life and reusability of nesting burrows (Green and Anthony 1989, Holmes et al., in press). Specifically, the friable nature of sandy soils results in relatively high rates of burrow failure due to erosion and trampling by livestock. Silt-loam soils are more structurally stable and less likely to fail than are soils with a sand component.

Although badgers provide nesting sites for burrowing owls in Washington, they also are one of the owl's main predators (Haug et al. 1993). Burrowing owls line their nests with shredded livestock or ungulate dung, which may reduce nest predation by masking the owl's scent (Martin 1973, Zarn 1974, Green and Anthony 1989). However, several research teams have recently examined the use of dung by owls and found that this conclusion may not be true (C. Conway, personal communication).

Burrowing owls appear at breeding sites in February, and hatchlings emerge in May (C. Conway, personal communication). Recent observations suggest that resident owls initiate nesting earlier than migratory owls (C. Conway, personal communication). Incubation lasts approximately 28 days, and owlets emerge from the burrow about 2 weeks after hatching. At 2 to 3 weeks, the young begin to use other burrows near their nest burrow (C. Conway, personal observation). Paired owls will use up to 10 auxiliary burrows that are within 90 m (300 ft) of their primary nesting burrow (Climpson 1977). These auxiliary burrows are used to provide escape cover from predators, as secondary burrows for fledgling owlets and as alternates if the primary nest becomes heavily infested with parasites (Winchell 1994). Nests may also be located in natural cavities in small rock outcrops (Rich 1986). Nest burrows are often reused in successive years (Haug et al. 1993, Lutz and Plumpton 1999). There are no known records for a second brood during the breeding season in Washington (Haug et al. 1993).

The number of available burrows is not the only factor owls use to select a breeding site. They also look for areas that are open, with short and/or sparse vegetation and good horizontal visibility to see predators and locate prey (Green and Anthony 1989). In areas containing shrubs, they choose nesting burrows located near perches (Martin 1973, Green and Anthony 1989). Burrowing owls hunt by chasing prey items on foot or by catching them in the air (Haug et al. 1993). Their diet changes throughout the day, with insects most often caught during daylight and mammals preyed upon after dark (Martin 1973, Plumpton and Lutz 1993a).

Food availability and quality is likely to affect nesting densities of these owls for a given location (Desmond and Savidge 1996). Burrowing owls are opportunistic feeders, but they consume mostly insects and mammals (Green and Anthony 1989). Other prey species include birds, amphibians and reptiles (Zarn 1974, Gleason and Craig 1979, Mutafov 1992, Haug et al. 1993). Green and Anthony (1989) found a seasonal variation in diets, with rodents making up most of the owl's diet in the spring, and then shifting their diet almost exclusively to insects during the summer.

LIMITING FACTORS

Human activities that eliminate nesting and foraging habitat are likely the primary cause of this species decline (Haug et al. 1993, Sheffield 1997, Belthoff and King 2002). Intensive cultivation of shrub-steppe, grasslands and native prairies has long been recognized as a primary cause of the declining burrowing owl population (Haug et al. 1993). Agriculture and other development also expose owls to pesticides and increase their vulnerability to predation (Haug et al. 1993, Sheffield 1997). Although some burrowing owls take advantage of crop fields to exploit abundant food sources during the winter, intensive cultivation of native grasslands is a suggested cause of declines in populations of breeding owls (Haug et al. 1993). The burrowing owl is also limited

by the availability of mammal burrows. Additional mortality has been attributed to collisions with automobiles and shooting (Butts 1973, Haug et al. 1993).

Habitat Alteration

Although not all nesting burrowing owls use multiple burrows, some nests are associated with multiple burrows in close proximity to one another (Holmes et al., in press). The availability of burrows is reduced directly by destroying them (e.g., trampling of burrows by livestock and diking/tilling) and indirectly by eliminating or reducing the numbers of the animals that excavate the burrows (Haug et al. 1993). Burrow destruction by humans and dogs also occur. Thomsen (1971) estimated that 65% of the damaged burrows at her study site were caused by humans and 20% by domestic dogs. Large-scale efforts to control burrowing mammal populations can harm burrowing owls in areas where they rely on rodent burrows (Butts 1973, Holroyd et al. 2001).

Pesticides

Pesticides (specifically insecticides and rodenticides) can harm burrowing owls by causing direct mortality or sublethal effects such as decreased body weight and low reproductive success (Haug et al. 1993, Sheffield 1997, Holroyd et al. 2001). Indirect problems such as a decrease in available prey also occurs (James and Fox 1987). Burrowing owls are susceptible to secondary poisoning from insecticides and rodenticides because they feed on carcasses of poisoned prey species (Haug et al. 1993).

Direct exposure to carbofuran, a carbamate insecticide used to control grasshoppers, can significantly impact the survival and reproductive success of burrowing owls (James and Fox 1987, Mutafov 1992). When carbofuran (Furadan 480F) was applied over nest burrows, the number of young was reduced by 83% and nesting success was reduced by 82% (Mutafov 1992). In some instances, sprayed areas were less frequently occupied the following year by burrowing owls.

James et al. (1990) studied the control of ground squirrels with strychnine and its impacts on burrowing owls in southern Saskatchewan. They found, at least in the short term, no direct lethal effects on breeding burrowing owls. Adult survival, breeding success and chick weights were virtually the same in both treated and untreated areas. However, adult owls weighed significantly less in the treated versus the control sites, suggesting a sublethal effect on the species. Winchell (1994) states that nuisance rodent species can be baited or fumigated safely if care is taken not to treat burrows used by owls. However, even if burrowing owls escape inadvertent poisoning, their numbers will likely decrease because fewer burrowing mammals are creating new excavations for owl nesting and because of reduced available prey (C. Conway, personal communication).

Other Human Disturbances

Burrowing owls seem tolerant of human presence. However, Millsap and Bear (1988) found that reproductive success of burrowing owls in Florida was less at sites where home construction was taking place than at sites adjacent to construction, or where construction was absent.

Burrowing owls can also apparently become accustomed to vehicular traffic. However, nesting near roads may increase burrowing owl road kills. Plumpton and Lutz (1993b) found that vehicular traffic on roads near nesting sites did not create disturbance significant enough to influence the behavior of nesting owls. Unfortunately, owls frequently sit and hunt on roads at night, and collisions with vehicles occur frequently (Mutafov 1992).

Competition

Green and Anthony (1989) conducted a two-year study of 76 burrowing owl nests in the north-central Oregon and found nesting success to be only 57% the first year and 50% the second. Desertion was the primary reason for nest failure, which may have been related to the proximity of other nesting owls. Nestling mortality was greatest when pairs nested closer than 110 m (360 ft) apart. Green and Anthony (1989) suggested that in the Columbia Basin, nest sites were both clumped and scarce, forcing owls to nest too closely. If food sources are scarce, competition may then be strong enough to force some pairs to abandon their nests. Bryant (1990) found that competition might also limit the nesting success and return rates of burrowing owls reintroduced to areas

they historically occupied. Owls returning to their breeding grounds selected burrows as far away from neighboring owls as possible.

MANAGEMENT RECOMMENDATIONS

Protect Existing Habitat

Important ecological characteristics of areas used by burrowing owls should be maintained (Sheffield 1997). This includes preserving areas of native vegetation (e.g., shrub-steppe) and protecting burrowing mammal species (e.g., ground squirrels, badgers that create nesting habitat) for burrowing owls (Holroyd et al. 2001, Holmes et al., in press). Colonies of burrowing mammals should be preserved in areas where burrowing owls occur.

Nesting and satellite burrows should be protected from disturbance (Winchell 1994). Problems such as agricultural equipment collapsing burrow entrances and the inadvertent application of pesticides to occupied burrows can be reduced by placing markers near the burrows (Zarn 1974). Rangelands with sandy soils are especially prone to destruction of burrows by livestock (Holmes et al., in press). Where damage to burrows is likely or occurring, changes should be made in stocking rates, duration and/or season of grazing.

Activities such as oil and gas exploration and development, or other sources of human disturbance, should be restricted within 0.8 km (0.5 mi) of burrowing owl nests between 15 February and 25 September (T. Lloyd, personal communication; C. Conway personal communication). Direct destruction of burrows through chaining (dragging a heavy chain over an area to remove shrubs), cultivation, and urban, industrial, or agricultural development should be entirely avoided. Irrigation troughs should be regularly maintained because burrows often flood as a result of leaking irrigations systems (C. Conway, personal communication).

Local and regional government programs should be reviewed to ensure they address long-term conservation of burrowing owl habitat (Holroyd et al. 2001). Specifically, critical areas protection that fall under Washington's Growth Management Act could be a useful tool to conserve species, such as the burrowing owl, that are limited by loss of native habitat. Local development regulations could be designed to require mitigation and provide incentives to reduce potential impacts to this species resulting from proposed projects in owl habitat. Many resource agencies, including WDFW, have staff that can provide recommendations to assist in critical areas planning.

Pesticides

Insecticides and rodenticides are likely to harm burrowing owls directly through poisoning as well as indirectly by reducing populations of burrowing mammals (Holroyd et al. 2001). Therefore, it is recommended that alternatives should be researched thoroughly before resorting to their use. If pesticide use is planned for areas where burrowing owls occur, refer to Appendix A for contacts that can help evaluate pesticides and their alternatives.

Insecticides used in grasshopper control programs, especially carbofuran, have been shown to reduce reproductive productivity in burrowing owls. Carbofuran should not be applied within 250 m (820 ft) of active burrowing owl nests (Haug et al. 1993). Active burrowing owl nests should not be directly sprayed with any pesticide (James and Fox 1987, Lynch 1987).

Fumigation, treated bait or other means of poisoning nuisance animals should not be used in areas where burrowing owls occur. Burrowing owls are likely to scavenge the carcasses of poisoned rodents, making the owls potentially vulnerable to indirect poisoning (Sheffield 1997).

In cases where there are no alternatives to controlling burrowing mammals with poisoned bait or fumigation, thoroughly survey the area for burrowing owls during the nesting season (March through September) (Zarn 1974). Identify and mark nesting and satellite burrows by observing sentry owls, owl droppings and tracks, pellets, and dry, shredded animal dung. The use of treated grain to poison mammals should be restricted to the months of January and February (Butts 1973, Zarn 1974).

Mitigation

Artificial nest burrows are useful for expanding the capacity of existing nesting sites, and in transplant operations where burrowing owls are reintroduced into parts of their former range (Thomson 1988). Artificial burrows can also give researchers opportunities to study burrowing owl nesting ecology without destroying existing burrows (Bryant 1990, Olenick 1990, Haug et al. 1993). Dring (2000) and Green and Anthony (1997) have published papers that touch upon the design and use of artificial nesting burrows. State or federal wildlife agencies should be consulted for additional guidance prior to using artificial nesting burrows.

Artificial perches such as fence posts or stakes can be used in areas where vegetation is greater than 5 cm (2 in) tall (Green and Anthony 1989). Several perches scattered throughout the nesting area should benefit this species. Additionally, these and other mitigation measures could be incorporated into local critical areas ordinances where this species exists.

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KEY POINTS

Habitat Requirements

- Burrowing owls inhabit open, dry areas in well-drained grasslands, shrub-steppe, prairies and deserts. They also nest on agricultural lands and suburban areas.
- Preferred characteristics of burrowing owl habitat include a complex of available burrows, short and/or sparse vegetation that provides good visibility, and an adequate availability of prey.

Management Recommendations

- Preserve areas of native vegetation (e.g., shrub-steppe) used by the burrowing owl.
- Protect populations of badgers and other burrowing mammals that provide nesting habitat for burrowing owls.
- Direct local and regional government programs and policies (e.g., critical areas regulations) to ensure the survival of species, such as the burrowing owl, that are limited by loss of native habitat.
- Refer to Appendix A for contacts that should be used when evaluating pesticides and their alternatives. Insecticides and rodenticides have the potential to harm burrowing owls, and it is recommended that alternatives should be carefully considered before resorting to their use.
- Carbofuran should not be applied within 250 m (820 ft) of active burrowing owl nests. Active burrowing owl nests should not be directly sprayed with any pesticide.
- Fumigation, treated bait or other means of poisoning nuisance animals should not be used in areas where burrowing owls occur. Burrowing owls are likely to scavenge the carcasses of poisoned rodents and are potentially vulnerable to secondary poisoning.
- If there are no alternatives to controlling burrowing mammals with poisoned bait or fumigation, survey for burrowing owls during the nesting season (March through September). Identify and mark burrows used by owls by observing sentry owls, owl droppings and tracks, pellets, prey remains and burrows lined with dried animal feces.
- If all alternatives have been exhausted, poisoning of burrowing mammal colonies with treated grain should be restricted to January and February to minimize harmful effects to burrowing owls.
- Protect both nesting and auxiliary burrows from disturbance. Markers placed at burrows can direct earth moving and other heavy equipment away from burrowing areas and help prevent the collapse of underground passages. In addition, markers can help direct pesticide applications away from occupied burrows.
- Where damage to burrows from livestock trampling is likely or is occurring already, changes should be made in stocking rates, duration and/or season of grazing.
- Restrict activities such as oil and gas exploration and development or other sources of human disturbance within 0.8 km (0.5 mi) of burrowing owl nests between 15 February and 25 September. Direct destruction of burrows by urban, industrial or agricultural development should be avoided entirely.
- Artificial nest burrows can be used to expand the capacity of existing nesting sites and can aid in the reintroduction of owls into parts of their former range.
- Artificial perches, such as fence posts or stakes can be used in areas where vegetation is greater than 5 cm (2 in) tall. Several perches scattered throughout the nesting area might be required to benefit this species.



Flammulated Owl

Otus flammeolus

Last updated: 2003

Written by David W. Hays and Elizabeth A. Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Flammulated owls are found in mountainous areas of western North America from Guatemala to Canada (American Ornithologists' Union 1983).

In Washington, they are breeding residents along the eastern slope of the Cascades, Okanogan Highlands and Blue Mountains. (see Figure 1; Smith et al. 1997).

RATIONALE

The flammulated owl is a State Candidate species. Limited research on the flammulated owl indicates that its demography and life history, coupled with narrow habitat requirements, make it vulnerable to habitat changes. The mature and older forest stands that are used as breeding habitat by the flammulated owl have changed during the past century due to fire management and timber harvest.

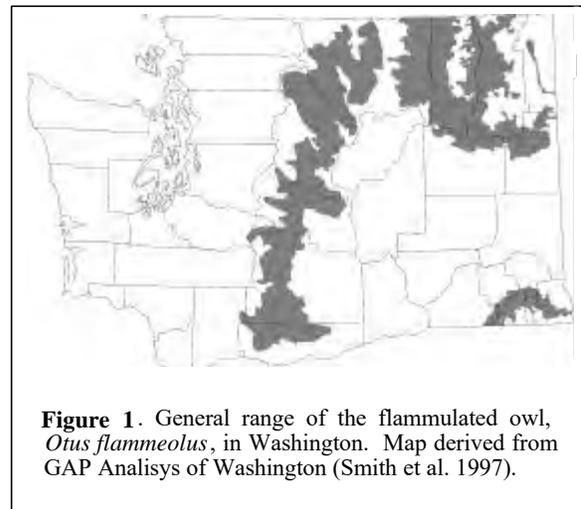


Figure 1. General range of the flammulated owl, *Otus flammeolus*, in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

HABITAT REQUIREMENTS

Flammulated owls are typically found in mid-elevation coniferous forests containing mature to old, open canopy yellow pine (ponderosa pine [*Pinus ponderosa*] and Jeffrey pine [*Pinus jeffreyi*]), Douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*) (Bull and Anderson 1978, Goggans 1986, Howie and Ritchie 1987, Reynolds and Linkhart 1992, Powers et al. 1996). In central Colorado, Linkhart and Reynolds (1997) reported that 60% of the habitat within the area defended by territorial males consisted of old (200-400 year) ponderosa pine/Douglas-fir forest. Territories most consistently occupied by breeding pairs (>12 years) contained the greatest (>75%) amount of old ponderosa pine/Douglas-fir forest. Marcot and Hill (1980) reported that California black oak (*Quercus kelloggii*) and ponderosa pine occurred in 67% and 50%, respectively, of the flammulated owl nesting territories they studied in northern California. In northeastern Oregon, Bull and Anderson (1978) noted that

ponderosa pine was an overstory species in 73% of flammulated owl nest sites. Powers et al. (1996) reported that ponderosa pine was absent from their flammulated owl study site in Idaho and that Douglas-fir and quaking aspen (*Populus tremuloides*) accounted for all nest trees.

The owls nest primarily in cavities excavated by flickers (*Colates* spp.), hairy woodpeckers (*Picoides villosus*), pileated woodpeckers (*Dryocopus pileatus*), and sapsuckers (*Sphyrapicus* spp.) (Bull et al. 1990, Goggans 1986, McCallum 1994). Bull et al. (1990) found that flammulated owls used pileated woodpecker cavities with a greater frequency than would be expected based upon available woodpecker cavities. There are only a few reports of this owl using nest boxes (Bloom 1983). Reynolds and Linkhart (1987) reported occupancy in 2 of 17 nest boxes put out for flammulated owls.

In studies from northeastern Oregon and south central Idaho, nest sites were located 5-16 m (16-52 ft) high in dead wood of live trees, or in snags with an average diameter at breast height (dbh) of >50 cm (20 in) (Goggans 1986, Bull et al. 1990, Powers et al. 1996). Most nests were located in snags. Bull et al. (1990) found that stands containing trees greater than 50 cm (20 in) dbh were used more often than randomly selected stands. Reynolds and Linkhart (1987) suggested that stands with trees >50 cm (20 in) were preferred because they provided better habitat for foraging due to the open nature of the stands, allowing the birds access to the ground and tree crowns. Some stands containing larger trees also allow more light to the ground that produces ground vegetation, serving as food for insects preyed upon by owls (Bull et al. 1990).

Both slope position and slope aspect have been found to be important indicators of flammulated owl nest sites (Goggans 1986, Bull et al. 1990). In general, ridges and the upper third of slopes were used more than lower slopes and draws (Bull et al. 1990). It has been speculated that ridges and upper slopes may be preferred because they provide gentle slopes, minimizing energy expenditure for carrying prey to nests. Prey may also be more abundant or at least more active on higher slopes because these areas are warmer than lower ones (Bull et al. 1990).

Breeding occurs in mature to old coniferous forests from late April through early October. Nests typically are not found until June (Bull et al. 1990). The peak nesting period is from mid-June to mid-July (Bent 1961). Mean hatching and fledging dates in Idaho were 26 June and 18 July, respectively (Powers et al. 1996).

In Oregon, individual home ranges averaged about 10 ha (25 ac) (Goggans 1986). Territories are typically found in core areas of mature timber with two canopy layers present (Marcot and Hill 1980). The uppermost canopy layer is formed by trees at least 200 years old. Core areas are near, or adjacent to clearings of 10-80% brush cover (Bull and Anderson 1978, Marcot and Hill 1980). Linkhart and Reynolds (1997) found that flammulated owls occupying stands of dense forest were less successful than owls whose territories contain open, old pine/fir forests.

Day roosts are located in mature mixed conifer stands with dense, multi-layered canopies (Bull and Anderson 1978, Goggans 1986). Dense stands presumably provide cover from weather and predators, and they may form core areas of the owls' territories.

Flammulated owls are presumed to be migratory in the northern part of their range (Balda et al. 1975), and winter migrants may extend to neotropical areas in central America. In Oregon, they arrive at the breeding sites in early May and begin nesting in early June; young fledge in July and August (Goggans 1986; E. Bull, personal communication). In Colorado, owlets dispersed in late August and the adults in early October (Reynolds and Linkhart 1987).

Flammulated owls are entirely insectivores; nocturnal moths are especially important during spring and early summer (Reynolds and Linkhart 1987). As summer progresses and other prey become available, lepidopteran larvae, grasshoppers, spiders, crickets, and beetles are added to the diet (Johnson 1963, Goggans 1986). In Colorado, foraging occurred primarily in old ponderosa pine and Douglas-fir with an average tree age of approximately 200 years (Reynolds and Linkhart 1992). Old growth ponderosa pine were selected for foraging, and young Douglas-firs were avoided. Flammulated owls principally forage for prey on the needles and bark of large trees. They also forage in the air, on the ground, and along the edges of clearings (Goggans 1986; E. Bull, personal communication; R. Reynolds, personal communication). Grasslands in and adjacent to forest stands are thought to be important foraging sites (Goggans 1986). However, Reynolds (personal communication) suggests that ground

foraging is only important from the middle to late part of the breeding season, and its importance may vary annually depending upon the abundance of ground prey. Ponderosa pine and Douglas-fir were the only trees selected for territorial singing in male defended territories in Colorado (Reynolds and Linkhart 1992).

LIMITING FACTORS

Availability of suitable nest cavities and/or arthropod prey in ponderosa pine or mixed conifer forests are likely limiting. Reasons for the apparent narrow elevation range exhibited by flammulated owls are not known, but reasons are likely related to food and ecological tolerances (R. Reynolds, personal communication).

MANAGEMENT RECOMMENDATIONS

Creation of large areas of even-aged timber is likely detrimental to flammulated owls. Uneven stands of open mature and old timber located near brushy clearings provide good habitat for flammulated owls. The selection for mature to old-growth ponderosa pine/Douglas-fir forests in areas where owls have been studied throughout the west indicates that this habitat may also be important in Washington. Marcot and Hill (1980) noted the potential importance of old black oak trees to flammulated owls in California because of their numerous natural cavities. Washington's white oak/conifer forests should be surveyed for these owls.

All conifers and hardwoods having natural or excavated cavities in and adjacent to flammulated owl territories should be left undisturbed (Marcot and Hill 1980). Bull et al. (1990) suggests leaving large snags and trees (>50 cm [20 in] dbh and 6 m [20 ft] tall) along ridge-tops, and south and east facing slopes in ponderosa pine/Douglas-fir or grand fir forest types. Reynolds (personal communication) recommends leaving at least 5 snags/ha (2/ac) in ponderosa pine habitat.

Future nest snags should be recruited by continually retaining large, mature trees in or adjacent to suitable flammulated owl habitat (Marcot and Hill 1980). Where snags are lacking, large trees can be topped to promote woodpecker use and cavity formation. Fuelwood collection should be limited where flammulated owls occur because this practice eliminates nest snags.

Areas with brushy understory vegetation may provide insect prey and feeding cover when flammulated owls forage near the ground. Therefore, forest practices (e.g., application of herbicide) that remove brush from clearings adjacent to flammulated owl territories should be avoided. Application of insecticides that affect the owl's prey species should not occur within close proximity to flammulated owl home range areas, approximately 305 m (1,000 ft) from the nest. If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

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KEY POINTS

Habitat Requirements

- Associated with mid-elevation coniferous forest.
- Nest and roost in mature and old, multi-storied stands.
- Nest in cavities.
- Insectivorous, forage in open areas.

Management Recommendations

- Maintain stands of open, mature timber near brushy clearings.
- Retain all trees with cavities in or adjacent to flammulated owl territories.
- Maintain at least 5 snags/ha (2/ac) >50 cm (20 in) dbh and >6 m (20 ft) tall in ponderosa pine forests.
- Ensure snag recruitment by retaining large, mature trees in or adjacent to flammulated owl habitat.
- Where snags are lacking, top large trees to promote woodpecker use and cavity formation.
- Limit fuelwood collection where flammulated owls occur.
- Leave brush in clearings near owl territories.
- Do not apply insecticides or herbicides in areas used by owls.



Vaux's Swift

Chaetura vauxi

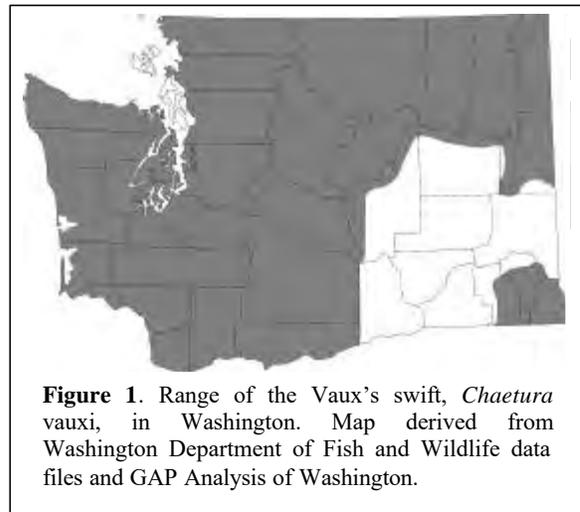
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Written by Jeffrey C. Lewis, Morie Whalen, and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Vaux's swifts breed from southeastern Alaska, northwestern and southern British Columbia, western Montana, and northern Idaho south to central California and west to the Pacific Coast. They winter from northern Mexico south to Central America and Venezuela (Bull and Collins 1993, DeGraaf and Rappole 1995, Sibley 2000).

Vaux's swifts are summer residents throughout wooded areas of Washington (see Figure 1; Hoffman 1927, Jewett et al. 1953, Manuwal and Huff 1987, Lundquist and Mariani 1991). They usually arrive in Washington around early May and remain until September (Hoffman 1927). Breeding populations may occur in forested habitats throughout the state (Kitchin 1949, Jewett et al. 1953, Thomas et al. 1979, Brown 1985).



RATIONALE

The Vaux's swift is a State Candidate species associated with old-growth and mature forests in the Cascade Range (Manuwal and Huff 1987, Lundquist and Mariani 1991), Olympic Peninsula (Kitchin 1949), and Blue Mountains (Jewett et al. 1953). Throughout their breeding range they are highly dependent on large hollow trees and snags for nesting and roosting (Baldwin and Zaczkowski 1963, Bull 1991, Bull and Cooper 1991). Loss of old-growth and mature forested habitat in Washington (Harris 1984, Thomas et al. 1990) threaten Vaux's swift populations (Bull 1991, Bull and Hohmann 1993).

HABITAT REQUIREMENTS

Vaux's swifts are strongly associated with old-growth forests (Manuwal and Huff 1987, Gilbert and Allwine 1991, Huff and Raley 1991, Lundquist and Mariani 1991, Manuwal 1991, Bull and Hohmann 1993), nesting primarily in old-growth coniferous forests (Baldwin and Zaczkowski 1963, Bull and Cooper 1991, Bull and Hohmann 1993). However, the characteristics of the stand as a whole (i.e., age, canopy layering, stem density) may not be as critical as the availability of suitable nesting or roosting structures (Bull and Hohmann 1993). The availability of suitable nesting or roosting structures is suspected to be the limiting factor for this species (Bull and Hohmann 1993). They

require hollow chambers in large snags or live trees with broken tops for nesting and night roosting. The height where swifts nest in hollow trees or snags may vary, ranging from near base level (Baldwin and Zaczkowski 1963) to an average of 12 m (39 ft) (Bull and Cooper 1991). Bull and Cooper (1991) found that nest trees averaged 25 m (82 ft) in height and 68 cm (27 in) in diameter at breast height (dbh). Many Vaux's swifts nest in hollow trees used by roosting pileated woodpeckers (*Dryocopus pileatus*). Swifts enter these trees through holes excavated by pileated woodpeckers. Without the aid of pileated woodpecker excavation, swifts would have no access to many hollow tree chambers (Bull and Collins 1993). Sterling and Paton (1996) suggested that Vaux's swifts may rely on pileated woodpeckers to create nesting habitat, potentially explaining the similar ranges of these two species in California.

Vaux's swifts have been frequently observed nesting or roosting in chimneys (Jewett et al. 1953, Huey 1960, Griffee 1961, Baldwin and Hunter 1963, Thompson 1977, Sterling and Paton 1996). Historical documentation indicates they prefer older construction, brick chimneys (Huey 1960, Baldwin and Hunter 1963, Baldwin and Zaczkowski 1963, Bull and Collins 1993). Vaux's swifts have been reported using chimneys at least 6.2 m (20 ft) in height, with openings ranging from 23 cm x 23 cm (9 in x 9 in) to 36 cm x 41 cm (14 in x 16 in), securing their nests in the chimney corners (Griffee 1961, Baldwin and Hunter 1963, Thompson 1977). Griffee (1961) observed up to 5 nesting pairs per chimney; however, 1 nest per chimney or tree is typical (Baldwin and Zaczkowski 1963, Thompson 1977, Bull and Collins 1993). Although chimneys are used by this species, hollow trees are favored by nesting and roosting swifts making them more vulnerable to the loss of old-growth forests as opposed to the loss of suitable artificial structures (Bull and Collins 1993).

Vaux's swifts feed exclusively while flying. Their diet consists primarily of flying insects and they forage mainly within a 0.40 km (0.25 mi) radius of the nest site when feeding their young (Bull and Beckwith 1993). Forests at various stages of development, grasslands and aquatic habitats are all used for foraging (Bull and Beckwith 1993).

LIMITING FACTORS

The strong connection of this species to old-growth forests suggest that availability of this type of forested habitat and its associated features (e.g., large, hollow snags and live trees) limit the swift's distribution and abundance during breeding season.

MANAGEMENT RECOMMENDATIONS

Vaux's swifts are found at their highest densities in old-growth forested habitat (Carey 1989, Carey et al. 1991, Gilbert and Allwine 1991, Huff and Raley 1991, Lundquist and Mariani 1991, Manuwal 1991, Bull and Hohmann 1993). The higher abundance of large, hollow snags and live trees appear to explain the greater density of swifts in old-growth versus younger forested stands (Bull and Collins 1993). Protection of existing old-growth should benefit Vaux's swifts, along with managing forest stands on long rotations (>200 years) and maintaining large hollow snags and live trees (Cline et al. 1980, Bull and Collins 1993, Bull and Blumton 1997). Large snags and live trees intended for future snag replacement should be retained and adequately distributed in harvest units (Bull and Collins 1993). Leave all hollow snags and live trees intact [preferably >50 cm (20 in) dbh]. Large defective trees, especially those showing signs of decay such as top rot, broken tops, fungal conks, dead branch stubs, or other defects, should be retained (Cline et al. 1980, Neitro et al. 1985).

Avoid disturbing chimneys that are occupied by nesting or roosting Vaux's swifts during the breeding season or during migration (early May - September). Chimneys are becoming less accessible because insulated pipe are replacing many old brick design, and others are covered with screen spark-arresters (Bull and Collins 1993). The retention of traditional chimney designs are preferred by nesting and roosting swifts. However, safe design should also be accounted for during chimney construction and modification.

Insecticides can greatly reduce Vaux's swift's primary food source and are a risk to swift populations (Brown 1985). All insecticide use should be avoided in or near nests and roosts. Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to birds

(McEwen et al. 1972, Grue et al. 1983, Grue et al. 1986, Smith 1987). Synthetic pyrethroid insecticides (e.g., permethrin) may be an alternative to these compounds outside of snag-rich habitat, because these chemicals are not persistent in the environment or toxic to birds at recommended concentrations. However, synthetic pyrethroids are highly toxic to aquatic invertebrates and fish (Grue et al. 1983, Smith and Stratton 1986). Refer to Appendix A for contacts to assess pesticides, herbicides, and their alternatives.

Appropriate buffer widths for insecticide application near sensitive riparian and wetland areas range from 31-500 m (100-1,640 ft) (Kingsbury 1975, Payne et al. 1988, Terrell and Bytnar-Perfetti 1989). Buffer width calculations for insecticide application adjacent to snag-rich habitat should take into account the droplet size, volume of the compound and weather conditions that could influence wind drift (Kingsbury 1975, Brown 1978, Payne et al. 1988). Maintain a buffer of 500 m (1,640 ft) (Kingsbury 1975) from snag-rich areas when spraying insecticides (Brown 1978, Smith 1987).

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KEY POINTS

Habitat Requirements

- Vaux's swifts nest in hollow chambers created by decay within live or dead trees.
- Large hollow snags and live trees averaging 25 m (82 ft) tall, and 68 cm (27 in) dbh located in old-growth and mature forests are used for nesting. Many Vaux's swifts nest in hollow trees excavated by pileated woodpeckers.
- Overall stand characteristics (e.g., age, canopy layering, stem density) do not appear to be as important to Vaux's swifts as the availability of large, hollow snags and live trees.
- Vaux's swifts will nest/roost in unused brick chimneys with openings at least 23 cm x 23 cm (9 in x 9 in).

Management Recommendations

- Maintain existing old-growth as well as mature forest habitat. Manage stands on longer rotations ($t > 200$ years).
- Retain all large, hollow large snags and large "defective" live trees, especially in younger, managed stands.
- Avoid disturbance of chimneys that are occupied by nesting and roosting Vaux's swifts during the breeding season (early May - September).
- Retain traditional chimney designs for use by nesting and roosting swifts. However, safe design should also be strongly considered for chimney construction and modification.
- Avoid using insecticides in areas inhabited by Vaux's swifts. Refer to Appendix A for contacts to assess pesticides, herbicides, and their alternatives.
- Substitute with synthetic pyrethroid insecticides (e.g., permethrin) or diflubenzuron (e.g., dimilin). Restrict the use of organophosphorous, organochlorine, and carbamate compounds to locations outside of snag-rich areas, away from swift nests and roosts.
- Maintain a 500 m (1,640 ft) buffer around snag-rich areas when spraying insecticide and apply during appropriate weather to avoid wind drift.

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018



Lewis' Woodpecker *Melanerpes lewis*

Last updated: 2002

Written by Jeffrey C. Lewis, Morie Whalen, and Elizabeth A. Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The Lewis' woodpecker breeds from British Columbia and southern Alberta, south to Utah and Colorado, and from South Dakota west to the Cascades. It is either a year-round resident or winters from Oregon south to Baja, California, and east to western Texas and Oklahoma (Tobalske 1997).

Historically, this woodpecker was known to breed throughout the Puget Trough, southwest Washington, and the Olympic Peninsula (Jewett et al. 1953, Jackman 1975, MacRoberts and MacRoberts 1976). Currently in Washington, Lewis' woodpeckers only breed east of the Cascades from the Columbia Gorge north, and east into the Okanogan highlands and northeast Washington (see Figure 1). Their present breeding range also includes the Blue Mountains (Tobalske 1997).

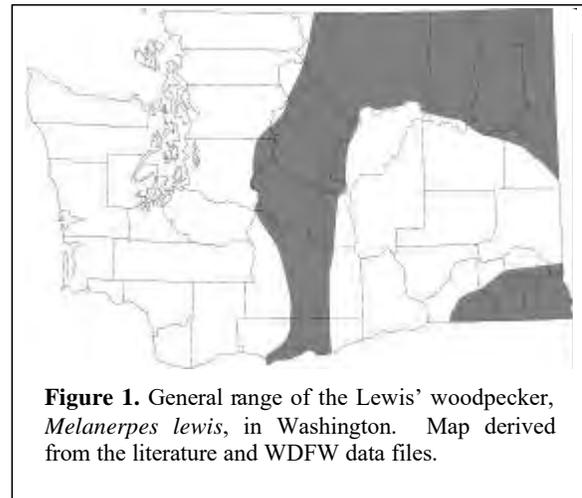


Figure 1. General range of the Lewis' woodpecker, *Melanerpes lewis*, in Washington. Map derived from the literature and WDFW data files.

RATIONALE

The Lewis' woodpecker is a State Candidate species. This species has shown a recent decline in the Western states, possibly due to competition for snags and nest cavities and loss of their historic riparian and ponderosa pine habitat (U.S. Fish and Wildlife Service 1985, Saab and Vierling 2001, Sauer et al. 2001). In Washington, the Lewis' woodpecker is only locally abundant as a breeding bird, and its range has contracted within the last half of this century to include only habitats east of the Cascade crest. This species is vulnerable to the loss of snag habitat, and to habitat loss as a result of fire suppression and brush control (Tobalske 1997, Saab and Vierling 2001).

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

HABITAT REQUIREMENTS

The Lewis' woodpecker prefers a forested habitat with an open canopy and a shrubby understory, with snags available for nest sites and hawking perches (Bock 1970). Bock (1970) states that the critical features of Lewis' woodpecker habitat are forest openness, understory composition, and availability of insect fauna. Additionally, optimum habitat for the Lewis' woodpecker has been defined by the following factors (Sousa 1983):

- total tree canopy closure $\leq 30\%$,
- total shrub crown cover $\geq 50\%$,
- crown cover of mast (nut) producing shrubs $\geq 70\%$,
- percent of total tree canopy closure comprised of hard mast trees $\geq 70\%$, and
- distance to potential mast storage sites ≤ 0.8 km (0.5 mi).

Breeding

Breeding populations of the Lewis' woodpecker in Washington are locally distributed, often in colonies, and occur frequently in burned forests (Jewett et al. 1953, Raphael and White 1984, Block and Brennan 1987, Tobalske 1997). Riparian areas dominated by cottonwoods (*Populus trichocarpa*), and oak (*Quercus garryana*) woodlands are major breeding habitats, as are open or park-like ponderosa pine (*Pinus ponderosa*) forests (Sousa 1983, Saab and Vierling 2001). Burned stands of Douglas-fir (*Pseudotsuga menziesii*) and mixed conifers are also used by this woodpecker as breeding habitat (Bock 1970, Raphael and White 1984). Openness is the characteristic common to all breeding habitats, and is related to this woodpecker's foraging methods of hawking and gleaning in brush (Bock 1970). Brushy undergrowth that supports insects on which Lewis' woodpeckers feed is an important component of their preferred breeding habitat (Tobalske 1997). In eastern Washington, undergrowth consisting of species such as sagebrush (*Artemisia* spp.), golden currant (*Ribes aureum*), bitterbrush (*Purshia tridentata*) and rabbitbrush (*Chrysothamnus* spp.) is typically present where this woodpecker breeds.

Lewis' woodpeckers will also use selectively logged or burned coniferous forests that are structurally similar to open ponderosa pine (Raphael and White 1984). In the normal cycle of reforestation, a burn may become suitable habitat for Lewis' woodpeckers between the 10th and 30th year of regeneration, when a shrub understory develops and insects are prevalent (Bock 1970, Jackman and Scott 1975). However, Saab and Dudley (1995) found Lewis' woodpeckers using a ponderosa pine stand two years after it burned. They reported Lewis' woodpeckers displacing hairy woodpeckers and western bluebirds from nest cavities that had been excavated in snags before the fire. This behavior had not been reported before in this species. Lewis' woodpecker nesting sites within salvaged stands of burned forests had an average of 59 snags/ha (24/ac) >23 cm (9 in) diameter at breast height (dbh) and 16 snags/ha (16.5/ac) >51 cm (20 in) dbh (Saab and Dudley 1997).

Riparian areas are also used as breeding habitat for Lewis' woodpeckers. Groves of cottonwood trees are especially suitable because they are open and usually have dead trees that offer nest and roost sites. Insects are abundant due to the lush vegetation within riparian areas (Bock 1970, Jackman and Scott 1975).

Lewis' woodpeckers have high nest site fidelity and often use the same cavity in consecutive years (Bock 1970). This woodpecker will excavate its own nest cavity, but it also uses natural cavities or holes excavated by other woodpeckers. Being a weak excavator, the Lewis' woodpecker prefers soft snags to live trees (Raphael and White 1984). Nest snags and trees in the Sierra Nevada averaged 11.4 m (37 ft) in height and 66.5 cm (26 in) dbh; mean nest height was 7.3 m (24 ft), and the mean diameter at nest-height was 52 cm (20 in) (Raphael and White 1984).

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

Feeding

The Lewis' woodpecker is an opportunistic feeder that breeds where insects are locally abundant, and it winters where hard nut producing trees are readily available (Bock 1970). Their diet during the spring and summer consists primarily of insects including ants, bees and wasps, beetles, grasshoppers and true bugs (Tobalske 1997). Fruits and berries were the most frequently eaten foods in late summer and fall, whereas winter foods consisted of acorns, commercial nuts, and corn. The feeding behavior of Lewis' woodpeckers is atypical among woodpeckers. Bock (1970) found that in summer they spent approximately 60% of their foraging time capturing insects in flight, 30% ground/brush foraging, and 10% gleaning insects from trees. Raphael and White (1984) reported that of Lewis' woodpeckers' foraging time, 76% was spent capturing insects in flight, 22% gleaning, and 2% drilling. During winter, Lewis' woodpeckers feed mostly on cached acorns and insects, and they spend some time flycatching and gleaning insects (Bock 1970). Although these woodpeckers protect only their immediate nest site during the breeding season, they defend a feeding area in winter (Bock 1970).

LIMITING FACTORS

The availability of snags, nest holes excavated by other woodpeckers, and abundant prey populations are the predominant factors that limit distribution and abundance of the Lewis' woodpecker (Jackman 1975). The selection of one specific area by this woodpecker probably depends on insect abundance. Certain timber management practices and heavy livestock grazing can impact an area's suitability for Lewis' woodpeckers (Jackman 1975, Jackman and Scott 1975). Fire suppression also has likely impacts on the availability of suitable habitat for this species (Saab and Dudley 1997, Tobalske 1997).

Certain habitats are only temporarily suitable, such as logged or burned forests prior to regeneration of second-growth stands. However, post-burn forests likely provide suitable habitat for longer periods within the dryer portions of Lewis' woodpecker range (e.g., eastern fringe of the Cascades) as a result of slower regrowth. Logged or burned coniferous forest is an important part of Lewis woodpecker habitat, but it is generally only suitable in the shrub stage. Unfortunately the brushy stage is undesirable for timber management, and efforts are made to eliminate it. Management practices that remove snags and damaged or diseased trees also limit the availability of nest sites. Additionally, livestock grazing can destroy native understory vegetation, which decreases insect abundance (Jackman and Scott 1975).

Frequent human disturbance at nest sites can also have a negative effect on this species. Lewis' woodpeckers become agitated by continued disturbance at the nest site and will occasionally desert their nest (Bock 1970).

MANAGEMENT RECOMMENDATIONS

In areas where the Lewis' woodpecker occurs, as many standing dead, insect infested, and damaged trees should be retained as possible during thinning and cutting operations (Jackman 1975, Saab and Dudley 1997). Large, soft snags that are suitable for Lewis' woodpecker nest sites are particularly valuable. In managed forests, retaining clusters of trees benefits this species over the retention of uniformly distributed trees for partially logged or salvaged units (Saab and Dudley 1997).

When replanting after a timber harvest, attempts should be made to duplicate natural tree species composition, rather than replanting with a single species (Jackman 1975). Sections of logged or burned forest should be left to regenerate naturally to brush (Jackman and Scott 1975). The brushy forest stage is important for maintaining a healthy insect populations and should not be suppressed (Jackman 1975).

Green forests that are either maintained for timber harvest or have a high risks of a stand-replacement fire should be managed in a way that snag numbers will replenish themselves over time (particularly by retaining broken-topped trees). This management practice will contribute to the continuous availability of easily excavated post-fire nesting trees. In burned forests, retain as many large (>50 cm (20 in) dbh) snags as possible (Saab and Dudley 1997).

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations will likely have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982). If pesticides or herbicide use is planned in areas inhabited by this species, refer to Appendix A which lists contacts useful when assessing pesticides, herbicides and their alternatives.

Livestock grazing should be limited where the Lewis' woodpecker occurs, so that native understory vegetation is not destroyed. However, more research is necessary to determine the specific threshold limits on grazing pressure to protect habitat for species. A brushy understory is necessary to provide an adequate insect prey base (Jackman 1975, Jackman and Scott 1975).

Frequent or prolonged human disturbance at nest sites of Lewis' woodpeckers should be avoided. Adult woodpeckers become agitated by continual disturbance at the nest site, and may desert the nest (Bock 1970).

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KEY POINTS

Habitat Requirements

- Critical features of Lewis' woodpecker include forested habitat with an open canopy, a shrubby understory composition, insect fauna and snags available for nest sites and hawking perches.
- Optimum habitat for the Lewis' woodpecker has been defined by the following factors:
 - total tree canopy closure $\leq 30\%$,
 - shrub crown cover $\geq 50\%$,
 - crown cover of mast (nut) producing shrubs $\geq 70\%$,
 - percent of total tree canopy closure comprised of hard mast trees $\geq 70\%$, and
 - distance to potential mast storage sites ≤ 0.8 km (0.5 mi).
- Mainly inhabits riparian stands dominated with cottonwoods, oak woodlands, and park-like ponderosa pine forests with brushy understory. They also use Douglas-fir, and mixed-conifer forests, and logged or burned areas up to 30 years old.
- Excavates cavities or uses available nest holes in snags.
- Feeds mainly on insects and hard nut crops and uses perches to scan for and catch insects in flight.

Management Recommendations

- Retain as many standing dead, insect infested, and damaged trees as possible during thinning and cutting operations. Large, soft snags are particularly valuable. In managed forests, retaining clusters of trees benefits this species over the retention of uniformly distributed trees for partially logged or salvaged units.
- Duplicate natural tree species composition when replanting after a timber harvest rather than replanting stands with a single species of tree. Sections of logged or burned forest should be left to regenerate naturally to brush. A brushy successional stage is important for healthy insect populations and should not be suppressed.
- Manage green forests that are either maintained for timber harvest or have a high risk of a stand-replacement fire in a way that snag numbers will replenish themselves over time (particularly by retaining broken-topped trees). This management practice will contribute to the continuous availability of easily excavated post-fire nesting trees. In burned forests, retain as many large (>50 cm (20 in) dbh) snags as possible.
- Refer to Appendix A that lists useful contacts for evaluating pesticides, herbicides and other alternatives if pesticide use is planned in areas where this woodpecker occurs.
- Limit livestock grazing where the Lewis' woodpecker occurs, so that native understory vegetation is not destroyed.
- Avoid frequent or prolonged human disturbance at nest sites of Lewis' woodpeckers.



Black-backed Woodpecker

Picoides arcticus

Last updated: 2003

Written by Jeffrey C. Lewis, Elizabeth A. Rodrick, and Jeffrey M. Azerrad

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The black-backed woodpecker inhabits the boreal forests of North America, including the Cascade Mountains, the northern portions of the Sierra Nevada and Rocky Mountains, much of Canada, southeastern Alaska, northern New England, and the upper Midwest

In Washington, this woodpecker is found on the eastern slopes of the Cascade Mountains and in the coniferous forests of the Okanogan Highland, Selkirk and the Blue Mountains (see Figure 1; Smith et al. 1997).

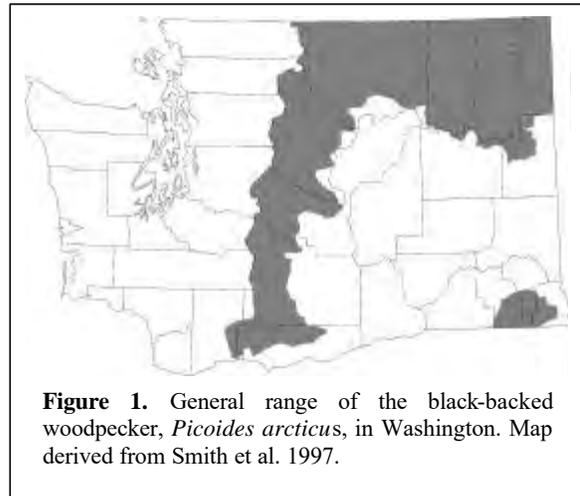


Figure 1. General range of the black-backed woodpecker, *Picoides arcticus*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The black-backed woodpecker is a State Candidate species and is in danger of population decline through loss of breeding and foraging habitat.

HABITAT REQUIREMENTS

Black-backed woodpeckers primarily inhabit standing dead lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*) and mixed coniferous forests (Dixon and Saab 2000, Kotliar et al. 2002). This species' dependence on burned forests and forests that have undergone other types of large-scale disturbances (e.g., insect infestation, blowdowns) is well documented (Hutto 1995, Caton 1996, Kreisel and Stein 1999, Dixon and Saab 2000, Kotliar et al. 2002). They have a scattered distribution with populations responding to prey abundance (Caton 1996). Disturbed forests are attractive to the black-backed woodpecker because they feed on insects (mainly larvae of wood-boring beetles) that are particularly abundant following a disturbance event. In northeast Washington, black-backed woodpeckers were 20 times more abundant in burned versus unburned forests (Kreisel and Stein 1999), and often were restricted to standing dead forests created by recent stand-replacement fires

(Hutto 1995, Caton 1996). Home ranges in mature and old-growth forests of central Oregon ranged between 59 and 193 ha (147 and 478 ac; Goggans et al. 1988).

Nesting

In mature ponderosa pine and mixed conifer forests, black-backed woodpeckers nest predominantly in ponderosa and lodgepole pine (Bull et al. 1986). However, tree species composition varies regionally (Dixon and Saab 2000) and appears not to be as important a factor as forest condition (e.g., burned, insect damaged) for explaining the presence of nesting birds. This species nests in taller, small diameter, recently dead trees (>15 m [50 feet] in height, <50 cm [20 inches] in diameter-at-breast-height [dbh], and dead for five years or less) (Raphael and White 1984, Bull et al. 1986). They excavate nest cavities in live trees and hard snags (Spring 1965, Raphael and White 1984, Saab and Dudley 1997). Black-backed woodpeckers were commonly found in unlogged ponderosa pine/Douglas-fir forests with a high density of relatively small, hard snags (Saab and Dudley 1997). Johnsgard (1986) found black-backed woodpeckers nesting in similar habitat as the three-toed woodpecker (*Picoides tridactylus*).

In central Oregon's mixed conifer and lodgepole pine forests, black-backed woodpeckers selected mature and old-growth stands, and nested exclusively in lodgepole pine (Goggans et al. 1988). They avoided young stands and logged areas for both nesting and feeding. Live trees and snags used for nesting had heartrot and a mean dbh of 28 cm (11 in). However, it should be noted that lodgepole pine-dominated forests, such as the forests examined in the central Oregon research, are uncommon in Washington (J. Buchanan, personal communication).

Feeding

In northeastern Oregon, black-backed woodpeckers foraged in both live and dead trees, and showed a preference for ponderosa pine (Bull et al. 1986). During winter months, black-backed woodpeckers foraged almost entirely upon standing dead trees, and preferred western larch within burned forests of northeast Washington (Kreisel and Stein 1999). The larvae of wood-boring beetles such as the pine beetle (*Dendroctonus* spp.) constituted most of their diet (Goggans et al. 1988, Dixon and Saab 2000). Trees used for foraging averaged 19 m (62 ft) in height with a dbh of 34 cm (13 in) and had been dead less than 2 years (Bull et al. 1986). Black-backed woodpeckers most often used the trunk as foraging substrate (Raphael and White 1984, Villard 1994). They frequently obtained insects by chipping bark from dead and dying trees (Short 1974, Kreisel and Stein 1999), but also excavated into the wood of tree trunks and logs in search of insect larvae (Raphael and White 1984, Villard 1994).

Roosting

In Oregon's mixed conifer and lodgepole pine forests, black-backed Woodpeckers roosted mainly in cankers, trunk scars, mistletoe clumps or directly on pine trunks (Goggans et al. 1988). They chose mature and old-growth forests with an average canopy closure of 40%. Trees used for roosting averaged 28 cm (11 in) in diameter and 20 m (65 ft) in height. Studies examining roosting patterns in habitat-types more closely associated with the Washington landscape are lacking.

LIMITING FACTORS

The availability of burned areas that are not subjected to salvage logging, and of insect-damaged forests with numerous snags, limits the distribution of the black-backed woodpecker (Kotliar et al. 2002). Hutto (1995) found that this species is highly restricted to early post-fire conditions that become less suitable 5 to 6 years after a fire due to declining prey availability. Historical and recent fire management policies have negatively impacted this species by reducing the chance of large, high intensity wildfires that create suitable conditions for the black-backed woodpecker (Dixon and Saab 2000).

MANAGEMENT RECOMMENDATIONS

Suitable mature, old-growth and recently dead lodgepole pine, ponderosa pine and pine-dominated mixed coniferous forest stands that have experienced recent pine beetle infestation, large blowdowns or fire are important for the black-backed woodpecker (Dixon and Saab 2000). A recent review of studies in the western United States on post-fire salvage logging documented the serious negative impacts of this activity to the viability of black-backed woodpeckers (Kotliar et al. 2002). The review concluded that this species rarely used even partially-logged post-fire forests. Therefore, where salvage logging is planned, it is important to delay any work for the first five years after the disturbance event (Hutto 1995, Dixon and Saab 2000). This span is critical in providing habitat because the woodpecker's primary food source (wood-boring beetles) becomes less abundant after this period (Caton 1996). Salvage operations should also retain >104-123 snags/ha (>42-50 snags/ac) that are >23 cm dbh (>9 in dbh) (Dixon and Saab 2000, Wisdom et al. 2000).

Goggans et al. (1988) suggested that the traditional approach of managing cavity nesters by retaining a relatively small number of snags and green replacement trees in harvested stands may not maintain enough foraging substrate to sustain viable black-backed woodpecker populations. Instead, this specialized species may require larger areas of decaying, multi-layered older forests. They proposed that Woodpecker Management Areas (WMAs) be identified and withdrawn from commercial or salvage forestry and placed under special management to promote mature and old-growth conditions (Goggans et al. 1988). They suggest that WMAs should each encompass at least 387 ha (956 ac) of pine-dominated, mixed-conifer forest in mature or old-growth condition. This area is estimated based on average home-range sizes for nesting pairs during periods of abundant food. The researchers also recommended that WMAs be located below 1,372 m (4,500 ft) because this species is better adapted to conditions at lower elevations.

Goggans et al. (1988) recommended using the black-backed woodpecker rather than the three-toed woodpecker (*Picoides tridactylus*) as a management indicator species for mature and old-growth lodgepole pine forests. Black-backed woodpeckers are a better indicator species because they use a wider elevation range and are easier to monitor.

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations should have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982).

If pesticide or herbicide use is planned in areas inhabited by black-backed woodpeckers, refer to Appendix A, which lists contacts for assessing the use of pesticides, herbicides and other alternatives.

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PERSONAL COMMUNICATIONS

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 Washington Department of Fish and Wildlife
 Olympia, Washington

KEY POINTS

Habitat Requirements

- Inhabit mature and old-growth lodgepole pine, ponderosa pine, and mixed-conifer forests with numerous standing dead trees. Most abundant in burned and insect-infested stands.
- Forage on insects, mainly beetle larvae, in pole- and small sawtimber-sized snags.

Management Recommendations

- Avoid salvage logging of suitable mature and old-growth lodgepole pine forest stands that have experienced pine beetle infestation or large blowdowns.
- Retain >104-123 snags/ha (>42-50 snags/ac) that are >23 cm dbh (>9 in dbh) where salvage logging is planned. It is important to delay any salvage operation for approximately five years in woodpecker habitat areas after a disturbance event.
- Establish Woodpecker Management Areas of at least 387 ha (956 ac) within managed forests. The areas should be in pine-dominated, mixed-conifer forest in mature or old-growth condition located below an elevation of 1,372 m (4,500 ft).
- Refer to Appendix A if pesticide or herbicide use is planned in areas inhabited by this species. This lists useful contact for assessing the use of pesticides, herbicides, and other alternatives.

White-headed Woodpecker

Picoides albolarvatus

Last updated: 2002



Written by Jeffrey C. Lewis and Elizabeth Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

White-headed woodpeckers breed from southern British Columbia and Idaho to southern California (Garrett et al. 1996).

In Washington they are found in ponderosa pine (*Pinus ponderosa*) forests on the east slopes of the Cascade Mountains as well as in the Okanogan Highland, Selkirk and Blue Mountain areas of the state (see Figure 1). They are uncommon throughout their range, but they can be locally abundant in optimal habitat.

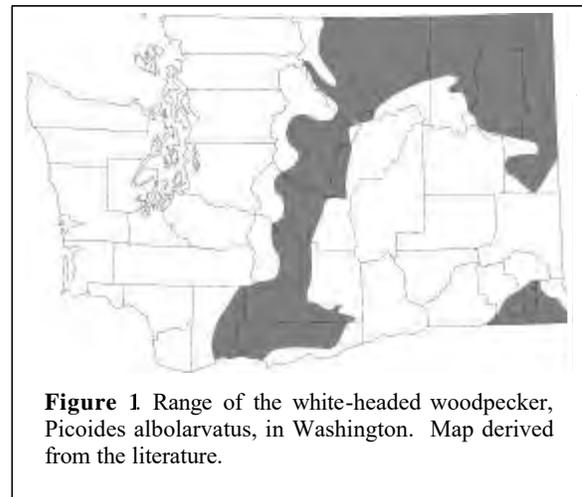


Figure 1. Range of the white-headed woodpecker, *Picoides albolarvatus*, in Washington. Map derived from the literature.

RATIONALE

The white-headed woodpecker is a State Candidate species. This species is vulnerable to loss of older, pine-dominated forests, and to the loss of large trees and snags within these forests.

HABITAT REQUIREMENTS

White-headed woodpeckers are primarily associated with open-canopied, mature and old-growth ponderosa pine forests. They require large, decayed snags for nesting and roosting while they forage primarily in the bark of large ponderosa pines [>60 cm (24 in) dbh] (Thomas et al. 1979, Raphael and White 1984, Garrett et al. 1996). White-headed woodpeckers prefer to forage for insects on the scaly bark of live trees (Raphael and White 1984, Morrison et al. 1987), and they feed heavily on seeds from unopened pine cones during winter (Ligon 1973, Garrett et al. 1996).

Nesting

The white-headed woodpecker usually nests low to the ground [<10 m (33 ft), mean = 2-3 m (6.5-10 ft)] in cavities within snags and stumps (Raphael and White 1984, Milne and Hejl 1989). This species infrequently nests in live trees (J. Buchanan, personal communication). Nest trees include ponderosa pine, jeffrey pine (*Pinus jeffreyi*), lodgepole pine (*Pinus contorta*), sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), red fir (*Abies magnifica*), and occasional quaking aspen (*Populus tremuloides*) (Raphael and White 1984, Milne and Hejl 1989, Dixon 1995b, Garrett et al. 1996). Studies conducted outside of Washington found that white-headed woodpeckers prefer nesting in snags or trees that are 4-8 m (13-26 ft) tall with a dbh of 65-80 cm (26-31 in) (Raphael and White 1984; Milne and Hejl 1989; Dixon 1995a, b; Garrett et al. 1996). Recent findings in eastern Washington concluded that this species nests primarily in ponderosa pine snags averaging 12.6 m (41.3 ft) in height with a mean dbh of 51.5 cm (20.3 in) (J. Buchanan, personal communication). Larger trees and snags characterized the immediate surroundings of active nest sites. The canopy closure in sites containing nesting birds was considerably open, averaging 7.2%.

Nest excavation begins in April to early May, while nesting occurs from late May to late June (Garrett et al. 1996). Incubation takes 14 days, and young leave the nest in late June to early July after a 26-day fledging period (Garrett et al. 1996).

Foraging

A significant portion of white-headed woodpecker diet consists of pine seeds, especially during winter and early spring (Ligon 1973). Other food sources include invertebrates, sap and other plant matter (Ligon 1973, Garrett et al. 1996). Their diet displays significant seasonal variation. The importance of pine seed in the white-headed woodpeckers diet appears to vary regionally (Morrison and With 1987).

Foraging involves gleaning insects from the trunks of live trees and snags, typically pines and firs (Raphael and White 1984, Morrison et al. 1987). Foliage gleaning and drilling into pine cones are also typical foraging techniques. Feeding on sap occurs only occasionally for this species (Garrett et al. 1996). White-headed woodpeckers regularly drink from open water sources, including pools, creeks, and puddles (Garrett et al. 1996).

Roosting

White-headed woodpeckers most frequently roost in cavities, but also roost in spaces behind peeling bark and in crevices within tree trunks (Dixon 1995a, b; Garrett et al. 1996). They typically roost in ponderosa pines (live trees and snags) averaging 60 cm (24 in) dbh and 7 m (23 ft) tall. Males roost in the nest cavity with their young until they fledge. Cavities are used as winter roosts, and frequently the same cavity is used over an entire season (Dixon 1995a, b; Garrett et al. 1996).

Home Range

Home ranges of white-headed woodpeckers in old-growth habitat averaged 104 ha (257 ac) and 212 ha (524 ac) for central and south-central Oregon, respectively. Home ranges in fragmented habitat average 321 ha (793 ac) and 342 ha (845 ac) for the same regions, respectively (Dixon 1995a, b).

LIMITING FACTORS

Availability of mature and old growth ponderosa pine forests with adequate snags for nesting and winter foraging has resulted in the decline of this species (Garrett et al. 1996). Logging of old ponderosa pine reduces suitable habitat and maintaining even-aged stands limits a site's capacity to replenish itself with large trees and snags. Fire suppression results in closed canopy, less suitable habitat, and eventually displaces important ponderosa pine with firs.

MANAGEMENT RECOMMENDATIONS

Management of habitat for this species should focus on providing snags suitable for nesting and the retention of large live trees for foraging (J. Buchanan, personal communication). Large trees should constitute 40-70% of the forest trees (Neitro et al. 1985).

Connor (1979) states that managing for the minimum habitat requirements may cause gradual population declines. Therefore, it is recommended that forests be managed using average rather than minimum suggested values. Based on research in eastern Washington, forest management should seek to retain 6-8 snags averaging 42.1 cm (16.6 in) dbh/0.8 ha (2-4 snags/ac) and 8 - 10 live trees averaging 63.4 cm (25.0 in) dbh/0.8 ha (4-5 trees/ac) in the immediate vicinity of nesting areas (J. Buchanan, personal communication). These figures are based on a sample of snags \$ 20 cm (7.9 in) dbh and live trees \$ 50 cm (19.7) dbh. Additionally, open canopy conditions are recommended for these same sites.

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations should have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982). If pesticides or herbicide use is planned in areas inhabited by this species, refer to Appendix A, which lists useful contacts for assessing pesticides, herbicides, and other alternatives.

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PERSONAL COMMUNICATIONS

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KEY POINTS

Habitat Requirements

- Mature and old-growth ponderosa pine and mixed conifer forests.
- Nests in snags averaging >65 cm (26 in) dbh.
- Home ranges in Oregon average 100-200 ha (247-484 ac) in old-growth habitat, and over 300 ha (741 ac) in fragmented habitat.
- Forages on insects in large [>60 cm (24 in) dbh] snags and live trees, and on pine seeds during winter and early spring.

Management Recommendations

- Maintain mature forest conditions or limit timber removal to moderate levels of selective cutting to maintain white-headed woodpecker populations. Mature ponderosa pine should constitute 40-70% of the forest trees.
- Retain 6-8 snags averaging 42.1 cm (16.6 in) dbh/0.8 ha (2-4 snags/ac) and 8 - 10 live trees averaging 63.4 cm (25.0 in) dbh/0.8 ha (4-5 trees/ac) where nesting occurs.
- Maintain open canopy conditions for sites within the immediate vicinity of nesting white-headed woodpeckers.
- Refer to Appendix A, that lists useful contacts for assessing pesticides, herbicides, and their alternatives, if pesticide or herbicide use is planned in areas inhabited by this species.

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Pileated Woodpecker

Dryocopus pileatus

Last updated: 2003

Written by Jeffrey C. Lewis and Jeffrey M. Azerrad

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Pileated woodpeckers are year-round residents from northern British Columbia, across Canada to Nova Scotia, south through central California, Idaho, Montana, eastern Kansas, the Gulf Coast and Florida (Bull and Jackson 1995). The Washington range encompasses the forested areas of the state (see Figure 1; Smith et al. 1997).

RATIONALE

The pileated woodpecker is listed as a State Candidate species in Washington. The pileated woodpecker is a significant functional component of a forest environment because it creates nesting cavities used by other forest wildlife species (Aubry and Raley 2002a). Their deep foraging excavations provide foraging opportunities for weak excavators, and they accelerate the decay process by physically breaking apart wood and exposing prey that can be consumed by other species (Aubry and Raley 2002a). For these reasons the pileated woodpecker is considered a “keystone habitat modifier” (Aubry and Raley 2002a). The availability of large snags (standing dead trees) and large decaying live trees used for nesting and roosting by pileated woodpeckers has declined in many areas as a result of forest conversion (e.g. removal of forest for urban development) and timber management practices (Bull and Jackson 1995, Ferguson et al. 2001).

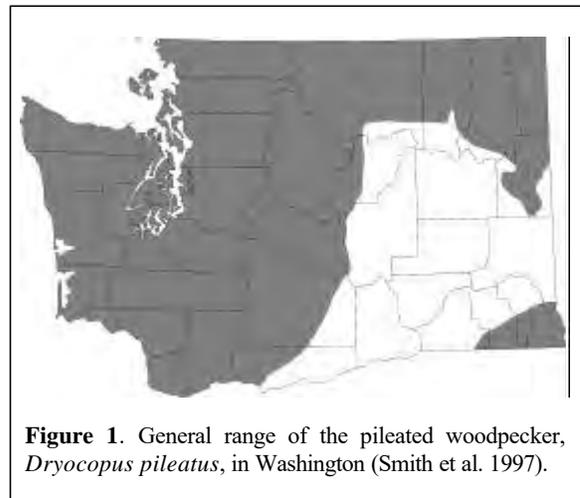


Figure 1. General range of the pileated woodpecker, *Dryocopus pileatus*, in Washington (Smith et al. 1997).

HABITAT REQUIREMENTS

Pileated woodpeckers inhabit mature and old-growth forests, and second-growth forests with large snags and fallen trees (Bull and Jackson 1995, Aubry and Raley 1996). Large snags and large decaying live trees in older forests are used by pileated woodpeckers for nesting and roosting throughout their range (Mellen et al. 1992, Bull and Jackson 1995, Aubry and Raley 2002b). In western Oregon and western Washington, they may use younger forests (<40 years old) as foraging habitat (Mellen et al. 1992, Aubry and Raley 1996).

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Nesting and Roosting

Pileated woodpeckers excavate large nest cavities in snags or large decaying live trees (Bull et al. 1986, Aubry and Raley 2002b).

In northeast Oregon, Bull (1987) reported the dimension of the nest entrances were 12 cm (5 in) in height and 9 cm (4 in) in width; the internal dimensions were 57 cm (22 in) deep and 21 cm (8 in) wide. Wood chips are typically found on the cavity floor (Bull and Jackson 1995). During the breeding season, birds may start a number of cavity excavations, but only complete one nest cavity (Bull and Jackson 1995, Aubry and Raley 2002a). The breeding and nesting periods of the pileated woodpecker extends from late March to early July (Bull et al. 1990). Pileated woodpeckers lay 1-6 eggs/clutch; the eggs are white in coloration and are about 3.3 cm (1.3 in) in length and 2.5 cm (1 in) in breadth (Bull and Jackson 1995).

Preferred nest tree species and characteristics vary to some degree among different regions of the northwest (Table 1). Most nest cavities were observed in hard snags with intact bark and broken tops, or live trees with dead tops. Hard snags are characterized as being comprised of sound wood while soft snags are composed primarily of wood in advanced stages of decay or deterioration (Brown 1985). Researchers studying pileated woodpeckers on the Olympic Peninsula found that woodpeckers used snags and large decaying live trees for nesting (Aubry and Raley 2002b). Sites used for nesting and roosting in the Olympics had a higher diversity of tree species and a greater density of large decaying live trees and large snags than surrounding forested areas (Aubry and Raley 2002b).

Table 1. Diameter at breast height (DBH), height, and tree species reported for pileated woodpecker nest trees in Oregon and Washington.

Location	DBH (average)	DBH (range)	Height (average)	Height (range)	Species	References
Olympic Peninsula	101 cm (40 in)	65-154 cm (26-61 in)	39 m (128 ft)	17-56 m (56-184 ft)	Pacific silver fir (<i>Abies amabilis</i>), western hemlock (<i>Tsuga heterophylla</i>)	Aubry and Raley 2002b
Western Oregon	69 cm (27 in)	--	27 m (87 ft)	--	Douglas-fir (<i>Pseudotsuga menziesii</i>), grand fir (<i>Abies grandis</i>)	Mellen 1987, Nelson 1989
Northeastern Oregon	80-84 cm (31-33 in)	52-119 cm (20-47 in)	28 m (92 ft)	10-43 m (33-141 ft)	grand fir, ponderosa pine (<i>Pinus ponderosa</i>), western larch (<i>Larix occidentalis</i>)	Bull 1987; Bull et al. 1992b; E. Bull, personal communication

Pileated woodpeckers roost in hollow trees or vacated nest cavities at night and during inclement weather (Bull and Jackson 1995). Excavation of roost cavities may occur at any time during the year (E. Bull, personal communication). Pileated woodpeckers may use up to 11 roosts over a 3-10 month period; however, some individuals will use one roost for a long period before switching to a new roost, while others regularly switch among several roosts (Bull et al. 1992b). The availability of roost trees apparently explained why some birds roosted in a limited number of trees (Bull et al. 1992b)

Roost and nest trees of pileated woodpeckers differ with respect to species and physical characteristics. Pileated woodpeckers used live trees or snags for roosting and nesting and selected these based on tree species, wood condition and diameter at breast height (dbh) in both northeastern Oregon and the Olympic peninsula (Bull et al. 1992b, Aubry and Raley 2002b). Bull et al. (1992b) reported that roost trees [mean = 70 cm dbh (28 in)] were smaller than nest trees [mean = 80 cm dbh (31 in)]; in contrast to nest trees, roosts trees in northeastern Oregon were often hollow. The hollow interior of roost chambers was typically the result of heartwood decay rather than excavation (Bull et al. 1992b, Aubry and Raley 2002b). In northeastern Oregon, roost chambers had more entrance holes than nests, and roosts were predominantly in grand fir, whereas nest trees were predominantly ponderosa pine and western larch (Bull et al. 1992b). In the Olympics, pileated woodpeckers preferred to roost within western redcedar (*Thuja plicata*) (Aubry and Raley 2002b). The extensive use of grand fir in northeast Oregon and western redcedar in

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the Olympics was attributed to the greater propensity for these species to form large, hollow chambers (Bull et al. 1992b, Aubry and Raley 2002b). Aubry and Raley (1996) found that 88% of all roosts were located in old or mature forests. The remaining roosts were primarily found in naturally regenerated young forests that were approximately 75 years old (Aubry and Raley 1996). Roosts east of the Cascades were also primarily found in old-growth forests (Bull et al. 1992b, McClelland and McClelland 1999). General characteristics of roost trees in Oregon and Washington are described in Table 2.

Table 2. DBH, height, and tree species reported for pileated woodpecker roost trees in Oregon and Washington.

Location	DBH (average)	DBH (range)	Height (average)	Height (range)	Species	References
Olympic Peninsula	149 cm (59 in)	37-309 cm (15-122 in)	36.5 m (120 ft)	11-63 m (36-207 ft)	Pacific silver fir, western hemlock, western redcedar	Aubry and Raley 2002b
Western Oregon	112 cm (44 in)	40-208 cm (16-82 in)	--	--	--	Mellen et al. 1992
Northeastern Oregon	71 cm (28 in)	40-131 cm (16-52 ft)	22 m (72 ft)	6-44 m (20-144 ft)	grand fir, ponderosa pine, western larch	Bull et al. 1992b; E. Bull, personal communication

Foraging

Pileated woodpeckers forage in forests containing large trees and snags that support abundant insect prey associated with dead and dying wood. Large rectangular/oval excavations in snags are indicative of pileated woodpecker foraging (McClelland 1979, Neitro et al. 1985, Bull and Jackson 1995). In Oregon and Washington, prey consisted of carpenter and thatching ants (Hymenoptera), beetle larvae (Coleoptera), termites (Isoptera), and other insects (Bull et al. 1992a, Torgersen and Bull 1995, Aubry and Raley 1996). Mature and old-growth coniferous forest are considered high quality foraging habitat (Aubry and Raley 1996), but forests as young as 40 years of age are used if snags, particularly large residual snags from burns or harvests, are present (Mellen et al. 1992). Pileated woodpeckers seldom use clearcuts, but will forage in clearcuts or shelterwood cuts if substantial foraging habitat is retained (see Mannan 1984, Mellen 1987). Researchers working in the Oregon Coastal Range determined that pileated woodpeckers used deciduous riparian for foraging activities (Mellen et al. 1992).

Pileated woodpeckers forage on large snags [>50 cm (20 in) dbh], live trees, logs, and stumps (Bull et al. 1986, Bull 1987, Torgersen and Bull 1995). Snags and live trees take on special importance in winter when logs and stumps may be covered with snow (McClelland 1979, Bull and Holthausen 1993). Pileated woodpeckers forage on snags in a broad range of decay conditions but appear to prefer large snags that may harbor more insects and larvae than smaller snags (Mannan et al. 1980). In contrast to foraging behavior east of the Cascade Range, downed logs are rarely used as foraging substrate in wet coastal forests (Aubry and Raley 2002b).

Home Range

Home ranges vary in size within the Pacific Northwest, ranging from 407 ha (1,006 ac)/breeding pair (data collected between June and March) in northeastern Oregon (Bull and Holthausen 1993), 480 ha (1,186 ac)/breeding pair during the summer in the central Oregon Coast Range (Mellen et al. 1992), and 863 ha (2,132 ac)/breeding pair annually on the Olympic Peninsula (Aubry and Raley 1996). The home range figures reported in the central Oregon Coast Range are likely smaller than the actual year-round home range for the pileated (Mellen et al. 1992). Home ranges for individuals that lost mates are larger than those of mated individuals (Bull and Holthausen 1993, Aubry and Raley 1996), and pairs with young have larger home ranges than pairs without young (Mellen et al. 1992). Although home ranges in the central Oregon Coast Range were actively defended, the ranges of adjacent birds overlapped (9-30% of an individual's home range overlapped) (Mellen et al. 1992). Home ranges in northeastern

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Oregon generally consisted of >85% forested habitat (Bull and Holthausen 1993). Home ranges consisted primarily of late-successional forested habitat or second-growth forest with residual large snags (Bull and Holthausen 1993, Bull and Jackson 1995, Aubry and Raley 1996).

Urban/Suburban Habitat Use

Pileated woodpeckers are residents in some developing areas throughout Washington (M. Tirhi; P. Thompson; H. Ferguson, personal communications). In these areas they occupy remnant patches of forest, parks, and green-belts. Because of their need for large trees and their sizeable territory requirements, loss or reduction of extensive wooded tracts and large trees will impact the species (Moulton and Adams 1991). Pileated woodpeckers in suburban areas forage on a variety of substrates, including large and small diameter coniferous and hardwood trees and snags (P. Thompson, personal communication; J. Lewis, unpublished data), and occasionally on suet feeders, utility poles, and fruit trees (Bull and Jackson 1995; J. Buchanan, personal communication).

Although habitat use in urbanizing environments in Washington has been given little attention, it is likely that pileated woodpeckers select large diameter trees and snags for nesting and roosting. Similarly, sizes of home ranges in urban environments are unknown, but they may be relatively large due to the fragmented nature of remnant forest habitats in most suburban landscapes. The relationship between cavity-nesters and urbanizing areas in Washington has only been investigated by a single study in the greater Seattle area (see Rohila 2002)

LIMITING FACTORS

Timber harvest can significantly impact pileated woodpecker habitat (Bull and Jackson 1995). The removal of large snags, large decaying live trees and downed woody debris of the appropriate species, size and decay class eliminates nest and roost sites and foraging habitat. Intensively managed forests typically do not retain these habitat features (Spies and Cline 1988). However, more recent state and federal forest management guidelines call for the retention of a specified number of wildlife trees during timber harvest (Washington Forest Practices Board 2001, Aubry and Raley 2002a). Bull and Jackson (1995) suggest that fragmentation of forested habitat may lead to reduced population density and increased vulnerability to predation as birds are forced to fly between fragmented forested stands; however, information on predation effects is currently lacking. Known predators include the northern goshawk (*Accipiter gentiles*), Cooper's hawk (*A. cooperii*), red-tailed hawk (*Buteo jamaicensis*), great horned owl (*Bubo virginianus*), American martin (*Martes americana*), and gray fox (*Urocyon cinereoargenteus*) (Bull and Jackson 1995).

The amount of forest retained in the suburban and urbanizing environment will influence the degree to which an area is used by pileated woodpeckers for foraging and reproduction (Moulton and Adams 1991, Rohila 2002). If the collective area of these retained forest tracts is large enough, suburban and other urbanizing environments could support pileated woodpeckers (Rohila 2002). However, because of their need for larger trees and their sizeable territory requirements, loss or reduction of wooded tracts and large trees could eliminate or preclude pileated woodpeckers from an urbanizing area (Moulton and Adams 1991).

MANAGEMENT RECOMMENDATIONS

General Recommendations

Specific management prescriptions should be developed for actions that will be undertaken at the home range scale (Mellen et al. 1992, Bull and Holthausen 1993) as discussed later in this chapter. Management activities for pileated woodpeckers should focus on providing and maintaining a sufficient number of appropriate large snags and large decaying live trees for nesting and roosting (Aubry and Raley 2002b). Retaining snags and decaying live trees (of appropriate size, species and decay classes) provides suitable nesting and roosting structure for a longer period of time than retaining only hard snags (Aubry and Raley 2002b). Trees, snags and stumps with existing pileated nest cavities and foraging excavations should be retained (Bonar 2001).

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Management of nesting and roosting habitat may be accomplished in several ways in managed forests. A variety of snag creation techniques are being developed and it is likely that such techniques can produce suitable snags in older second growth forests (e.g., removal of tree-top, girdling) (Neitro et al. 1985, Bull and Partridge 1986, Lewis 1998). Properly conducted uneven-aged management of forest stands can create adequate canopy closure and sufficient large snags and large decaying live trees to maintain suitable nesting and roosting habitat for pileated woodpeckers. Defective or cull trees can be retained during commercial thinning operations, or these can be recruited to become snags in subsequent rotations (Neitro et al. 1985). Because of the difficulties in recruiting large snags in managed forests (Wilhere 2003), one of the most effective means to improve snag densities may involve extending the length of harvest rotations (Neitro et al. 1985).

Managers may have some flexibility when providing foraging habitat. Naturally formed stumps and numerous large logs in various stages of decay can be retained to improve foraging habitat (Torgersen and Bull 1995). Management for large snags, culls, and green replacement trees can ultimately provide large downed logs as foraging habitat. Protection of riparian habitat throughout Washington and the provisions of buffers along streams may also ensure that adequate foraging habitat exists for pileated woodpeckers (Mellen et al. 1992, Knutson and Naef 1997). However, we currently lack adequate information to define appropriate riparian buffers for pileated woodpeckers in managed forests.

Forest managers often apply minimum size standards that are determined through research (e.g., the smallest recorded nest tree dbh) to achieve a combination of wildlife conservation and resource extraction goals (McClelland and McClelland 1999). Conner (1979) argued that managing forests using minimum size standards may cause gradual population declines and suggested that average values for habitat components should be used in forest management. The following set of recommendations is based primarily on average (rather than minimum) standards.

Western Washington

The following recommendations are primarily based on the goals identified by the Partners in Flight (PIF) Conservation Plan for the Westside Coniferous Forest region (Altman 1999). These goals were derived from research conducted in the Oregon Coast Range and Washington's Olympic Peninsula (Nelson 1989, Mellen et al. 1992, Aubry and Raley 1996, 2002b). The PIF recommendations for managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older include maintaining >70% canopy closure and an average of ≥ 5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in). In areas used for both nesting and roosting, an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) should be retained (Aubry and Raley 2002b). Trees ≥ 27.5 m (≥ 90 ft) in height should be retained to provide nesting and roosting structures (Aubry and Raley 2002b). Overall, pileated woodpeckers selected larger trees for roosting than those used for nesting (see Buchanan, in press). Based on Aubry and Raley's (2002b) work in the Olympics, trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting. In addition, an average of 30 foraging snags/ha (12 snags/ac) (mix of hard and soft snags) should be provided in the following size classes (see Table 3; Altman 1999).

Table 3. Suggested number of foraging snags to retain.

Size class	Foraging snags retained
• 25-50 cm dbh (10-20 in) = ≥ 18 snags/ha (7 snags/ac)	
• 51-76 cm dbh (20-30 in) = ≥ 8 snags/ha (3 snags/ac)	
• >76 cm dbh (>30 in) = ≥ 5 snags/ha (2 snags/ac)	

Population targets suggested by the PIF conservation plan called for about nine pairs of pileated woodpeckers per township (9.7 pairs/100 km²), based on an average breeding season home range of 600 ha (Altman 1999:36-37). Using the annual home range size of 863 ha for the Olympic Peninsula (Aubry and Raley 1996), a comparable target could be adjusted to about six pairs per township (6.4/100 km²) on the Olympic Peninsula (Buchanan, in press). At the landscape-level, an average of 60% of a landscape management unit (e.g., watershed, township) should be retained as suitable habitat (early successional forest with adequate snag densities, young forest [40-80 years] with adequate snag densities, and late successional forest), and >40% of this

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suitable habitat should be retained in late-successional forest. Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers (see above).

Eastern Washington

The following recommendations are based on research conducted in the Blue Mountains of northeastern Oregon (Bull 1987, Bull and Holthausen 1993) as well as research conducted in northwestern Montana (McClelland and McClelland 1999). Because most work on pileated woodpeckers in the inland northwest was conducted in the Blue Mountains, it should be noted that the following recommendations might be less applicable to areas outside of this region.

Several key habitat components are necessary to maintain suitable pileated woodpecker habitat. These include a mature forest with ≥ 2 canopy layers, the uppermost being 25-30 m (82-98 ft) in height; large live trees to provide cover and eventual replacement of dead trees; large dead trees for nesting; and dead trees and downed woody material for foraging (Bull 1987). Territory size for breeding pairs in the Blue Mountains averaged 407 ha (1006 ac) and was considered an adequate size to manage for each breeding pair in that region (Bull and Holthausen 1993). Researchers working in the Blue Mountains recommended that 75% of management areas be in grand fir forest types and they suggested that the composition of this area include 25% old growth and 75% mature stands. Additionally, they suggested that $\geq 50\%$ of the management areas have $\geq 60\%$ canopy closure and that at least 40% of the stands remain unlogged (Bull and Holthausen 1993).

Bull and Holthausen (1993) recommended retaining 8 snags/ha (3.2 snags/ac) with at least 20% being ≥ 51 cm (20 in) dbh for both nesting and roosting. Based on Bull's (1987) research, trees ≥ 28 m (92 ft) should be retained to provide nesting structures. Bull and Holthausen (1993) recommended retaining ≥ 100 logs/ha (40/ac) as foraging substrate in management areas, with a preference for logs ≥ 38 cm (15 in) dbh that include all species except lodgepole pine (*Pinus contorta* var. *latifolia*). McClelland and McClelland (1999) suggested that the optimum dbh for nest and roost trees should be: 77-91 cm (30-36 in) for western larch, 76-96 cm (30-38 in) for ponderosa pine, and 75-100 cm (30-39 in) for black cottonwood (*Populus balsamifera*).

Urban/Suburban Areas

Although pileated woodpeckers are known to use suburban and other urbanizing areas (Moulton and Adams 1991, Rohila 2002), few studies have examined habitat use in these areas. Consequently, the following generalized recommendations address the principle needs of pileated woodpeckers based primarily on the findings of a recent study conducted in the greater Seattle area (Rohila 2002). Additional research will be necessary to develop specific guidelines for urban and suburban areas.

In urbanizing areas, the greatest negative influence to pileated woodpeckers is likely the clearing of remnant forest patches. Based on research in greater Seattle, Rohila (2002) recommended that planners retain forest in the largest patches available (>30 ha [74 ac] would be considered large). Where large patches are unavailable, smaller patches should be retained; where the average size of smaller patches should be no less than approximately 3 ha (7 ac) (see Rohila 2002). Forest patches with high densities of existing snags and live trees should be targeted when selecting areas to retain during the planning process (Rohila 2002). The creation of snags or decaying live trees (Lewis 1998) may benefit pileated woodpeckers in suburban areas (see previous sections for preferred snag and tree size guidelines). Pileated woodpeckers and other cavity-dependent species would benefit from the retention of snags as well as the retention of live trees in the largest size classes available in the stand (Rohila 2002). Because designated suburban and urban parks often contain large forested tracts, park managers should also consider pileated woodpecker requirements.

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KEY POINTS

Habitat Requirements

- Inhabits mature and old-growth forests, and second-growth forests with large snags and fallen trees
- Excavates large nest cavities in snags or large decaying live trees
- Breeds and nests between late March to early July
- Roosts in hollow trees or vacated nest cavities at night and during inclement weather
- Forages in forests containing large trees and snags, and dead and dying wood

Pileated Woodpecker removed from Priority Habitat and Species list in 2021

- Preys on carpenter and thatching ants, beetle larvae, termites, and other insects
- Present in some urban and suburban areas throughout Washington

Management Recommendations

General Recommendations

- Maintain large snags and large decaying live trees for nesting and roosting
- Retain naturally formed stumps and numerous large logs in various stages of decay to improve foraging habitat
- Use average size standards (rather than minimums) for managing pileated woodpecker habitat components (e.g., nest size standards).

Western Washington

- Maintain managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older at >70% canopy closure and an average of ≥ 5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in)
- Retain an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) in areas used for both nesting and roosting
- Retain trees ≥ 27.5 m (≥ 90 ft) in height to provide nesting and roosting structures. Trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting
- Retain an average of 30 foraging snags/ha (12 snags/ac)

Eastern Washington

- Maintain mature forest with ≥ 2 canopy layers, the uppermost being 25-30 m (82-98 ft) in height; large live trees to provide cover and eventual replacement of dead trees; large dead trees for nesting; and dead trees and downed woody material for foraging
- Retain 8 snags/ha (3.2 snags/ac) with at least 20% being ≥ 51 cm (20 in) dbh for both nesting and roosting
- Retain ≥ 100 logs/ha (40/ac) as foraging substrate in management areas, with a preference for logs ≥ 38 cm (15 in) dbh

Urban/Suburban Areas

- Conserve larger forest patches with large trees and snags
- Retain forest in the largest patches available (≥ 30 ha [74 ac] would be considered large). Where large patches are unavailable, smaller patches should be retained; where the average size of smaller patches should be no less than approximately 3 ha (7 ac).
- Retain or create snags as well as retain live trees in the largest size classes available in the stand

Loggerhead Shrike

Lanius ludovicianus

Last updated: 2003



Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Loggerhead shrikes are found in portions of British Columbia, Alberta and Saskatchewan, and throughout much of the United States (although rare in the northeastern U.S.) south to southern Mexico (Yosef 1996, Sibley 2000).

In Washington, the shrike is primarily a breeding resident of the shrub-steppe zone (see Figure 1; Miller 1931, Poole 1992). Shrikes depart for their migration south by September (Morrison 1981, Burnside 1987) and return around March (Poole 1992). Some individuals remain year-round in eastern Washington (Washington Department of Fish and Wildlife's Wildlife Information System, unpublished data).

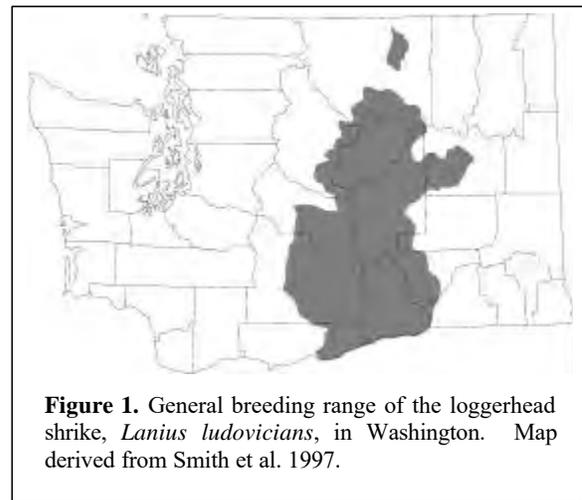


Figure 1. General breeding range of the loggerhead shrike, *Lanius ludovicianus*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The Loggerhead shrike is a State Candidate species that has shown decreases in population from historical densities and distribution (Morrison 1981, Fraser and Luukkonen 1986, Sauer et al. 1995, Cade and Woods 1997). A recent analysis of Breeding Bird Survey data for the Columbia River Basin shows a significant decline in the shrike population over the last 26 years (Saab and Rich 1997). Loss of shrub-steppe habitat partially explains local declines of this species (Cade and Woods 1997). The Interior Columbia River Basin Ecosystem Management Project has listed loggerhead shrike as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Loggerhead shrikes use open habitat during both breeding and nonbreeding seasons. Grasslands or pastures with short or patchy grasses are usually used for foraging. Scattered trees, shrubs or hedgerows are most often used for nesting and perching (Kridelbaugh 1983, Bohall-Wood 1987, Gawlik and Bildstein 1990). In the shrub-steppe of eastern Washington, Poole (1992) found shrikes were most abundant in lowland communities of sagebrush (*Artemisia* spp.), Sandberg's bluegrass (*Poa sandbergii*), and cheatgrass (*Bromus tectorum*); mixed shrub communities containing big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), Sandberg's bluegrass, Indian ricegrass (*Oryzopsis hymenoides*), and needle and thread grass (*Stipa comata*); and bitterbrush communities containing bitterbrush, Indian ricegrass, and needle and thread grass. Surveys in eastern Washington shrub-steppe revealed a greater abundance of loggerhead shrikes in deep, sand soil communities than in communities with loamy or shallow soils (Vander Haegen et al. 2000). The shrub-steppe communities occupied by shrikes could be described as a mixture of shrub patches and grassy or sandy openings (Poole 1992). Leu (1995) reported greater foraging success by juvenile shrikes in shrub-steppe stands having a more open grass/forb layers, where birds could readily spot and capture prey on the ground.

Trees or shrubs used for nesting share the common characteristics of having dense foliage (Poole 1992), being very bushy, and/or thorny (Kridelbaugh 1983, Brooks and Temple 1990a). Selection criteria for nesting trees or shrubs appear to be based on the amount of cover and protection the plant provides rather than a preference for a particular species of tree or shrub (Porter et al. 1975, Gawlik and Bildstein 1990). In eastern Washington, shrub species with the greatest number of nests were big sagebrush and bitterbrush, but nests also were found in mock orange (*Philadelphus lewisii*), greasewood (*Sarcobatus vermiculatus*) and clematis (*Clematis* spp.) (Miller 1931, Poole 1992). Shrikes in Idaho shrub-steppe nested in big sage (65.4%), bitterbrush (20.4%) and greasewood (12.3%), with shrubs used for nesting averaging 162 cm (64 in) in height (Woods and Cade 1996). Choice of nest shrub seemed unrelated to the success or failure of shrike nests in Idaho; other variables such as presence of foraging perches may have been more important in determining adequate shrike habitat (Woods and Cade 1996).

Loggerhead shrikes are highly territorial, maintaining larger territories than other insectivorous perching bird species of similar size (Yosef 1996). Mean territory size from 8 different studies ranged from 7.5 ha to 34 ha (18.5 - 84 ac) (Yosef 1996). Poole (1992) found that shrikes defended territories averaging 13.9 ± 2.0 ha (34.35 ± 4.9 ac) on the Hanford Site in Washington. The average distance a shrike nested to the closest adjacent nesting shrike was 610 m (2,000 ft) in shrub-steppe habitat in Washington (Poole 1992) and ranged from 115-670 m (377-2198 ft) in Idaho shrub-steppe (Woods 1995). In the upper Midwest, Brooks and Temple (1990a) observed shrikes hunting up to 400 m (1,312 ft) away from their nest site during nesting season.

Loggerhead shrikes are generalists, feeding on any animal they can subdue (Fraser and Luukkonen 1986, Gawlik and Bildstein 1990, Scott and Morrison 1990). Their diet consists of insects, small mammals, birds, reptiles and amphibians. On the Hanford Site, shrikes preferred grasshoppers, lizards and small mammals (Poole 1992). These prey items were more abundant in sagebrush and bitterbrush communities than in grassland and rabbitbrush (*Chrysothamnus* spp.) communities. Shrikes are the only perching birds that regularly kill and consume vertebrate prey by means of impaling (Fraser and Luukkonen 1986).

LIMITING FACTORS

Specific factors limiting loggerhead shrikes are unknown. Suggested causes of population decline include loss of breeding habitat (Kridelbaugh 1981, Burnside and Shepherd 1985, Tyler 1992), low overwinter survival through loss of wintering areas (Hass and Sloane 1989, Brooks and Temple 1990a,b), contamination by pesticides (Kridelbaugh 1981, Fraser and Luukkonen 1986) and high mortality due to vehicle collision (Gawlik and Bildstein 1990, Flickinger 1995).

MANAGEMENT RECOMMENDATIONS

Shrub-steppe communities should be left in reasonably undisturbed condition and fragmentation should be minimized (Woods and Cade 1996). Management activities that increase cheatgrass invasion or increase risk of wildfire also must be avoided (Leu and Manuwal 1996).

In shrub-steppe and associated riparian habitats, retain patches of tall shrubs for nesting and perching (Leu and Manual 1996). Herbaceous cover should average <20% and should be dominated by native species >30% of the ground should be bare (including areas of cryptogamic crust) (Altman and Holmes 2000). In agricultural areas, retain scattered trees, shrubs, hedgerows, as well as trees along fence lines for nesting and perching (Yosef 1996).

Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration. Sagebrush cover should be reduced on a site only after careful consideration of how the methods used may affect sagebrush regeneration and the opportunity for exotic vegetation to invade the site. Burning may create the greatest risk to local shrike populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones because disturbance often leads to cheatgrass invasion and because sagebrush recovery is slow (e.g., Benton, Franklin and Grant Counties) (Wisdom et al. 2000). If chemical use is planned for areas where loggerhead shrikes occur, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Livestock grazing at low to moderate levels has not been shown to be detrimental to loggerhead shrike habitat (Saab et al. 1995); however, sustained grazing likely will reduce habitat suitability (Altman and Holmes 2000). In keeping with recommendations published for other shrub-steppe passerines (Altman and Holmes 2000), we recommend that grazing levels should be sufficiently low to allow >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

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KEY POINTS

Habitat Requirements

- Open habitats with short and/or patchy grasses for foraging and scattered trees, shrubs, or hedgerows for nesting and perching sites.
- The shrub-steppe communities occupied by shrikes could be described as a mixture of shrub patches and grassy or sandy openings.

Management Recommendations

- Retain shrub-steppe communities, especially big sagebrush and mixed shrub communities.
- Avoid wildfires and activities that may increase invasion by exotic vegetation.
- Retain patches of tall shrubs for nesting and perching in shrub-steppe and associated riparian habitats.
- Livestock grazing should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- In agricultural areas (e.g., pastures), establish or retain scattered trees and tall shrubs, wind break, and hedgerow vegetation.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives if chemical use is planned for areas where this species occurs.

Purple Martin removed from Priority Habitat and Species list in 2018



Purple Martin *Progne subis*

Last updated: 2003

Written by David W. Hays and Ruth Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Purple martins breed locally from southern Canada to central Mexico (Brown 1997) and winter in South America (Ehrlich et al. 1988)

In Washington, they typically breed near the waters around the Puget Sound, along the Strait of Juan de Fuca, the southern Pacific coastline, and near the Columbia River (see Figure 1; S. Kostka, personal communication). Unconfirmed records suggest that other potential breeding areas might also be found from the Willamette Valley up through Thurston County.

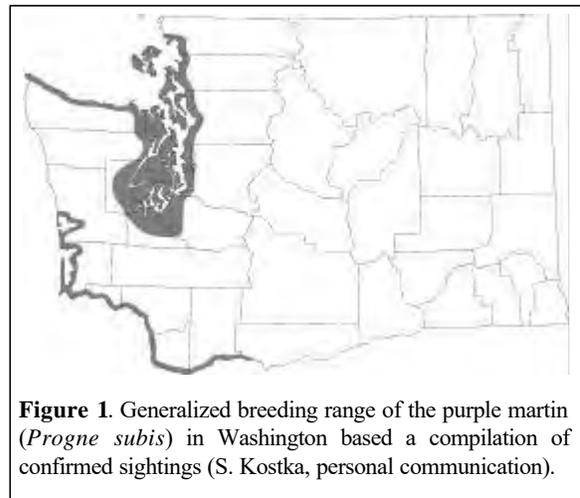


Figure 1. Generalized breeding range of the purple martin (*Progne subis*) in Washington based a compilation of confirmed sightings (S. Kostka, personal communication).

RATIONALE

The purple martin is a State Candidate species. This species has a high public profile and are vulnerable to population fluctuations due to a limited distribution and loss of suitable natural nesting cavities (Brown 1997).

HABITAT REQUIREMENTS

Purple martins are insectivorous, colonial nesting swallows that nest in cavities (Brown 1997). In Washington, most martins have been reported nesting in artificial structures near cities and towns in the lowlands of western Washington. Historically, they probably bred in old woodpecker cavities in large dead trees, but only a few such nests are known to exist in Washington today (Brown 1997, Russell and Gauthreaux 1999). The eastern race of purple martins often nest in apartment-style nest-boxes, while the western subspecies, found here in Washington, prefer to nest individually (Pridgeon 1997).

The nest site preferences of the purple martin have been studied at Fort Lewis in Pierce County (Bottorff et al. 1994). Martins nested in a variety of artificial nesting structures, including wood duck boxes. No purple martin nesting activity was detected in artificial nesting structures on land; all artificial cavities were over freshwater wetlands, ponds or saltwater. Swallows were found nesting in both natural and artificial cavities intermingled with martin nests, possibly competing for nest sites. More recent observations documented four pairs nesting in natural snag cavities near water at Fort Lewis (S. Kostka, personal communication). Martins were also recently found nesting in boxes well away from water just outside of the fort in Spanaway.

Purple Martin removed from Priority Habitat and Species list in 2018

Purple martins feed in flight on insects (Ehrlich et al. 1988, Brown 1997). Favorable martin foraging habitat includes open areas, often located near moist to wet sites, where flying insects are abundant.

LIMITING FACTORS

The decline of the purple martin is attributed to the lack of snags containing nest cavities (Bottorff et al. 1994) as well as competition for nesting cavities with more aggressive European starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*; Bottorff et al. 1994, Brown 1997).

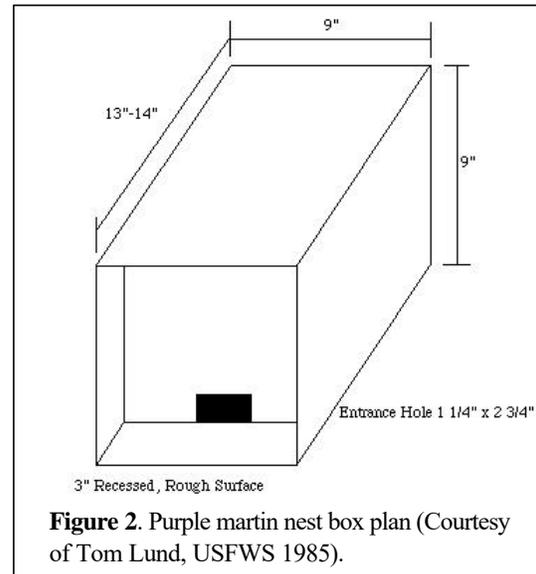
MANAGEMENT RECOMMENDATIONS

In Washington, purple martins are known to nest in cavities located in old pilings over water and occasionally in snags (United States Fish and Wildlife Service 1985, Milner 1987). These pilings and snags (especially snags near water) should be protected and left standing. The removal of creosote-coated pilings that contain a purple martin nest box or that possibly contain cavities used by martins should be closely coordinated with the Washington Department of Fish and Wildlife (M. Tirhi, personal communication). Snags should be retained during timber harvesting operations near saltwater and wetlands (Milner 1988), including salvage operations after burns, blow-downs, and insect infestations (United States Fish and Wildlife Service 1985). Prescribed burns can be used as a tool to create favorable martin foraging habitat. Snags can be created in forest openings, or at forest edges (e.g., by topping trees) where nesting cavities are lacking, especially within 16 km (10 mi) of an existing purple martin colony (United States Fish and Wildlife Service 1985). Because northern flickers and pileated woodpeckers excavate cavities used by martins, managing for these species will indirectly benefit martins (K. Bettinger, personal communication).

Because of their dependence on insects for food, purple martins can be impacted by the broad use of pesticides (United States Fish and Wildlife Service 1985). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

Although artificial nesting structures are an important tool for the conservation of purple martins, they should not replace the protection of natural nesting structures (e.g., snags) and the habitat used by this species (S. Kostka, personal communication). If natural sites are lacking and cannot be provided by manipulating habitat, artificial nesting structures can be provided. A number of artificial nest designs have been developed and work relatively well. Below are the specifications for one such design (United States Fish and Wildlife Service 1985):

- 1) Construct nest boxes using a design such as that shown in Figure 2. Box dimensions should be at least 10" x 7" x 7". It is important to make the entrance 1 1/4" high, continuous with the porch floor. The top of the opening should be sanded smooth. The porch is a necessary feature, and the floorboard should be rough to provide traction. These features, particularly the size of the opening, will aid in dissuading house sparrows and starlings from taking over the nest boxes.
- 2) Protect boxes from wet weather by sealing edges with caulking material. Painting or varnishing the wood, using cedar for construction or protecting the roof with galvanized tin, can provide additional protection. Provide drainage holes in the box floor and ventilation holes near the top.



Purple Martin removed from Priority Habitat and Species list in 2018

- 3) Locate boxes in existing colonies first. Locate additional boxes in suitable habitat within 16 km (10 mi) of existing colonies. A minimum of 3 boxes should be erected at each site for this colonial nesting species (J. Bortorff, personal communication); however, populations in the west do not appear to use the apartment style houses that eastern populations are so well known for (B. Tweit, personal communication).
- 4) Locate boxes near (preferably above) water or wetlands with minimum clear air space of 4.5 m (15 ft), preferably 30 m (100 ft), for circling and foraging around the nest. Erect houses high enough above the ground or water to avoid vandalism and high tides. J. Bortorff, personal communication) noted no difference in use of boxes erected from 1 m (3 ft) to 3 m (10 ft) above the water.
- 5) It is not necessary to remove martin nests from previous years. If nesting material is removed, it should be done in the spring and the contents placed in a dry spot beneath the nest. This is to allow for the emergence of chalcid wasps, which help to control *Protocalliphora*, a parasite on martin nestlings. The wasp larvae live in nest materials and will return to the martin boxes if old nests are left nearby.
- 6) Where European starlings and house sparrows are a problem, plug the box entrances from October to mid-April. If starlings establish themselves in a box, remove their nests, eggs, and young on a routine basis (they will renest several times in a breeding season). The same measures can be taken with house sparrows early in the breeding season; however, removal of sparrow nests later in the cycle may cause sparrows to wander into martin nests and destroy their young. Adult sparrows may be controlled. If this is impossible, remove eggs and young, but leave sparrow nests in later months to prevent sparrows from taking over martin nests.
- 7) Starlings and house sparrows are not classified as a protected species. However, other cavity-nesters that may inhabit martin boxes, such as swallows, are protected, and occupied swallow nests should not be removed.

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Purple Martin removed from Priority Habitat and Species list in 2018

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KEY POINTS

Habitat Requirements

- \$ Nests in natural and artificial cavities, usually over water.
- \$ Readily nest in bird boxes in areas where the species is already established.
- \$ Usually nest in colonies.
- \$ Foraging habitat includes open areas, often located near moist to wet sites, where flying insects are abundant.

Management Recommendations

- \$ Retain snags during timber harvesting (especially near saltwater and wetland sites).
- \$ Retain old pilings. The removal of creosote-coated pilings that contain a purple martin nest box or that contain cavities used by martins should be coordinated closely with the Washington Department of Fish and Wildlife.
- \$ Create snags in forest openings and along forest edges if snags are lacking or limited.
- \$ Use fires to create or maintain favorable martin foraging habitat, where appropriate.
- \$ If pesticides are to be used in areas inhabited by martins, refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.
- \$ Put up nest boxes when natural cavities are lacking or limited and cannot be created (see text for details).

Sage Thrasher

Oreoscoptes montanus

Last updated: 2003



Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sage thrashers breed from British Columbia to eastern Montana, south to northern Arizona and west to California. They winter from central California to central Texas, south to southern Baja California into northern Mexico (American Ornithologists' Union 1983).

In Washington, they are found in the Columbia Basin shrub-steppe region (see Figure 1). Sage thrashers are documented in Adams, Asotin, Benton, Douglas, Franklin, Grant, Kittitas, Lincoln, Okanogan, Walla Walla and Yakima counties (Smith et al. 1997).

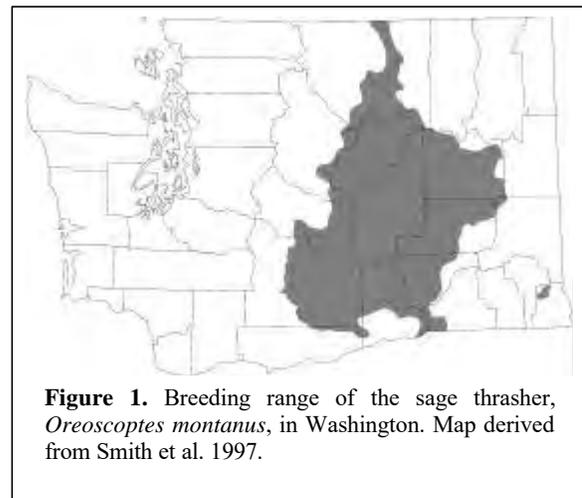


Figure 1. Breeding range of the sage thrasher, *Oreoscoptes montanus*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The sage thrasher is a State Candidate species that is highly dependent on healthy shrub-steppe communities comprised of tall, dense sagebrush (*Artemisia* spp.) (Rich 1980, Reynolds 1981, Reynolds and Rich 1978, Petersen and Best 1991). Shrub-steppe in Washington has become severely fragmented and reduced in extent over the last century (Dobler et al. 1996). Furthermore, the Interior Columbia River Basin Ecosystem Management Project listed the sage thrasher as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Sage thrashers are closely associated with sagebrush and are considered obligates of sagebrush communities (Braun et al. 1976). In Idaho, sage thrashers used sites that were characterized as having high sagebrush cover within large blocks of shrub-steppe (Knick and Rotenberry 1995). Shrub-steppe describes a plant community consisting of one or more layers of grasses with a discontinuous overstory of shrub cover (Daubenmire 1988). Sage thrashers nest in stands of big sagebrush (*Artemisia tridentata*), placing their nests in or beneath shrubs that are generally 55 to 90 cm (22-36 in) tall (Reynolds and Rich 1978, Rich 1980, Reynolds 1981, Petersen and Best 1991). In Washington, nest shrubs averaged 102 cm tall (n = 122) (Washington Department of Fish and Wildlife, unpublished data). Thrasher nests are bulky and usually located in large bushes with substantially thick branches that provide adequate support

(Reyser 1985, Rich 1985). Reynolds (1981) found that nests built either on the ground or within shrubs had approximately the same depth of foliage over their nests (57.5 cm [23 in]). Petersen and Best (1991) reported that sage thrashers favored shrubs with high foliage density. They also found that thrashers preferred nesting in shrubs having branches or foliage within 30 cm (11.7 in) of the ground. Sage thrashers require a relatively open understory for foraging (Reynolds et al. 1999); however, the amount of bare ground around a typical nest site is usually less than that of the surrounding area (Petersen and Best 1991).

Sage thrashers in Washington occurred in greater abundance in shrub-steppe communities that ranged from fair to good condition (characterized by fewer invasive exotic plants) than at poor condition sites (Vander Haegen et al. 2000). Additionally, sage thrashers were more abundant in shrub-steppe communities with loamy and shallow soils rather than sandy soils.

Mean territory size for sage thrashers ranged from 0.39 ha (1 ac) in Washington (Stephens 1985) to 0.96 ha \pm 0.12 ha (2.37 ac \pm 0.3 ac) in Idaho (Reynolds and Rich 1978). Sage thrashers will nest in fragments of shrub-steppe set within agricultural areas (Vander Haegen et al. 2002). However, birds using these fragmented sites may experience greater rates of nest predation than their counterparts nesting in large blocks of shrub-steppe.

Sage thrashers forage primarily on the ground and mainly consume grasshoppers, ants, beetles and other insect larvae during the spring (Ryser 1985, Stephens 1985, Petersen and Best 1991). In summer, small fruits are added to their diet (Ryser 1985).

LIMITING FACTORS

Availability of shrub-steppe communities containing tall sagebrush for nesting likely limit the distribution of sage thrashers in Washington (Reynolds et al. 1999). Additionally, degradation of sagebrush stands by invasive plants such as cheatgrass (*Bromus tectorum*) also render sites less suitable to sage thrashers. Fragmentation of shrub-steppe by agriculture apparently does not exclude sage thrashers but will result in lost breeding habitat (Reynolds et al. 1999).

MANAGEMENT RECOMMENDATIONS

In order to maintain sage thrasher populations, shrub-steppe communities should be left in reasonably undisturbed condition and fragmentation should be minimized (Reynolds et al. 1999, Wisdom et al. 2000). Management activities that increase cheatgrass invasion or increase risk of wildfire also must be avoided.

Optimum habitat for sage thrashers in Washington consists of blocks of shrub-steppe > 16 ha (40 ac) with sagebrush cover ranging between 5-20% and shrubs averaging >80 cm (32 in) tall (Altman and Holmes 2000). An herbaceous cover of native species should average 5-20%, with 10% of the ground bare (including areas of cryptogamic crust) to allow movement on the ground. Exotic annual grasses should cover <10% of the ground. Although much of Washington's shrub-steppe is fragmented by agriculture, habitat restoration on formerly tilled fields could expand the range of shrub-steppe obligate birds in fragmented landscapes (Vander Haegen et al. 2000).

Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration (Wisdom et al. 2000). Sagebrush cover should only be reduced after careful consideration of how the removal methods may affect sagebrush regeneration and the spread of exotic vegetation. Burning may lead to serious negative impacts to local sage thrasher populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones (e.g., Benton, Franklin and Grant Counties) because exotic plants overwhelm the natives plants and sagebrush is slow to recover (Knick and Rotenberry 1995, Reynolds et al. 1999, Wisdom et al. 2000). If chemical use is planned for areas where this species occurs, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Although data are limited on this subject, livestock grazing at low to moderate levels has not been shown to be detrimental to sage thrasher habitat (Saab et al. 1995). Because sage thrashers frequently nest and forage at ground level, Altman and Holmes (2000) state that grazing levels should be kept at low intensities. They also suggest allowing >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

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KEY POINTS

Habitat Requirements

- Closely associated with sagebrush and considered obligates of sagebrush communities. Require extensive stands of shrub-steppe.
- Nest in stands of big sagebrush, placing their nests in or beneath shrubs. Nests are bulky and usually located in large bushes having substantially thick branches that provide adequate support. Favor shrubs with high foliage density that have branches or foliage within 30 cm (11.7 in) of the ground.
- Abundant in shrub-steppe communities with loamy and shallow soils rather than communities with sandy soils.
- Feed primarily on insect larvae.

Management Recommendation

- Retain sagebrush communities and avoid fragmentation of existing sagebrush stands.
- Avoid activities that may increase invasion of cheatgrass and other exotic vegetation.
- Grazing of livestock should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- Control wildfires in sagebrush habitat, especially in low rainfall zones.
- Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration.
- Retain blocks of shrub-steppe > 16 ha (40 ac) with sagebrush cover ranging from 5-20% and shrubs averaging >80 cm (32 in) tall. An herbaceous cover of native species should average 5-20%, with $\geq 10\%$ of the ground bare (including areas of cryptogamic crust). Exotic annual grasses should cover <10% of the ground.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.



Sage Sparrow

Amphispiza belli

Last updated: 2003

Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sage sparrows breed from southeastern Washington to northwestern Colorado, and south to southern California, northern Arizona and northwestern New Mexico (Martin and Carlson 1998). They winter at low elevations in southern portions of their range (Farrand 1983).

In Washington, their distribution coincides with sagebrush (*Artemisia* spp.) and bunchgrass (*Agropyron* spp.) communities of the central portion of the state (Larrison and Sonnenberg 1968). Sage sparrows are documented in Adams, Benton, Douglas, Franklin, Grant, Kittitas, Lincoln, Okanogan and Yakima Counties (see Figure 1; Smith et al. 1997).

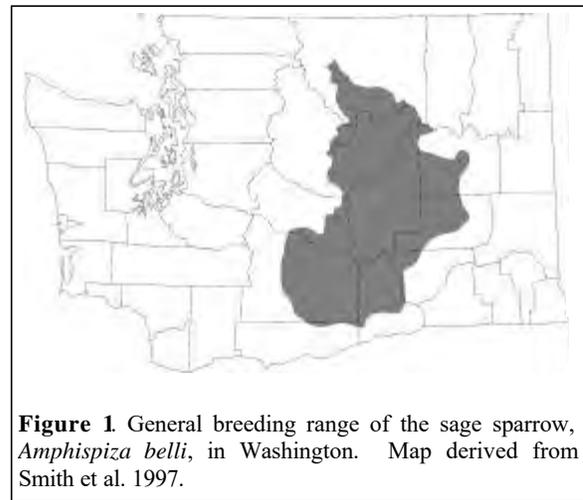


Figure 1. General breeding range of the sage sparrow, *Amphispiza belli*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The sage sparrow is a State Candidate species that depends almost entirely on sagebrush-steppe habitat (Braun et al. 1976, Rich 1980, Reynolds 1981, Petersen and Best 1985). This habitat in Washington has become severely fragmented and reduced in extent over the last century (Dobler et al. 1996), particularly the deep-soil communities that this species apparently prefers (Vander Haegen et al. 2000). Furthermore, the Interior Columbia River Basin Ecosystem Management Project listed the sage sparrow as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Sage sparrows are closely associated with sagebrush-steppe plant communities (Braun et al. 1976, Wiens and Rotenberry 1981). Sagebrush-steppe describes a plant community consisting of one or more layers of grasses and forbs with a discontinuous overstory of sagebrush shrub cover (Daubenmire 1988). Sage sparrows are sensitive to fragmentation of sage cover and are found more frequently in extensive areas of continuous sage (Knick and Rotenberry 1995, Vander Haegen et al. 2000).

Sage sparrows commonly nest within or beneath sagebrush plants (Martin and Carlson 1998). Nesting takes place from late March through June, with pairs typically producing 1-2 broods/year (Bent 1968, Alcorn 1978, Rich 1980, Ryser 1985, Petersen and Best 1987). Shrubs that are at least 75% living are selected for nesting, and nests are always located outside of the dead portion of the shrub (Petersen and Best 1985). The height of shrubs used for nesting generally ranged between 40 and 100 cm (16-40 in) (Rich 1980, Reynolds 1981, Petersen and Best 1985) and averaged 90 cm (35 in) in eastern Washington (Washington Department of Fish and Wildlife, unpublished data).

Contiguous breeding territories generally are established by males in March (Petersen and Best 1987). Territory sizes of mated males vary greatly (Weins et al. 1985), ranging from 0.8 ha (2 ac) (Petersen and Best 1987) to 4.4 ha (11 ac) (Rich 1980). A study in southeastern Washington found that the size of breeding territories ranged between 0.65 ha (1.6 ac) and 1.57 ha (3.9 ac); territories also tended to decrease in size with an increase in population density (Weins et al. 1985). Boundaries between adjacent territories have been found to overlap, and the size and shape may fluctuate daily during the breeding season (Rich 1980).

In spring, sage sparrows are primarily insectivorous, feeding on grasshoppers, beetles and moth larvae (Martin and Carlson 1998). They glean food from the ground and from shrub branches within reach of the ground (Moldenhauer and Wiens 1970, Petersen and Best 1985, Ryser 1985). Sparrows also have been observed walking to and from their nests (T. Rich personal communication and B.M. Winter personal communication *in* Petersen and Best 1985). Thus, optimal foraging habitat should include an overstory of shrubs with clearings in the grass/forb layer to allow movement on the ground (Petersen and Best 1985).

LIMITING FACTORS

Availability of extensive sagebrush-steppe habitat is a primary factor limiting sage sparrow populations (Martin and Carlson 1998, Vander Haegen et al. 2000). Sage sparrows are sensitive to fragmentation of sagebrush stands and are found more frequently in large, undisturbed stands (Vander Haegen et al. 2000). Degradation of sagebrush stands by invasive plants such as cheatgrass (*Bromus tectorum*) also may render sites less suitable to sage sparrows (Dobler et al. 1996).

MANAGEMENT RECOMMENDATIONS

Sage sparrows are dependent on stands of sagebrush for nest sites, food, and cover (Martin and Carlson 1998). In order to maintain sage sparrow populations, sagebrush communities should be left in relatively undisturbed condition and fragmentation should be avoided. Management activities that increase cheatgrass and other exotic species that increase the risk of wildfire also should be avoided.

Optimum habitat for sage sparrows in Washington consists of large (>1000ha) blocks of sagebrush-steppe with sagebrush cover ranging from 10-25% and shrubs averaging >50 cm in height (Altman and Holmes 2000). Herbaceous cover of native species should average >10%, with \geq 10% of the ground remaining bare (including areas of cryptogamic crust) to allow movement on the ground. Exotic annual grasses should cover <10% of the ground. Although much of Washington's sagebrush-steppe is fragmented by agriculture, habitat restoration on formerly tilled fields could expand the range of sagebrush-steppe obligate birds in fragmented landscapes (Vander Haegen et al. 2000).

Removal of sagebrush should be avoided, with the exception of rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration (Wisdom et al. 2000). Sagebrush cover should be reduced on a site only after careful consideration of how the methods used may affect sagebrush regeneration and the opportunity for exotic vegetation to invade the site. Burning may lead to serious negative impacts to local sage sparrow populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones (e.g., Benton, Franklin, and Grant Counties) where exotic vegetation often becomes dominant and sagebrush is slow to recover (Knick and Rotenberry 1995, Wisdom et al. 2000). If chemical use is planned for areas where this species

occurs, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Although limited data are available on this subject, livestock grazing at low to moderate levels has not been shown to be detrimental to sage sparrow habitat (Saab et al. 1995). Because sage sparrows in Washington frequently nest on the ground early in the spring (Washington Department of Fish and Wildlife, unpublished data), and because they primarily forage at ground level, grazing levels should be kept at low levels (Altman and Holmes 2000). Researchers suggest allowing >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

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KEY POINTS

Habitat Requirements

- Strong association with sagebrush habitat, especially in extensive, unfragmented stands.
- Sagebrush cover between 10 and 25%, with shrubs averaging >50 cm in height.
- Herbaceous cover (native species) >10%, with \geq 10% of the ground bare (including areas of cryptogamic crust); exotic annual grasses should cover <10% of the ground.

Management Recommendation

- Retain large blocks of sagebrush communities and avoid fragmentation of existing stands.
- Establish or retain 10-25% sagebrush cover and shrubs averaging >50 cm in height. Maintain an herbaceous cover of native species averaging >10%, with \geq 10% of the ground bare (including areas of cryptogamic crust). Reduce exotic annual grasses to <10% of the ground cover.
- Avoid activities that may increase invasion of cheatgrass and other exotic vegetation.
- Livestock grazing should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- Control wildfires in sagebrush habitat, especially in low rainfall zones.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and other alternatives.
- Avoid the removal of sagebrush, with the exception of rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration.

APPENDIX A: Contacts to assist in evaluating the use of herbicides, pesticides, and their alternatives

Government Organizations

United States Environmental Protection Agency

Provides information, brochures, and technical help on pesticide application.
Region 10 Public Affairs Office, Seattle 1-800-424-4372

Washington State Department of Agriculture

Pesticide Management

General Information.....(360) 902-2010
Toll Free General Information(877) 301-4555
Assistant Director.....(360) 902-2011

Compliance

Enforces state and federal pesticide laws; investigates complaints of pesticide misuse.

Manager(360) 902-2036
Olympia Compliance(360) 902-2040
Moses Lake(509) 766-2575
Spokane Compliance(509) 533-2690
Wenatchee Compliance.....(509) 664-3171
Yakima Compliance(509) 225-2647

Registration and Licensing

Registers pesticides sold and used in Washington.

Manager(360) 902-2026
Pesticide Registration - Olympia(360) 902-2030
Pesticide Registration - Yakima(509) 255-2647

Program Development

*Licenses pesticide application equipment and pesticide dealers; commercial, public, and private pesticide applications; and operators and consultants.
Conducts waste pesticide disposal program; responsible for public outreach and education.*

Manager(360) 902-2051
Pesticide Licensing and Recertification
 Eastern Washington.....(509) 225-2639
 Western Washington.....(360) 902-1937

Waste Pesticide Collection.....(360) 902-2050
Farmworker Ed. and Pest. Licensing - Yakima(509) 255-2639

Washington Department of Ecology, Regional Contacts

DOE provides information and permits on applying pesticides directly or indirectly into open bodies of water.

Eastern Region, Spokane(509) 456-2926
Central Region, Yakima(509) 575-2490
Northwest Region, Bellevue(206) 649-7000
Southwest Region, Lacey.....(360) 407-6300

Washington Department of Fish and Wildlife

Regional Contacts

Your regional program manager will direct your questions to a biologist. The department can provide information on what priority habitats and species are known to be in your area, and the life requisites of priority species.

Region 1, Spokane(509) 456-4082
Region 2, Ephrata(509) 754-4624
Region 3, Yakima(509) 575-2740
Region 4, Mill Creek.....(206) 775-1311
Region 5, Vancouver.....(360) 696-6211
Region 6, Montesano(360) 249-4628

Habitat Research and Information Services

Mapped information and management recommendations for Washington's priority habitats and species can be obtained by calling (360) 902-2543.

Washington Poison Control Center(800) 222-1222

Provides information on who to contact in case of exposure to or spill of pesticides or other toxic substances.

Non-Government Organizations

Agricultural Support Groups

Tilth Producers.....(206) 442-7620
Chapter of Washington Tilth
P.O. Box 85056
Seattle, WA 98145-1056

Provides a directory of organic growers, food and farm suppliers, and resources, called the Washington Tilth Directory. Can help place farmers wishing to reduce pesticide use in touch with those who have already done so.

Northwest Coalition for Alternatives to Pesticides.....(541) 344-5044
P.O. Box 1393
Eugene, OR 97440-1393

Provides information on a network of farmers practicing sustainable agriculture.

Palouse-Clearwater Environmental Institute(208) 882-1444
P.O. Box 8596
112 W. 4th, Suite 1
Moscow, ID 83843

Coordinates farm/consumer improvement clubs in eastern Washington and is the western coordinator of the Campaign for Sustainable Agriculture.

Alternative Energy Resources Organization...(406) 443-7272
25 S. Ewing Suite 214
Helena, MT 59601

Coordinates a network of farm improvement clubs and produces a list of organic growers in Montana. Has information on growing grains in the Palouse region.

Financial Support for Farmers Shifting to Sustainable Agriculture

Cascadia Revolving Loan Fund(206) 447-9226
1901 NW Market Street
Seattle, WA 98107

A non-profit organization that lends money to small businesses.

Sustainable Agriculture Research and Education(435) 797-2257
Western Region SARE
Room 305 Agricultural Science Building
4865 Old Main Hill Road
Logan, UT 84322-4865

A federal grant program for farmer-directed, on-farm research. The grants are called Farmer/Rancher Research Grants.

The Organic Farming Research Foundation.....(831) 426-6606
P.O. Box 440
Santa Cruz, CA 95061

Provides funding for organic farming methodology research.

Insectaries

Northwest Biocontrol Insectary/Quarantine Insectary.....(509) 335-5504
Terry Miller

Can provide limited technical advice on using beneficial insects as biological control agents.

Integrated Pest Management and Non-Chemical Alternatives

Bio-Integral Resource Center)(510) 524-2567

P.O. Box 7414

Berkeley, CA 94707

Publishes "Common Sense Pest Control Quarterly", and "The IPM Practitioner Monitoring the Field of Pest Management."

Integrated Fertility Management.....(800) 332-3179

333 Ohme Gardens Rd.

Wenatchee, WA 98801

Provides information on organic farming, biological pest control, and soil amendments. Also provides a network with which growers can contact each other.

Northwest Coalition for Alternatives to Pesticides.....(541) 344-5044

Located in Oregon, provides information regarding integrated pest management, a list of private consultants, as well as other sources and contacts.

Washington Toxics Coalition.....(206) 632-1545

Has an information file on many topics involving chemical pesticides, including effects on the environment and on human health, as well as alternatives to household and garden chemicals.

National Organizations

Appropriate Technology Transfer for Rural Areas.....(800) 346-9140

P.O. Box 3657

Fayetteville, AR 72702

Information service on sustainable agriculture. Not ideal for questions that are regionally specific, but good for crop production questions.

Chemical Referral Center(800) 262-8200

This center, which is sponsored by the Chemical Manufacturers Association, will refer the caller to the manufacturer of the chemical in question, and provide telephone numbers of other hotlines.

National Agricultural Library(301) 504-6559

Alternative Farming Systems Information Center

10301 Baltimore Blvd.

Beltsville, MD 20705-2351

Provides bibliographies on topics such as cover crops, living mulches, compost, etc. Will do individual searches on national agricultural databases for free. This organization's strong point is specific, technical information.

National Pesticide Telecommunication Network(800) 858-PEST (7378)
Provides 24-hour information on pesticide products, poisoning, cleanup and disposal, enforcement contacts, certification and training programs, and pesticide laws.

Safety, Storage, Handling, and Disposal

Washington Toxics Coalition.....(206) 632-1545
Has an information file on many topics involving chemical pesticides, including effects on the environment and on human health.

Local Solid Waste/Recycling Centers

Your county or municipal solid waste center may be of assistance when disposing of pesticides and herbicides.

Washington State University Cooperative Extension Service, County Agents

County	Address	City	Phone #	County	Address	City	Phone #
Adams	210 W. Broadway	Ritzville 99169	(509) 659-3209	Lewis	360 NW North St. MS: AES01	Chehalis 98532	(360) 740-1212
Asotin	2535 Riverside Drive	Asotin 99402	(509) 758-5147	Lincoln	PO Box 399	Davenport 99122	(509) 725-4171
Benton	5600-E W Canal Drive	Kennewick 99336	(509) 735-3551	Mason	11840 Hwy 101 N.	Shelton 98584	(360) 427-9670 Ext. 395
Chelan	303 Palouse Street	Wenatchee 98801	(509) 667-6540	Okanogan	PO Box 391	Okanogan 98840	(509) 422-7245
Clallam	223 East 4th St.	Port Angeles 98362	(360) 417-2279	Pacific	PO Box 88	South Bend 98586	(360) 875-9331
Clark	11104 NE 149th Street	Bush Prairie 98606	(360) 397-6060	Pend Oreille	PO Box 5045	Newport 99156	(509) 447-2401
Columbia	202 S. 2nd Street	Dayton 99328	(509) 382-4741	Pierce	3049 S 36 th , Suite 300	Tacoma 98409	(253) 798-7180
Cowlitz	207 4th Ave N	Kelso 98626	(360) 577-3014	San Juan	221 Weber Way, Suite LL	Friday Harbor 98250	(360) 378-4414

County	Address	City	Phone #	County	Address	City	Phone #
Douglas	PO Box 550	Waterville 98858	(509) 745- 8531	Skagit	306 S First Street	Mount Vernon 98273	(360) 428- 4270
Ferry	350 E. Delaware Ave #9	Republic 99166	(509) 775- 5235	Skamania	PO Box 790	Stevenson 98648	(509) 427- 9427
Franklin	Courthouse 1016 N. 4 th	Pasco 99301	(509) 545- 3511	Snohomish	600 128th St. SE	Everett 98208	(425) 338- 2400
Garfield	PO Box 190	Pomeroy 99347	(509) 843- 3701	Spokane	222 N Havana	Spokane 99202	(509) 477- 2048
Grant	PO Box 37 35 C Street NW	Ephrata 98823	(509) 754- 2011 Ext. 413	Stevens	985 S Elm, Suite A	Colville 99114	(509) 684- 2588
Grays Harbor	PO Box R 32 Elma- McCleary Road	Montesano 98541	(360) 482- 2934	Thurston	720 Sleater Kinney Road SE, Suite Y	Lacey 98503	(360) 786- 5445
Island	PO Box 5000 101 NE 6 th	Coupeville 98239	(360) 679- 7327	Wahkiakum	PO Box 278	Cathlamet 98612	(360) 795- 3278
Jefferson	201 W. Patison	Port Hadlock 98339	(360) 379- 5610	Walla Walla	328 W Poplar Street	Walla Walla 99362	(509) 527- 3260
King	919 SW Grady Way, Suite 120	Renton 98055	(206) 205- 3100	Whatcom	1000 N Forest Street, Suite 201	Bellingham 98225	(360) 676- 6736
Kitsap	614 Division Street MS-16	Port Orchard 98366	(360) 337- 7157	Whitman	310 N Main, Room 209	Colfax 99111	(509) 397- 6290
Kittitas	507 Nanum Ave, Room 2	Ellensburg 98926	(509) 962- 7507	Yakima	128 N 2nd Street, Room 233	Yakima 98901	(509) 574- 1600
Klickitat	228 W Main, MS-CH 12	Goldendale 98620	(509) 773- 5817				

Appendix B. Native plants suitable for a thicket-like visual barrier around a heron colony.

Scientific Name	Common Name ^a	Comments
<i>Cornus sericea</i>	red-osier dogwood	<ul style="list-style-type: none"> • Wet and moist soils • Full sun • Native throughout Washington and British Columbia.
<i>Crataegus douglasii</i>	black hawthorn	<ul style="list-style-type: none"> • Moist soils • Partial shade • Thorny • Ensure you know the variety and care necessary to encourage growth as a shrub rather than a tree • Native throughout Washington and British Columbia
<i>Crataegus suksdorfii</i>	Suksdorf's hawthorn	<ul style="list-style-type: none"> • Moist soils • Partial shade • Thorny • Ensure you know the variety and care necessary to encourage growth as a shrub rather than a tree • Native to areas west of the Cascades
<i>Malus fusca</i>	western crabapple	<ul style="list-style-type: none"> • Wet and moist soils • Full to some shade • Thorny • Native to areas west of the Cascades
<i>Prunus emarginata</i>	bitter cherry	<ul style="list-style-type: none"> • Moist soils • Full sun • Native to coastal and interior Washington and British Columbia • For creating a barrier, plant the shrub variety (<i>Prunus emarginata</i> var. <i>emarginata</i>)
<i>Ribes divaricatum</i>	straggly gooseberry	<ul style="list-style-type: none"> • Dryer soils • Full to partial sun • Thorny • Native to areas west of the Cascades
<i>Rosa spp.</i>	native rose	<ul style="list-style-type: none"> • Native species include nootka rose, bald hip rose, and clustered rose.
<i>Rubus parviflorus</i>	thimbleberry	<ul style="list-style-type: none"> • Dryer soils • Mostly sunny • Native to areas west of the Cascades
<i>Rubus spectabilis</i>	salmonberry	<ul style="list-style-type: none"> • Wet and moist soils • Full to partial sun • Native from the East Cascades to the coast
<i>Spiraea douglasii</i>	hardhack	<ul style="list-style-type: none"> • Wet and moist soils • Full to mostly sunny • Native throughout region, except for in the Columbia Basin
<i>Symphoricarpos albus</i>	common snowberry	<ul style="list-style-type: none"> • Moist and dry soils • Mostly to part sun • Native throughout Washington and British Columbia

^aClick on common names for more information about requirements of each plant species.

Appendix 1. Ferruginous hawk survey assessment protocol

A *survey assessment* should be required for all proposals to develop any location in **Zone A** or when a proposal is in **Zone B** and flagged as occurring on lands consisting of the natural vegetation and agricultural cover types listed in Table 2. A survey assessment is required in **Zone C** when the result of a rapid assessment shows that it is needed (see Appendix 2). The survey assessment is used to document ferruginous hawks, nests, prey, and habitat within the proposed project boundary.

A qualified professional consultant should be contracted to conduct the survey assessment. The consultant should be skilled in identifying and mapping vegetation as well as surveying raptors and small mammals. These skills are important for anyone carrying out the survey assessment because this survey assessment will be used to generate the data necessary for writing the HMP. Prior to collecting data for this survey assessment, please carefully read Appendix 3 to become familiar with the type of data that will be necessary to write the HMP.

The local government overseeing the project should use information from the survey assessment when determining how permitting for the project will proceed.

Nest and raptor documentation

Surveys for nests and raptors will be used to provide the information required for subsection 2a in the HMP (see Appendix 3). Locations of individual raptors sighted during surveys may help to locate undiscovered nests.

- Search for any raptor nests between 15 March and 15 May. Use optics at a distance and do not approach nests to avoid disturbance. Search for nests that are on the parcel(s) where the development activity is being proposed. From as close and accessible a vantage as possible, also search adjacent properties for nests. Identify, record, and map the location of any observed nesting raptors to species. Suspected raptor or raven nests should also be mapped even when birds are not observed. Identify, document, map, and describe locations where there are elevated structures suitable for raptor nesting.
- Search elevated structures for nests including trees and artificial structures like utility towers and windmills. Search cliffs, talus slopes, and rock outcrops.
- Use photo documentation and/or field identification guides to identify species.
- Identify and record all raptors and ravens observed during the survey. Note which species of raptors were observed. Search for nests whenever a ferruginous hawk is seen.

Prey documentation

Conduct ground surveys for prey and prey habitat on the entire parcel(s) where development is being proposed. This data will provide the information required for subsection 2b in the HMP (see Appendix 3).

- Between 15 March and 15 June, conduct ground surveys to look for potential prey or the sign of prey (e.g., ground squirrel burrows).
- Surveys for ground squirrels and jackrabbits are labor-intensive because animals are timid; use signs of activity to determine animal presence (scat for both ground squirrels and jackrabbits, and vocalizations and active burrows for ground squirrels). Ground squirrels may reside in disturbed habitats (e.g., roadsides, edges of orchards) and some species, like California ground squirrels (*Otospermophilus beecheyi*), may reside in rocky outcrops. These areas should be surveyed by direct inspection. More open and level habitats should be systematically searched by walking and listening and looking for signs along geo-located transects for complete coverage of the survey area (see "Suggested Survey Protocol" in Finger et al. 2007). Spotlighting at night may enhance searches for jackrabbits (Smith and Nydegger 1985).
- The presence of pocket gophers is often evident by mounds of excavated soil in ground squirrel colonies or along edges of agricultural land.
- When jackrabbits, ground squirrels, and pocket gophers or signs of these species are located, map the location where these mammals (or their sign) were observed during the survey.

Habitat documentation

Survey and map lands proposed for development that are composed of any of the natural vegetation or agricultural cover types listed in Table 2. This data will provide the information required for subsection 2c in the HMP (see Appendix 3).

- Survey and map areas composed of the natural vegetation or agricultural cover types listed in Table 2 along with a description of their state of quality or level of degradation.
- The protocol in Appendix 9 in [Management Recommendations for Washington's Priority Habitats: Shrubsteppe](#) can be used to map natural vegetation types and describe their condition using a procedure known as an Ecological Integrity Assessment.

Record of survey assessment

The local government should review the results of the survey assessment and include them in the project file.

Appendix 2. Ferruginous hawk rapid assessment protocol

A rapid assessment involves an on-the-ground evaluation of the entire parcel(s) in Zone C (between 10 km and 20 km from a nest used by ferruginous hawks within the past five years) where a land development activity is proposed (Figure 5).

Within such parcels:

- Document ferruginous hawk nests and ferruginous hawks.
- Document evidence of ground squirrel colonies.

If either ferruginous hawks, ferruginous hawk nests, or ground squirrel colonies are identified, a survey assessment should then be required (Appendix 1). If ferruginous hawks, ferruginous hawk nests, or ground squirrel colonies are not identified on the parcel(s), then no further action is necessary.

The local government should review the results of the rapid assessment and include them in the project file.

Appendix 3. Habitat management plan template¹

PART 1

1a. Applicant's Full Name	1b. Applicant's mailing address:
1c. Plan prepared by: (Full name and company affiliation)	1d. Date submitted:
1e. County	1f. Parcel ID number(s) of proposed development site.
1g. Detailed description of the proposed project:	

PART 2

2a. Location of nests and raptors

In the space provided below, please briefly describe any nests found on or adjacent to the parcel(s) where the development activity is being proposed. This data is gathered as part of the survey assessment described in this report. Label on a map each nest with a unique nest ID (e.g., nest #1, nest #2). Include attribute information for each mapped nest by identifying which, if any, are occupied, by what species, and size and condition of each nest, and features supporting each nest (e.g., juniper, rock outcrop, telephone pole, ground). Also, identify, document, map, and describe locations where there are elevated structures suitable for raptor nesting as well as any ferruginous hawk nests mapped in WDFW's PHS database. Document and record any ravens and raptors observed during the survey, identifying all raptors to species whenever possible.

Attachment:
Map of site to scale clearly showing location of nests with their ID numbers, elevated structures suitable for raptor nesting, as well as the location(s) of the proposed development along with any disturbances.²

¹ Attach supplemental pages if space in template is insufficient. Indicate in template when content for a section is continued on a separate page and indicate on the sheet the section(s) where the content is continuing from (e.g., continued from 2a).

² Attach a single map (rather than 3 separate maps) clearly showing all information required in sections 2a, 2b, and 2c.

2b. Prey

Describe below any signs of prey species (e.g., burrows, scat, animal observations) on the parcel. This data is gathered as part of the survey assessment described in this report. Also, describe below any verified prey locations on site that are mapped in a WDFW database (e.g., PHS on the Web) or that are observed during the survey assessment. In the description, identify the species if known.

Attachment:

- Map of site to scale with locations along with legend clearly depicting species and type of sign.

2c. Space

Describe below the physical and ecological features that occur on the site. This includes the types of natural vegetation or agricultural cover types (Table 2), recent disturbances, location of waterbodies including creeks, as well as any physical features that ferruginous hawks might use for nesting. These include trees, rock outcrops and cliffs, as well as any elevated artificial features such as buildings or telephone poles. Natural vegetation types on site should be identified using [Ecological Systems of Washington State](#).

Attachment:

- Map of site to scale showing locations of all physical and ecological features. Natural vegetation or agricultural cover types (Table 2) should be shown on map as areas. Other features can be displayed with lines (e.g., creeks) or points (e.g., a single tree).

PART 3

3a. Mitigation sequencing

Describe below in detail the reasonable efforts made to apply mitigation sequencing to avoid to the greatest extent possible, minimize to the greatest extent possible, and provide restoration actions (on-site or off-site) that offset impacts resulting in (at a minimum) no net loss of ecosystem function.

3b Mitigation

On a separate sheet (attached to HMP) describe the actions you intend to implement to ensure No Net Loss of ecosystem functions important to ferruginous hawk (see Appendix 4 for examples of mitigation measures). The description must include adequate detail so that any reader will clearly understand the steps that will be taken, their precise mapped locations on the parcel, and their timing. Describe how these steps will ensure that NNL of ecosystem function is achieved, i.e., how the measures will fully offset the loss of function that may be caused by the land use activity.

Also, include a description of the process to monitor the conservation and restoration actions to ensure their success over the long-term. The process for monitoring should include observable benchmarks of successful mitigation, a timeline for measuring those benchmarks, and a description of follow-up actions if benchmarks are not met. Benchmarks can include nest productivity and occupancy as well as the species richness and density of available prey species within the home range.

3c. Financial guarantees

Please describe in detail the financial guarantees (i.e., performance bonds) that will be held to ensure compliance with the measures described in the mitigation section. Include a detailed justification of the proposed dollar amount, terms in which claims can be made against the bond, as well as the period that the bond will be in effect.

Appendix 4. Sample mitigation measures

Restoration / grazing and agriculture

- **Nest Substrate:** Maintain agricultural fence posts, lone trees or small groves, and other structures that provide perch and nesting habitat. Limit disturbance at nest sites during breeding season (1 April through 5 September) and protect (e.g., fence) and reinforce nest trees from cattle rubbing. Where nest substrates are limited, install artificial nest substrates after consultation with a WDFW district wildlife biologist (see Appendix 5).
- **Prey Abundance:** Implement agricultural practices that provide habitat for native prey populations, including ground squirrels, jackrabbits, and pocket gophers. Do not use rodenticides or shooting to control ground squirrels or small mammals on or adjacent to agricultural lands. Restore and protect edge of field habitats and hedgerows, especially on irrigated alfalfa fields. Do not burn or plow edges of fields except to promote native grass regeneration and to remove noxious weeds. Mow grain crops and other vegetation periodically to improve access to prey. After mowing or harvesting, maintain brush piles to provide cover for prey.
- **Range Restoration:** Rehabilitate pastures and range land through cheatgrass control and restoration of native grasses and shrubs. Leave lone or peripheral trees for potential nest substrates. See [Shrub-Steppe and Grassland Restoration Manual for the Columbia River Basin](#) (Benson et al. 2011) for guidance on conducting restoration activities.
- **Managed Grazing:** Implement a grazing management plan that maintains a diversity of native grasses and forbs needed by ferruginous hawk prey species.

Industrial development – wind energy

- Build turbine strings and infrastructure outside of ferruginous hawk core use areas and home ranges to avoid nests, prey concentrations, and disturbance and collision impacts.
- Maximize proposed construction in areas that are already disturbed (e.g., lands in use for more intensive agricultural practices) and reduce the project footprint to the minimum area necessary to meet project needs.
- Arrange turbines to avoid slope and rim edges and concentrate industrial development on unproductive agricultural land (Pearce et al. 2016).
- Erect fewer turbines.
- Reduce risk of turbines proposed inside home ranges by stopping turbine motion when hawks are present using “Identiflight” or similar technology or seasonal diurnal curtailment (Watson et al. 2018b, McClure et al. 2021). These systems are currently in development and would require identification algorithms trained to identify flying ferruginous hawks. Increasing “cut-in” speeds at which turbines activate has reduced probability of collision for some species (Anderson et al. 2022).
- Address impacts of related infrastructure, including access roads and transmission lines (see Industrial development – Transmission Lines).

- Require notification to WDFW district wildlife biologist for all documented ferruginous hawk mortalities on wind energy project sites no matter the cause of death.
- Require long-term nest surveys for at least 10-years post construction to look at changes in the presence of nesting ferruginous hawks as well as changes in nesting productivity and occupancy. This is in addition to post-construction fatality surveys and reporting of incidental raptor fatalities required on most projects.
- If the result of post-construction surveys finds that there has been any reduction in the presence of nesting ferruginous hawks or reduced nesting productivity or occupancy, then adaptive management measures should be taken to address declines.

Industrial development – solar energy

- Build solar farms and infrastructure outside of ferruginous hawk core use areas and home ranges to avoid nests, prey concentrations, disturbance, and collision impacts.
- Review the Washington Columbia Plateau Least-Conflict Solar Siting Gateway wsuenergy.databasin.org for more information on potential environmental resource conflicts and to identify locations with a lower likelihood of environmental resource conflicts.
- Maximize proposed construction in areas that are already disturbed and reduce the project footprint to minimum area necessary to meet project needs.
- Concentrate panels to cultivated areas to reduce impacts to raptors (Pearce et al. 2016).
- Set panels back from ridgelines to avoid potential impacts to ridge soaring, thermals, and hunting habitats.
- Address impacts of related infrastructure, including access roads and transmission lines (see Industrial development – Transmission Lines).
- For projects that use collection towers, spread aim points of mirrors to reduce temperatures and burn risk when facilities are in stand-by mode (Dwyer et al. 2018).
- Require notification to WDFW district wildlife biologist for all documented ferruginous hawk mortalities on solar energy project sites no matter the cause of death.
- Require long-term nest surveys for at least 10-years post construction to look at changes in the presence of nesting ferruginous hawks as well as changes in nesting productivity and occupancy. This is in addition to post-construction fatality surveys and reporting of incidental raptor fatalities required on most projects.
- If the result of post-construction surveys finds that there has been any reduction in the presence of nesting ferruginous hawks or reduced nesting productivity or occupancy, then adaptive management measures should be taken to address declines.

Industrial development – transmission lines

- Establish new distribution lines outside of hawk home ranges.

- Bury lines where possible.
- Develop raven monitoring and nest management (e.g., removal) plan for new transmission lines built within industrial developments.
- Apply state-of-the-art methods to prevent electrocutions and collisions (e.g., perch diverters, supplemental perches, wire-markers to improve visibility of lines).
- Report pole numbers and electrocution incidents to local utility companies and WDFW district wildlife biologist as soon as possible for remedial actions.

Industrial development – surface mining, gravel pit construction, and road construction

- Develop surface mines, gravel pits, and new roads outside of ferruginous hawk core use areas and home ranges to avoid nests, prey concentrations, and disturbance and collision impacts.
- Maximize line-of-site to hawk nests for projects located in coulees and narrow draws.
- Limit the number of access roads to minimize recreational use.
- Gate permanent roads to reduce access and post as “no-shooting”.
- Reclaim abandoned mines as soon as possible after completion of operation or construction.
- Leave remnant rockpiles in strategic locations to provide raptor perches and prey habitat.
- Improve ledges and crevices on solid banks to provide potential nest substrate.
- Implement program to remove road-killed carrion away from highways to prevent hawk collisions (Slater et al. 2022).

Residential development

- Cluster development away from key breeding and foraging habitat; set aside and permanently conserve areas with features important to breeding ferruginous hawks.
- Use open space/Public Benefit Rating System tax breaks or other incentives to maintain prey habitats within Zones A and B.

Mammal control and toxins

- Control small mammals if necessary for damage control rather than complete eradication.
- Do not use rodenticides to control ground squirrels or small mammals on or adjacent to agricultural lands.
- Prohibit recreational shooting at ground squirrel colonies.
- Do not use lead bullets. Only use non-toxic ammunition. If encountered, bury animal carcasses shot with lead (e.g., ground squirrels, coyotes, livestock).

Fire control, erosion, and climate change resiliency

Note: All proposed projects, whether they contribute to these impacts or not, should consider how to minimize effects of increased fire, cheatgrass invasion, and nest loss.

- Create and maintain firebreaks and develop fire control plans for pasture/grassland interface. Use controlled fire to mimic natural fires to improve small mammal communities in sagebrush habitats (Holmes and Robinson 2016).
- Remove cheatgrass and restore perennial grasses in pastures and native habitats (e.g., Clements et al. 2017).
- Reinforce and stabilize existing nests, nest trees, and cliff ledges to withstand extreme weather and provide protection from wind, sun, and rain (Shank and Bayne 2015, Migaj et al. 2011). See Appendix 5 for information on artificial nest structures.

Appendix 5. Artificial nest structures

Artificial nest structures (ANS) can be placed strategically to provide nest substrates on established ferruginous hawk territories or on vacant habitat that is otherwise limited by an absence of nest structures. For example, ANS may provide a substitute for nest trees lost to inclement weather, tree decadence, or cattle rubbing. They can also be used to create new potential nesting opportunities for ferruginous hawks, but only after consultation with a WDFW district wildlife biologist.

We advise against the placement of ANS to enhance ferruginous hawk nesting or as standard mitigation in areas being developed. This is because in more developed areas ANS may attract ravens and other raptors (e.g., red-tailed hawks, Swainson's hawks, and great horned owls) that are more tolerant than ferruginous hawks to anthropogenic activities such as development. These are species that can compete with or predate on ferruginous hawks. Artificial nest structures should also not be used, other than in exceptional cases (e.g., moving a nest from a hot distribution pole or from farm equipment), to permit or mitigate for the removal of ferruginous hawk nests or for translocating ferruginous hawks.

Ferruginous hawk nests on distribution poles that pose a risk should be removed only after the nesting season, and then should be replaced with perch deterrents. Artificial nest structures should then be installed 250-500 meters (820-1,640 feet) away from distribution poles where hawks were removed. Any movement of a nest in use should be done in the following stages (Kemper et al. 2020):

1. First, move the nest to a mobile artificial nest platform 25 meters (82 feet) away.
2. Second, move the nest to a permanent platform following the nesting season.

Before considering the use of an ANS, prioritize management and maintenance of existing trees. For long-term sustainability of nest substrates, trees can be planted within a fence near existing nest trees. Bases of nests in trees can be reinforced with wire netting where limbs are failing, and predator access to the nest can be reduced with tin sheathing placed around the base of trees (Craig and Anderson 1979). Groves of trees can be thinned as necessary to provide nest structure in individual trees or in scattered stands (Olendorff 1993). If an ANS is erected, plant trees nearby. The ANS can later be removed when planted trees reach maturity.

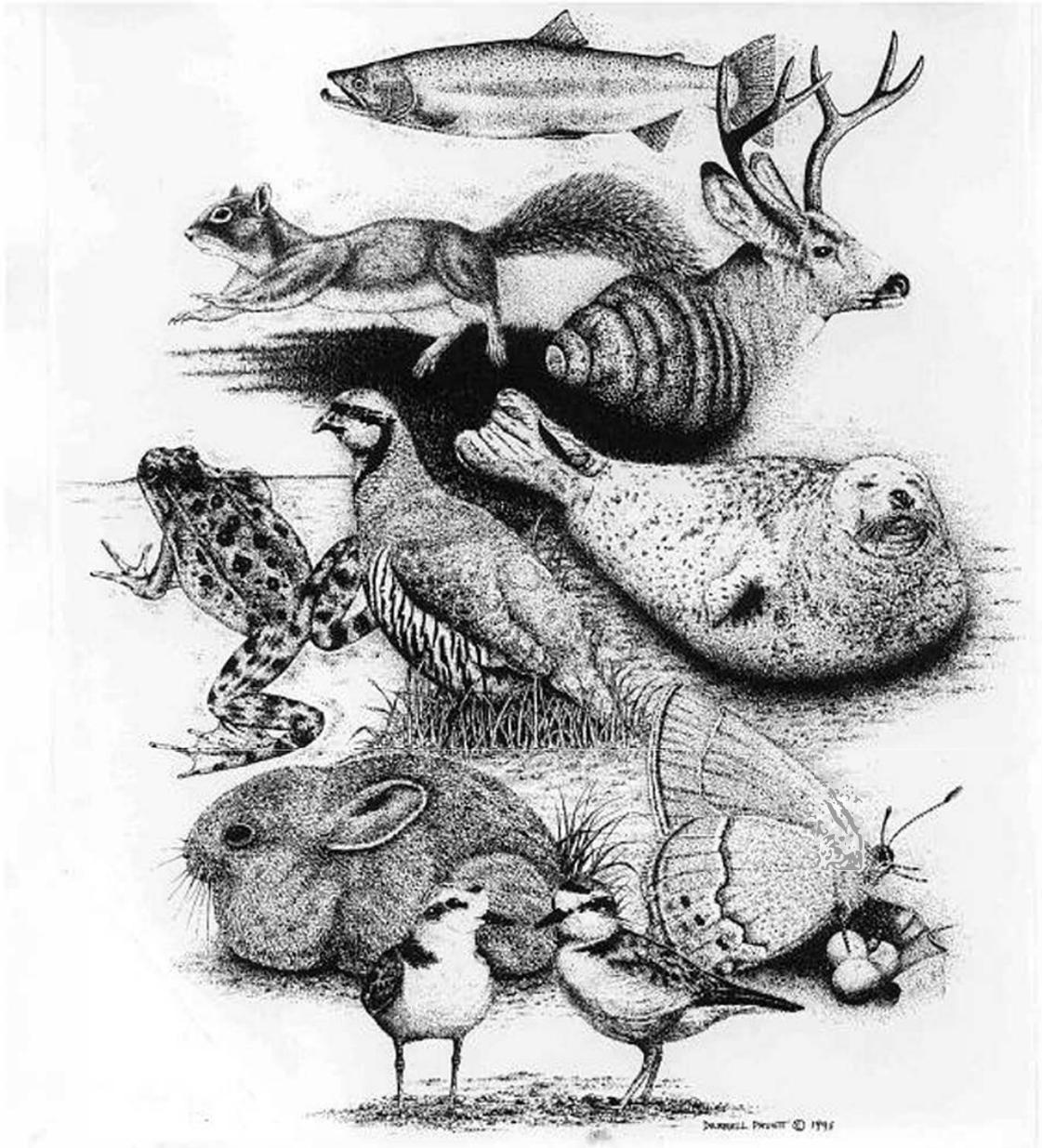
New ANS placement is recommended only after an authorized wildlife biologist identifies the right conditions for locating and erecting an ANS. These conditions include open habitats where there are no existing nest structures, an availability of prey populations, and where the nearest-neighbor distance (i.e., to the nearest nesting ferruginous hawk) is greater than 2.7 km (1.7 miles) – less than 2.7 km is okay in some situations, such as in high quality habitat. This is the distance that Cottrell (1981) found ferruginous hawk nests were spaced on adjacent territories in Oregon.

Neal et al. 2010 provides the following recommendations for ANS placement:

- Occupancy of ANS is highest when hawks are already habituated to disturbance or are known to use artificial substrates.
- ANS should be constructed where there is an extensive prey base.
- ANS should be constructed no greater than 1,000 meters (3,280 feet) and in the line-of sight of the nest when translocating nestlings or eggs to an ANS.

- Placement of ANS should consider the potential for attracting other species.
- Secure resources prior to installation for long-term monitoring, repair, and replacement of ANS.
- Consider whether habitat quality is too poor before siting an ANS, especially in areas already developed. An ANS sited in a poor location may attract hawks to sites prone to nest failure.
- Consider avoiding ANS installation where hawks might pose a threat of predation on other sensitive species such as sage grouse or burrowing owls.

Platform and pole designs for ANS are described elsewhere (Bohm 1977, Howard and Hilliard 1980, Schmutz et al. 1984, Olendorff 1993, Tigner et al. 1996, Skeen 1990, Neal 2007, Migaj et al. 2011). We recommend the use of sticks of the type and size used by ferruginous hawks on nest platforms (see description under the **Nests** subsection of the **Resource Requirements** section above). Most current evidence suggests shading of platforms is unnecessary or even detrimental to nesting ferruginous hawks. Howard and Hilliard (1980) recommended against “shade structure” based on two of three pairs of ferruginous hawks that preferred non-shaded structure. Red-tailed hawks preferred nesting on platforms with shade structures in Washington (M. Vekasy, pers. obs.). In contrast, Schmutz et al. (1984) found shaded nest platforms were used by ferruginous hawks twice as often as those that were unshaded. Woffinden and Murphy (1983) found hawks tree nests used over repeated years that had branches above them but that were otherwise unshaded. Panting behavior and an unusually wide gape are adaptations of ferruginous hawks to extreme temperatures and may help nestlings avoid the need to seek shade on exposed nests (Martin et al. 2015). Increasing summer temperatures from climate change, especially catastrophic heat episodes that have resulted in large-scale mortality of raptor nestlings, may increase future consideration for platform shading.



DANIEL DEWITT © 1914

Robby Eckroth

From: Kim Sanford <kimsanford@msn.com>
Sent: Monday, July 28, 2025 2:40 PM
To: PDS comments
Subject: SKAGIT COUNTY COMMISSIONERS PUBLIC HEARING – Critical Areas Ordinance Update

Subject: Re: SKAGIT COUNTY COMMISSIONERS PUBLIC HEARING – Critical Areas Ordinance Update

Please Protect our Critical Areas, including Big Lake, from Stormwater Pollution. Unfortunately, the county code allows new development to send polluted stormwater to Big Lake and other critical areas without treatment or scientific review. Please 'Plug the Hole' in the Approval Process. Require developers to prove their stormwater runoff designs protect the 'swimmable, fishable' functions and values of critical areas that receive the runoff, without regard to distance from the development.

The Planning Department is seeking to protect only critical areas 200' from a development boundary. But untreated, polluted stormwater runoff is carried longer distances in ditches and culverts directly to critical areas. Distance makes no difference. For example, the Overlook Crest development of 105 homes above Big Lake was approved in 2024 to send untreated stormwater runoff from 18+ acres of new impervious area in a big pipe directly to Big Lake. Approval was granted with no "critical area site-assessment" reviewing the impacts on Big Lake of the new polluted stormwater runoff. Why? Because Big Lake, the critical area, was 800+ feet from the development's discharge point instead of within the 200 foot review area.

Big Lake is sick and we all know it. The 2025 Algae Bloom is already beginning. One step of many to keep storm water from polluting is with CAOs that address stormwater runoff into critical areas, not just those areas within 200 feet.

I ask you to require developers to provide Critical Areas Site Assessments for the off-site impacts of their developments to critical areas without regard to distance. Big Lake and other critical areas should be protected from further degradation caused by stormwater pollution.

For forty years I have spent my summers on the lake and watched the water quality deteriorate. Everyone including developeers, property owners and lake users need be stewards of our critical areas.

As more development occurs around Big Lake and other critical areas in Skagit County, it so very important to protect these areas. This is not about stopping development, it is about protecting critical areas.

Thank you,
Kimberly Sanford
Mailing address
PO BOX 839
Lyman, Wa 98263

Physical address:
37938 Theo Lane
Concrete, WA

23904 N Westview Rd
Mount Vernon , WA 98274

On Fri, Jul 25, 2025, 11:54 AM Kim Sanford <kimsanford@msn.com> wrote:

Will you please read this over? I just copied some paragraphs and changed a bit . Very simple but it will be on record. Just in case I'm not able to make the hearing.

Please Protect our Critical Areas, including Big Lake, from Stormwater Pollution. Unfortunately, the county code allows new development to send polluted stormwater to Big Lake and other critical areas without treatment or scientific review. This is contrary to state law. **Plug the Hole in the Approval Process. Require developers to prove their stormwater runoff designs protect the 'swimmable, fishable' functions and values of critical areas that receive the runoff, without regard to distance from the development.**

The Planning Department is seeking to protect only critical areas 200' from a development boundary. But untreated, polluted stormwater runoff is carried longer distances in ditches and culverts directly to critical areas. Distance makes no difference. For example, the Overlook Crest development of 105 homes above Big Lake was approved in 2024 to send untreated stormwater runoff from 18+ acres of new impervious area in a big pipe directly to Big Lake. Approval was granted with no "critical area site-assessment" reviewing the impacts on Big Lake of the new polluted stormwater runoff. Why? Because Big Lake, the critical area, was 800+ feet from the development's discharge point instead of within the 200 foot review area.

Do we as a community really want this to continue? Will Big Lake become a dumping pond? Critical areas and stormwater have distinct codes and regulations, however, the first step to keep storm water from polluting is with CAOs that address stormwater runoff into critical areas, not just those areas within 200 feet.

I ask you to require developers to provide Critical Areas Site Assessments for the off-site impacts of their developments to critical areas without regard to distance. Big Lake and other critical areas should be protected from further degradation caused by stormwater pollution.

For forty years I have spent my summers on the lake and watched the water quality deteriorate. We all should be stewards of our critical areas. The CA ordinances should reflect stewardship .

As more development occurs around Big Lake and other critical areas in Skagit County, it so very important to protect these areas. This is not about stopping development, it is about protecting critical areas.

Thank you,
Kimberly Sanford
Mailing address
PO BOX 839
Lyman, Wa 98263

Physical address:
[37938 Theo Lane](#)
[Concrete,WA](#)

23904 N Westview Rd
Mount Vernon , WA 98274

Robby Eckroth

From: Kim Sanford <kimsanford@msn.com>
Sent: Monday, July 28, 2025 2:50 PM
To: Commissioners
Cc: PDS comments
Subject: Commisioners Hearing on CAO Updates / Conflict of Interest

Dear Commissioner Wesen, Commissioner Brown and Commissioner Janicki ,

Given the importance of removal of expanding or removing the limited 200' critical area assessment, and the significance it would have for developers of large parcels around Big Lake and other critical areas, will Commissioner Janicki recuse herself as she did for the Overlook Crest LLC appeal, November 2024? Commissioner Janicki, her husband and family members own large parcels around Big Lake which are prime for future development. Regardless of the decision to change or not change the critical area ordinance creates a conflict of interest for commissioner Janicki.

Thank you,

Kimberly Sanford
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Physical address:
23904 N Westview Rd
Mount Vernon, 98274

Robby Eckroth

From: Marlene Finley <marlenefinley17@gmail.com>
Sent: Monday, July 28, 2025 3:04 PM
To: PDS comments
Cc: Kyle Loring (LoringAdvising); Evergreen Islands Board of Directors
Subject: Comments on 2nd Draft of the Update to Critical Areas Regulations - Evergreen Islands
Attachments: Evergrn Isls cmts on Skagit CAO July cmts-2.docx; ECY App 8-C Buffer Guidance (July 2018)-3.pdf

Please find the attached comments to the 2nd Draft of the Update to Critical Area Regulations, submitted by

Evergreen Islands
P.O. Box 223
Anacortes WA 98221

evergreen.islands@outlook.com

~ Marlene Finley
Board President

EVERGREEN

ISLANDS

To: Skagit County Board of County Commissioners and Planning and Development Services Staff

From: Evergreen Islands (evergreen.islands@outlook.com)

Date: July 18, 2025

Re: **Comments on 2nd Draft of Update to Critical Areas Regulations**

Evergreen Islands respectfully submits the following comments to address the changes that Skagit County staff and consultants have proposed to the Critical Areas regulations and to propose additional changes consistent with the Best Available Science (“BAS”). Evergreen Islands is a local, nonprofit organization that has worked to protect, preserve and defend the saltwater islands and environment of Skagit County for over 48 years.

As an initial matter, we want to take a moment to express our appreciation for the many proposed revisions that would improve the likelihood that the Critical Areas regulations will effectively protect critical areas. This second draft improves on the first draft, which improved on the existing critical areas text. We note many of those improvements below. However, significant additional revisions must be made for consistency with the BAS and to protect the functions and values of critical areas. These include protections for all wetlands, adoption of true Riparian Management Zones, eliminating timber harvests from buffers, applying all recommended criteria to buffer averaging, and ensuring that activities like docks avoid critical areas and bulkheads be constructed in them only as a last resort. The following sections identify the changes we support, changes we oppose, and additional changes we recommend.

A. Evergreen Islands Recommendations That Have Been Added.

We appreciate that the current draft reflects the following recommended changes:

14.24.130. Restoration of the 3:1 replacement ratio for removed hazard trees.

14.24.090(2)(b)(ii). Removal of text suggesting that some buffer edges might not be permanently marked.

14.24.140. The addition of text under the Reasonable Use Exception decision criteria requiring satisfaction of the eligibility criteria.

14.24.230(4). The removal of “uncovered decks” from the list of activities that can occur within the full extent of the setback.

14.24.530(1)(d). **FWHCA protection standards. Setback.** The removal of “uncovered decks” from the list of activities that can occur within the full extent of the setback.

B. Proposed Changes That Should Be Adopted.

14.24.010. Introduction. We support the clarity provided by the revisions to the introductory language.

14.24.040. Applicability, jurisdiction and coordination. We appreciate and support the addition of subsection (2), which clarifies which local rule applies in the event of a conflict.

14.24.070(11).Maintenance activities such as mowing and normal pruning. We support the insertion of a date to guide the application of this provision.

14.24.080(2). Distance for critical areas review. We support the change to 300 feet for the distance that must be considered when determining whether a proposal will impact critical areas, since this coincides with the potential buffer for the most sensitive wetlands.

14.24.230(4). Wetland protection standards. Setback. We support the proposal to include structural setbacks as a practical matter for home repairs, gutter cleaning, and other needs to use the land surrounding structures.

14.24.230(5). Wetland protection standards. Previously established buffer. We support steps to ensure that functions be improved in severely inadequate buffers.

14.24.240(1). Wetland protection standards. We support the buffer width increasing provision that has been proposed.

14.24.300. Critical Aquifer Recharge Areas. We support the language at SCC
14.24.300(1)(b), “Identify groundwater resources at risk and activities/uses that impact groundwater quality,” as well as the addition in (1)(c) of the words “protection” and “prevent,” and at (4)(d), “Maintain groundwater dependent flow in anadromous fish habitat.”

14.24.380. Seawater Intrusion Areas. We support the newly proposed language to protect existing well users in seawater intrusion areas, including the proposal that an application be

submitted prior to drilling a new well in a seawater intrusion protection area. Toward that end, we recommend the following revision to 14.24.380(3)(a) “Prior to drilling any new well in an area designated as a seawater intrusion protection area, an application must be submitted that includes...” In addition, we recommend that the County retain the pump test language so that proposed wells may be evaluated for impacts under standard use conditions.

C. Changes That Should Be Declined.

14.24.130. Hazard Tree Removal.

In addition, the authorization to cut trees “[t]o avoid a threat to human life or public safety,” must be defined to avoid the unintended arbitrary application of that provision. For example, it could be revised by adding the underlined, bold text below:

(e) To avoid a threat to human life or public safety. **A hazard tree threatens human life or public safety when it poses an imminent threat of falling in an area regularly and frequently used by members of the public, such as public roads and gathering spaces.**

14.24.230(7). Wetland Protection Standards. Exemptions from protection for Category IV wetlands below 4,000 sq. ft. and from buffers for all wetlands below 1,000 sq. ft. While we appreciate that the CAO update would exempt fewer wetlands, neither Growth Management Hearings Board decisions nor the Best Available Science (“BAS”) support the exemption of smaller wetlands. Evergreen Islands does not support the exemption from buffer requirements for all wetlands less than 1,000 square feet and the exemption of Category IV wetlands less than 4,000 square feet from mitigation sequencing to avoid impacts. Both exemptions are likely to cause a net loss and therefore, do not meet the requirement to achieve No Net Loss of Ecological Functions.

Further, Growth Board decisions have repeatedly recognized the importance of wetlands of all sizes in striking provisions that allow development of wetlands.¹ In Hood Canal, the Board rejected an exemption for even very small, truly isolated and poorly functioning wetlands where there was no evidence of the likely number of exempt wetlands, or of the potential cumulative impacts to those wetlands, adaptive management, or monitoring to assure no net loss.² Similarly, in Larson Beach Neighbors v. Stevens County, the Board held that exemptions for certain wetland sizes did not comply with the GMA in the absence of BAS showing that such

¹ *E.g., Hood Canal Envtl. Council, et al., v. Kitsap County*, CPSGMHB No. 06-3-0023c, FDO, 19-20 (Aug. 28, 2006).

² CPSGMHB No. 06-3-0012c, FDO, 19-20 (Aug. 28, 2006).

actions would protect their functions and values.³ And in Pilchuck, the Board held that the structure, value, and functions of CAs are inviolate and that a county's discretion to craft regulations that might result in some localized impacts or even loss should be "wielded sparingly and carefully for good cause" and that no circumstances would allow "the net loss of the structure, value and functions of such natural systems within a watershed or other functional catchment area."⁴

The exemption to develop smaller wetlands also conflicts with the BAS. The development of smaller wetlands would impact each of the four basic functions and values they perform: (1) water purification;⁵ (2) maintenance of hydrologic functions and soil stability;⁶ (3) providing habitat;⁷ and (4) landscape beautification. Development adversely impacts these functions by altering hydrology with impervious surfaces, removing vegetation, constructing ponds, grading, and disturbing soil. Wetlands also can lose their capacity to filter pollutants once overloaded.⁸

The BAS strongly supports protecting wetlands of all sizes, and emphasizes the importance of smaller wetlands. Ecology's wetlands guidance states that "[t]he scientific literature does not support exempting wetlands that are below a certain size."⁹ Earlier Ecology literature noted that "the loss of small wetlands is one of the most common cumulative impacts on wetlands and wildlife in Washington."

Consequently, paragraph 14.24.230(7) should be deleted in its entirety.

14.24.350. Instream Flow Rules. We continue to recommend against deleting the local flow-sensitive basins and groundwater withdrawal limits for the Skagit River Basin at SCC 14.24.350(1)(a). While the state regulations may address flows within the Stillaguamish and Nooksack basins, they do not address the instream flows at the fine scale needed for the Skagit River Basin. Instead, they address flows at only a handful of locations and thus fail to capture the necessary flows along scores of creeks that Skagit County currently identifies.

³ EWGMHB No. 03-1-0003, FDO at 20-22 (Feb. 10, 2004).

⁴ See CPSGMHB Case No. 95-3-0047, FDO, at 16.

⁵ Wash. Dept. of Ecology, *Wetlands in Washington State, Vol. 1: A Synthesis of the Science*, 2-29 – 2-31 (2005) (wetlands improve water quality by: (1) decreasing contaminant loads; (2) removing excess nutrients like nitrogen and phosphorous; (3) retaining or killing harmful bacteria and viruses; (4) maintaining stream temperature; and (5) filtering out and stabilizing fine sediments suspended) (hereafter "Wetlands Synthesis") (attached hereto as Exhibit H).

⁶ *Id.* (wetlands: (1) promote infiltration of runoff into aquifers; (2) decrease erosion in gullies and small channels; (3) store water; (4) help sustain summer flow in small streams; and (5) maintain elevated humidity in uplands.

⁷ *Id.*

⁸ *E.g.*, Wetlands Synthesis, at 2-39 (discussing phosphorous saturation).

⁹ ECY Guidance, at 8.

14.24.380(4)(a)(iv). Seawater Intrusion Areas. We recommend against deleting the pump test requirements for a new well in a potential seawater intrusion area unless the initial testing indicates that it suffers from seawater intrusion. A pump test is an essential element in ensuring that a new well can provide an adequate water supply to a property.

14.24.540(5)(g). Timber harvest in buffers. We continue to firmly oppose allowing Timber Harvest in Riparian Buffers. Consistent with the BAS, Evergreen Islands objects to allowing timber harvest within the standard buffer width (or riparian management zone). The proposed CAO continues to allow for removal of timber within the standard buffer width and this must be eliminated. The GAP analysis maintains that logging within the RMZs leads to a loss of ecological functions

D. Additional Recommended Changes.

14.24.150. Variances. For consistency with other variance criteria, we recommend the addition of the following criterion:

(3)(j) The granting of the variance will not confer on the applicant any special privilege that is denied by this chapter to other lands, buildings, or structures under similar circumstances.

14.24.230(c). Wetland Protection Standards. Vegetated buffer standards. The GAP analysis and BAS review do not provide a justification for the proposal to use “an average of 80% native cover” to impliedly define “densely vegetated.” The County should explain how it determined that 80% cover qualifies as densely vegetated, and whether that means 80% canopy cover or 80% ground cover. To the extent that it is intended to refer to canopy cover, then 80% would not qualify as densely-vegetated.

14.24.240. Wetland performance-based buffer alternatives and mitigation standards. The term “decreased” should be deleted from the first paragraph under this section, consistent with the proposed removal of the buffer reduction provisions.

14.24.240(2). Buffer Width Averaging. For consistency with the BAS, we recommend that the following Washington Department of Ecology criteria¹⁰ be added to the list:

¹⁰ Washington Department of Ecology, Appendix 8C Buffer Guidance (July 2018). The proposed buffer averaging language also finds its source in the Department of Ecology Guidance, but would be allowed only for Reasonable Use Exceptions. Since the County is proposing to allow buffer averaging more broadly, it should include the criteria recommended above.

(f) averaging will improve wetland protection;

(g) the buffer is increased adjacent to the higher functioning area of habitat or more sensitive portion of the wetland and decreased adjacent to the lower-functioning or less sensitive portion;

14.24.380. Seawater Intrusion Areas. We support denying wells if chloride levels in groundwater exceed a certain level and urge you to ensure that the limit you set is prudent and protects water quality.

14.24.500. Fish and Wildlife Habitat Conservation Areas 14.24.500. As an initial matter, we agree with the GAP analysis and strongly recommend that the County adopt a Riparian Management Zone approach to its Fish and Wildlife Habitat Conservation Area protections. The Washington Department of Fish and Wildlife has already proposed a method for doing so based on site potential tree height and submitted to the County a report identifying the substantial impacts to riparian functions and values that have been caused by the buffer approach.

14.24.530 (1)(c). FWHCA protection standards. Riparian Management Zones. Although the CAO text now refers to Riparian Management Zones (“RMZ”), it does not establish RMZs based on 1 Site Potential Tree Height, as recommended by the July 1, 2025 Best Available Science report from the Washington Department of Fish and Wildlife that found that a substantial amount of riparian functions have been lost in recent years, and are predicted to occur in the future, in the absence of an RMZ system. We recommend that it do so, which would also avoid applying different buffer widths to different riparian areas. As WDFW has noted, RMZs should apply to all streams because there is “no evidence that full riparian ecosystem functions along non-fish-bearing streams are less important to aquatic ecosystems than full riparian ecosystem functions along fish-bearing streams.”

14.24.530(1)(c)(i). As with the wetland text, the County should explain how it determined that 80% cover qualifies as “densely vegetated,” and whether that means 80% canopy cover or 80% ground cover. To the extent that it is intended to refer to canopy cover, then 80% would not qualify as densely-vegetated.

14.24.540(2). Buffer Width Averaging. For consistency with the BAS, we recommend the following additions shown in underline, consistent with Washington Department of Ecology criteria:¹¹

¹¹ Washington Department of Ecology, Appendix 8C Buffer Guidance (July 2018). The proposed buffer averaging language also finds its source in the Department of Ecology Guidance, but would be allowed only for Reasonable

(b) The habitat contains variations in sensitivity due to existing physical characteristics, and the buffer is increased adjacent to the area of more sensitive habitat and decreased adjacent to the less sensitive portion; and

(f) The buffer width will not be reduced below 75% of the standard buffer width, or 100 feet, whichever is greater; and

(h) Averaging will improve FWHCA protection.

14.24.540(5)(b). Allowed Uses in HCAs or Buffers. Docks. This section needs to be revised consistent with the proposed Shoreline Master Program and to ensure that docks do not extend within 25 horizontal feet of a FWHCA.

14.24.540(5)(c). Allowed Uses in HCAs or Buffers. Bulkheads. This section needs to be revised consistent with the proposed Shoreline Master Program to ensure that an applicant demonstrates a need for the bulkhead that they did not create, that the bulkhead will not adversely impact shoreline geological or ecological functions, and that the bulkhead construction follows the mitigation sequence.

14.24.540(5)(e). Allowed Uses in HCAs or Buffers. Low-impact uses. The County needs to provide a definition for low-impact uses and activities to ensure that the activities allowed do not impact the buffer function. Consistent with that goal, the standards need to ensure that activities like trails do not fully encircle a water body or fully separate a water body from the surrounding riparian zone.

Defensible Space for Wildland Fire Protection

The CAO update should add Performance Standards for vegetation management within buffers for the purpose of defensible space from wildland fire. The proposed draft update for the Comprehensive Plan includes wildland fire prevention goals and actions yet the draft CAO fails to incorporate the recommendation in the GAP analysis for maintaining ecological functions in buffers when defensible space around existing structures is necessary. "If vegetation management for defensible space is allowed, then performance standards must be developed to ensure that it does not result in a net loss of ecological function." (GAP analysis page 7) This is not a philosophical discussion but a real dilemma faced by landowners working to maintain

Use Exceptions. Since the County is proposing to allow buffer averaging more broadly, it should include the criteria recommended above.

wildfire protection zones around existing structures while providing functioning buffers adjacent to wetlands and within riparian management zones.

Geologically Hazardous Areas

We recommend that the CAO improve and add data and maps on Mine Hazards to supplement the reference at SCC 14.24.410(5). The GAP analysis recommends improving mapping and databases for mine hazards.

Thank you for the opportunity to comment and please do not hesitate to contact me if you have questions or need clarification. Evergreen Islands looks forward to your thoughtful consideration of our comments.

/s/ Marlene Finley

Marlene Finley, President

Evergreen Islands

PO Box 223

Anacortes WA 98221

Appendix 8-C

Guidance on Widths of Buffers and Ratios for Compensatory Mitigation for Use with the Western Washington Wetland Rating System

8C.1 Introduction

This appendix provides guidance on widths of buffers, ratios for compensatory mitigation, and other measures for protecting wetlands that are linked to the *Washington State Wetland Rating System for Western Washington: 2014 Update*, Department of Ecology Publication #14-06-029 (October 2014). Refer to Appendix 8-D for guidance for eastern Washington. Appendices 8-C through 8-F have been formatted similar to the main text of this volume (i.e., with a numbering system) to help with organization.

The tables below list the recommended widths of buffers for various alternatives, examples of measures to minimize impacts, and ratios for compensatory mitigation.

- **Table 8C-1.** Width of buffers needed to protect wetlands in western Washington if impacts from land use and wetland functions are NOT incorporated (Buffer Alternative 1). [Page 4]
- **Table 8C-2.** Width of buffers based on wetland category and modified by the intensity of the impacts from changes in proposed land use (Buffer Alternative 2). [Page 5]
- **Table 8C-3.** Types of land uses that can result in high, moderate, and low levels of impacts to adjacent wetlands (used in Buffer Alternatives 2 and 3). [Page 5]
- **Table 8C-4.** Width of buffers needed to protect Category IV wetlands in western Washington (Buffer Alternative 3). [Page 6]
- **Table 8C-5.** Width of buffers needed to protect Category III wetlands in western Washington (Buffer Alternative 3). [Page 6]
- **Table 8C-6.** Width of buffers needed to protect Category II wetlands in western Washington (Buffer Alternative 3). [Page 7]
- **Table 8C-7.** Width of buffers needed to protect Category I wetlands in western Washington (Buffer Alternative 3). [Page 8]
- **Table 8C-8.** Examples of measures to minimize impacts to wetlands from different types of activities. [Page 10]

July 2018 Modified Habitat Score Ranges

- **Table 8C-9.** Comparison of recommended buffer widths for high intensity land uses between Alternative 3 (step-wise scale) and Alternative 3A (graduated scale) based on score for habitat functions [Page 14].
- **Table 8C-10.** Comparison of recommended widths for buffers between Alternative 3 and Alternative 3A for proposed land uses with high impacts with mitigation for impacts. [Page 14]
- **Table 8C-11.** Mitigation ratios for projects in western Washington. [Page 20]

The guidance in this appendix can be used in developing regulations such as critical areas ordinances for protecting and managing the functions and values of wetlands. The recommendations are based on the analysis of the current scientific literature found in Volume 1. The detailed rationale for the recommendations is provided in Appendices 8-E and 8-F.

The recommendations on buffer widths and mitigation ratios are general, and there may be some wetlands for which these recommendations are either too restrictive or not protective enough. The recommendations are based on the assumption that a wetland will be protected only at the scale of the site itself. They do not reflect buffers and ratios that might result from regulations that are developed based on a larger landscape-scale approach.

8C.2 Widths of Buffers

Requiring buffers of a specific width has been one of the primary methods by which local jurisdictions in Washington have protected the functions and values of wetlands. Generally, buffers are the uplands adjacent to an aquatic resource that can, through various physical, chemical, and biological processes, reduce impacts to wetlands from adjacent land uses. The physical characteristics of buffers (e.g., slope, soils, vegetation, and width) determine how well buffers reduce the adverse impacts of human development. These characteristics are discussed in detail in Chapter 5, Volume 1.

In addition to reducing the impacts of adjacent land uses, buffers also protect and maintain a wide variety of functions and values provided by wetlands. For example, buffers can provide the terrestrial habitats needed by many species of wildlife that use wetlands to meet some of their needs.

The review of the scientific literature has shown, however, that buffers alone cannot adequately protect all functions that a wetland performs. Additional guidance is, therefore, provided on other ways in which wetlands can be managed and regulated to provide some of the necessary protection that buffers alone do not provide. The following guidance for protecting the functions and values of wetlands is based on their category as determined through the rating system for western Washington.

July 2018 Modified Habitat Score Ranges

Basic assumptions for using the guidance on widths for buffers

Recommendations for widths of buffers assume that:

- The wetland has been categorized using the *Washington State Wetland Rating System for Western Washington: 2014 Update*, Department of Ecology Publication #14-06-029, October 2014.
- The buffer is vegetated with native plant communities that are appropriate for the *ecoregion* or with a plant community that provides similar functions. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. The U.S. Environmental Protection Agency maintains updated maps of 7 ecoregions that are available at <http://www.epa.gov/naaujydh/pages/models/ecoregions.htm>. Ecoregions currently mapped for Washington are: Coast Range, Puget Lowland, Cascades, Eastern Cascades Slopes and Foothills, North Cascades, Columbia Plateau, Blue Mountains, and Northern Rockies.
- If the vegetation in the buffer is disturbed (grazed, mowed, etc.), proponents planning changes to land use that will increase impacts to wetlands need to rehabilitate the buffer with native plant communities that are appropriate for the ecoregion, or with a plant community that provides similar functions.
- The width of the buffer is measured along the horizontal plane (see drawing below):



- The buffer will remain relatively undisturbed in the future within the width specified.

Three alternatives for protecting the functions of wetlands using buffers are described in the following sections:

- **Buffer Alternative 1.** Width based only on wetland category.
- **Buffer Alternative 2.** Width based on wetland category and the intensity of impacts from proposed changes in land use.
- **Buffer Alternative 3.** Width based on wetland category, intensity of impacts, and wetland functions or special characteristics. This alternative has two options for determining the widths of buffers when they are based on the score for habitat. Alternative 3 provides three buffer widths based on habitat scores, while Alternative 3A provides a graduated scale of widths for buffers based on habitat scores.

The buffer widths recommended for each alternative were based on the review of scientific information in Volume 1. The guidance in this appendix synthesizes the information about the types and sizes of buffers needed to protect the functions and special characteristics of wetlands.

July 2018

Modified from Appendix 8-C: Guidance on Buffers and Ratios for Western Washington Wetlands in Washington State Volume 2 – Protecting and Managing Wetlands Ecology Publication No. 05-06-008

July 2018 Modified Habitat Score Ranges

Appendices 8-C and 8-D do not provide the metric equivalents for buffer widths even though most of the research on buffers uses the metric scale. This decision was made because most local governments use the English Customary measures. For example, a buffer width is set at 50 feet rather than 15 meters.

8C.2.1 Buffer Alternative 1: Width Based Only on Wetland Category

This alternative, in which the width of buffers is based only on the category of the wetland, is the simplest (Table 8C-1). The width recommended for each category of wetland in Alternative 1 is the widest recommended for that category in both Alternatives 2 and 3 (discussed below). Alternative 1 provides the least flexibility because many different types of wetlands and types of human impacts are combined. For example, not all wetlands that fall into Category I or II need a 300-foot buffer. If no distinctions are made between the wetlands that fall into Category I or II, all wetlands that fall into these categories have to be protected with a 300-foot buffer so adequate protection is provided for those wetlands that do need a buffer this wide. Also, the widths recommended for this alternative are those needed to protect the wetland from proposed land uses that have the greatest impacts since no distinctions between impacts are made.

Table 8C-1. Width of buffers needed to protect wetlands in western Washington if impacts from land use and wetland functions are NOT incorporated (Buffer Alternative 1).

Category of Wetland	Widths of Buffers
IV	50 ft
III	150 ft
II	300 ft
I	300 ft

8C.2.2 Buffer Alternative 2: Width Based on Wetland Category and Modified by the Intensity of the Impacts from Proposed Land Use

The second alternative increases the regulatory flexibility by including the concept that not all proposed changes in land uses have the same level of impact (Table 8C-2). For example, one new residence being built on 5 acres of land near a wetland is expected to have a smaller impact than 20 houses built on the same 5 acres. Three categories of impacts from proposed land uses are outlined: land uses that can create high impacts, moderate impacts, and low impacts to wetlands. Different land uses that can cause these levels of impacts are listed in Table 8C-3.

July 2018 Modified Habitat Score Ranges

Table 8C-2. Width of buffers needed to protect wetlands in western Washington considering impacts of proposed land uses (Buffer Alternative 2).

Category of Wetland	Land Use with Low Impact *	Land Use with Moderate Impact *	Land Use with High Impact*
IV	25 ft	40 ft	50 ft
III	75 ft	110 ft	150 ft
II	150 ft	225 ft	300 ft
I	150 ft	225 ft	300 ft

* See Table 8C-3 below for types of land uses that can result in low, moderate, and high impacts to wetlands.

Table 8C-3. Types of proposed land use that can result in high, moderate, and low levels of impacts to adjacent wetlands.

Level of Impact from Proposed Change in Land Use	Types of Land Use Based on Common Zoning Designations *
High	<ul style="list-style-type: none"> • Commercial • Urban • Industrial • Institutional • Retail sales • Residential (more than 1 unit/acre) • Conversion to high-intensity agriculture (dairies, nurseries, greenhouses, growing and harvesting crops requiring annual tilling and raising and maintaining animals, etc.) • High-intensity recreation (golf courses, ball fields, etc.) • Hobby farms
Moderate	<ul style="list-style-type: none"> • Residential (1 unit/acre or less) • Moderate-intensity open space (parks with biking, jogging, etc.) • Conversion to moderate-intensity agriculture (orchards, hay fields, etc.) • Paved trails • Building of logging roads • Utility corridor or right-of-way shared by several utilities and including access/maintenance road
Low	<ul style="list-style-type: none"> • Forestry (cutting of trees only) • Low-intensity open space (hiking, bird-watching, preservation of natural resources, etc.) • Unpaved trails • Utility corridor without a maintenance road and little or no vegetation management.

* Local governments are encouraged to create land-use designations for zoning that are consistent with these examples.

8C.2.3 Buffer Alternative 3: Width Based on Wetland Category, Intensity of Impacts, Wetland Functions, or Special Characteristics

The third alternative provides the most flexibility by basing the widths of buffers on three factors: the wetland category, the intensity of the impacts (as used in Alternative 2), and the functions or special characteristics of the wetland that need to be protected as determined through the rating system. The recommended widths for buffers are shown in Tables 8C-4 to 8C-7. Using this alternative, a wetland may fall into more than one category in the table. For example, an interdunal wetland may be rated a Category III wetland because it is an isolated interdunal wetland, but it may be rated a Category II wetland based on its score for functions.

If a wetland meets more than one of the characteristics listed in Tables 8C-4 to 8C-7, the buffer recommended to protect the wetland is the widest one. For example, if a Category I wetland (Table 8C-7) scores 8 points for habitat and 7 points for water quality functions, a 300-foot buffer is needed for land uses with high impacts because the widths needed to protect habitat are wider than those needed for the other functions.

Table 8C-4. Width of buffers needed to protect Category IV wetlands in western Washington (Buffer Alternative 3 for wetlands scoring less than 16 points for all functions).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use	Other Measures Recommended for Protection
Score for all 3 basic functions is less than 16 points	Low - 25 ft Moderate – 40 ft High – 50 ft	No recommendations at this time ¹

¹No information on other measures for protection was available at the time this document was written. The Washington State Department of Ecology will continue to collect new information for future updates to this document.

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Table 8C-5. Width of buffers needed to protect Category III wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 16 - 19 points for all functions).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use	Other Measures Recommended for Protection
Moderate level of function for habitat (score for habitat 6 - 7 points)* *If wetland scores 8-9 habitat points, use Table 8C-6 for Category II buffers	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time
Score for habitat 3-5 points	Low - 40 ft Moderate – 60 ft High – 80 ft	No recommendations at this time

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Table 8C-6. Width of buffers needed to protect Category II wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 20 - 22 points for all functions or having the “Special Characteristics” identified in the rating system).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use (Apply most protective if more than one criterion is met.)	Other Measures Recommended for Protection
High level of function for habitat (score for habitat 8 - 9 points)	Low - 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas
Moderate level of function for habitat (score for habitat 6 - 7 points)	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time ²
High level of function for water quality improvement and low for habitat (score for water quality 8 - 9 points; habitat less than 6 points)	Low - 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Estuarine	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time ²
Interdunal	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time ²
Not meeting above characteristics	Low - 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time ²

² See footnote on the previous page.

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Table 8C-7. Width of buffers needed to protect Category I wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 23 points or more for all functions or having the “Special Characteristics” identified in the rating system).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use (Apply most protective if more than one criterion is met)	Other Measures Recommended for Protection
Wetlands Of High Conservation Value	Low - 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries No septic systems within 300 ft of wetland Restore degraded parts of buffer
Bogs	Low - 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries Restore degraded parts of buffer
Forested	Buffer width to be based on score for habitat functions or water quality functions	If forested wetland scores high for habitat, need to maintain connections to other habitat areas Restore degraded parts of buffer
Estuarine	Low - 100 ft Moderate – 150 ft High – 200 ft	No recommendations at this time ³
Wetlands in Coastal Lagoons	Low - 100 ft Moderate – 150 ft High – 200 ft	No recommendations at this time ³
High level of function for habitat (score for habitat 8 - 9 points)	Low – 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas Restore degraded parts of buffer
Interdunal wetland with high level of function for habitat (score for habitat 8 - 9 points).	Low – 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas Restore degraded parts of buffer
Moderate level of function for habitat (score for habitat 6 - 7 points)	Low – 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time ³
High level of function for water quality improvement (8 – 9 points) and low for habitat (less than 6 points)	Low – 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Not meeting any of the above characteristics	Low – 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time ³

³ See footnote on page 6.

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8C.2.4 Special Conditions for a Possible Reduction in Buffer Widths

8C.2.4.1 Condition 1: Reduction in Buffer Width Based on Reducing the Intensity of Impacts from Proposed Land Uses

The buffer widths recommended for proposed land uses with high-intensity impacts to wetlands can be reduced to those recommended for moderate-intensity impacts under the following conditions:

- For wetlands that score moderate or high for habitat (6 points or more for the habitat functions), the width of the buffer can be reduced if both of the following criteria are met:
 - 1) A relatively undisturbed, vegetated corridor at least 100-feet wide is protected between the wetland and any other Priority Habitats as defined by the Washington State Department of Fish and Wildlife. The latest definitions of priority habitats and their locations are available on the WDFW web site at: <http://wdfw.wa.gov/hab/phshabs.htm>)

The corridor must be protected for the entire distance between the wetland and the Priority Habitat by some type of legal protection such as a conservation easement.

- 2) Measures to minimize the impacts of different land uses on wetlands, such as the examples summarized in Table 8C-8, are applied.
- For wetlands that score less than 6 points for habitat, the buffer width can be reduced to that required for moderate land-use impacts by applying measures to minimize the impacts of the proposed land uses (see examples in Table 8C-8).

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Table 8C-8. Examples of measures to minimize impacts to wetlands from proposed change in land use that have high impacts. (This is not a complete list of measures.)

Examples of Disturbance	Activities and Uses that Cause Disturbances	Examples of Measures to Minimize Impacts
Lights	<ul style="list-style-type: none"> • Parking lots • Warehouses • Manufacturing • Residential 	<ul style="list-style-type: none"> • Direct lights away from wetland
Noise	<ul style="list-style-type: none"> • Manufacturing • Residential 	<ul style="list-style-type: none"> • Locate activity that generates noise away from wetland
Toxic runoff*	<ul style="list-style-type: none"> • Parking lots • Roads • Manufacturing • Residential areas • Application of agricultural pesticides • Landscaping 	<ul style="list-style-type: none"> • Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft of wetland • Apply integrated pest management
Stormwater runoff	<ul style="list-style-type: none"> • Parking lots • Roads • Manufacturing • Residential areas • Commercial • Landscaping 	<ul style="list-style-type: none"> • Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized flow from lawns that directly enters the buffer
Change in water regime	<ul style="list-style-type: none"> • Impermeable surfaces • Lawns • Tilling 	<ul style="list-style-type: none"> • Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
Pets and human disturbance	<ul style="list-style-type: none"> • Residential areas 	<ul style="list-style-type: none"> • Use privacy fencing; plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the ecoregion; place wetland and its buffer in a separate tract
Dust	<ul style="list-style-type: none"> • Tilled fields 	<ul style="list-style-type: none"> • Use best management practices to control dust
<p>* These examples are not necessarily adequate for minimizing toxic runoff if threatened or endangered species are present at the site.</p>		

8C.2.4.2 Condition 2: Reductions in Buffer Widths Where Existing Roads or Structures Lie Within the Buffer

Where a legally established, non-conforming use of the buffer exists (e.g., a road or structure that lies within the width of buffer recommended for that wetland), proposed actions in the buffer may be permitted as long as they do not increase the degree of non-conformity. This means no increase in the impacts to the wetland from activities in the buffer.

For example, if a land use with high impacts (e.g., building an urban road) is being proposed next to a Category II wetland with a moderate level of function for habitat, a 150-foot buffer would be needed to protect functions (see Table 8C-6). If, however, an existing urban road is already present and only 50 feet from the edge of the Category II wetland, the additional 100 feet of buffer may not be needed if the road is being widened. A vegetated buffer on the other side of the road would not help buffer the existing impacts to the wetland from the road. If the existing road is resurfaced or widened (e.g., to add a sidewalk) along the upland edge, without any further roadside development that would increase the degree of non-conformity, the additional buffer is not necessary. The associated increase in impervious surface from widening a road, however, may necessitate mitigation for impacts from stormwater.

If, however, the proposal is to build a new development (e.g., shopping center) along the upland side of the road, the impacts to the wetland and its functions may increase. This would increase the degree of non-conformity. The project proponent would need to provide the additional 100 feet of buffer extending beyond the road or apply buffer averaging (see Section 8C.2.6).

8C.2.4.3 Condition 3: Reduction in Buffer Widths Through an Individual Rural Stewardship Plan

A Rural Stewardship Plan (RSP) is the product of a collaborative effort between rural property owners and a local government to tailor a management plan specific for a rural parcel of land. The goal of the RSP is better management of wetlands than what would be achieved through strict adherence to regulations. In exchange, the landowner gains flexibility in the widths of buffers required, in clearing limits, and in other requirements found in the regulations. For example, dense development in rural residential areas can be treated as having a low level of impact when the development of the site is managed through a locally approved RSP. The voluntary agreement includes provisions for restoration, maintenance, and long-term monitoring and specifies the widths of buffers needed to protect each wetland within the RSP.

8C.2.5 Conditions for Increasing the Width of, or Enhancing, the Buffer

8C.2.5.1 Condition 1: Buffer is Not Vegetated with Plants Appropriate for the Region

The recommended widths for buffers are based on the assumption that the buffer is vegetated with a native plant community appropriate for the ecoregion or with one that performs similar functions. If the existing buffer is unvegetated, sparsely vegetated, or vegetated with invasive species that do not perform needed functions, the buffer should either be planted to create the appropriate plant community or the buffer should be widened to ensure that adequate functions of the buffer are provided. Generally, improving the vegetation will be more effective than widening the buffer.

8C.2.5.2 Condition 2: Buffer Has a Steep Slope

The review of the literature (Volume 1) indicates that the effectiveness of buffers at removing pollutants before they enter a wetland decreases as the slope increases. If a buffer is to be based on the score for its ability to improve water quality (see Tables 8C-4 through 8C-7) rather than habitat or other criteria, then the buffer should be increased by 50% if the slope is greater than 30% (a 3-foot rise for every 10 feet of horizontal distance).

8C.2.5.3 Condition 3: Buffer Is Used by Species Sensitive to Disturbance

If the wetland provides habitat for a species that is particularly sensitive to disturbance (such as a threatened or endangered species), the width of the buffer should be increased to provide adequate protection for the species based on its particular, life-history needs. Some buffer requirements for priority species are available on the Washington State Department of Fish and Wildlife web page (<http://wdfw.wa.gov/hab/phsrecs.htm>). The list of priority species for vertebrates is at <http://wdfw.wa.gov/hab/phsvert.htm>; for invertebrates it is at <http://wdfw.wa.gov/hab/phsinvrt.htm>. Information on the buffer widths needed by some threatened, endangered, and sensitive species of wildlife is provided in Appendix 8-H.

8C.2.6 Buffer Averaging

The widths of buffers may be averaged if this will improve the protection of wetland functions, or if it is the only way to allow for reasonable use of a parcel. There is no scientific information available to determine if averaging the widths of buffers actually protects functions of wetlands. The authors have concluded that averaging could be allowed in the following situations:

Averaging may not be used in conjunction with any of the other provisions for reductions in buffers (listed above).

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- Averaging to **improve wetland protection** may be permitted when **all** of the following conditions are met:
 - The wetland has significant differences in characteristics that affect its habitat functions, such as a wetland with a forested component adjacent to a degraded emergent component or a “dual-rated” wetland with a Category I area adjacent to a lower rated area
 - The buffer is increased adjacent to the higher-functioning area of habitat or more sensitive portion of the wetland and decreased adjacent to the lower-functioning or less sensitive portion
 - The total area of the buffer after averaging is equal to the area required without averaging
 - The buffer at its narrowest point is never less than 3/4 of the required width
- Averaging to **allow reasonable use** of a parcel may be permitted when **all** of the following are met:
 - There are no feasible alternatives to the site design that could be accomplished without buffer averaging
 - The averaged buffer will not result in degradation of the wetland’s functions and values as demonstrated by a report from a qualified wetland professional (see Appendix 8-G for a definition of a qualified wetland professional)
 - The total buffer area after averaging is equal to the area required without averaging
 - The buffer at its narrowest point is never less than 3/4 of the required width

8C.2.7 Modifying Buffer Widths in Alternative 3 Using a Graduated Scale for the Habitat Functions (Alternative 3A)

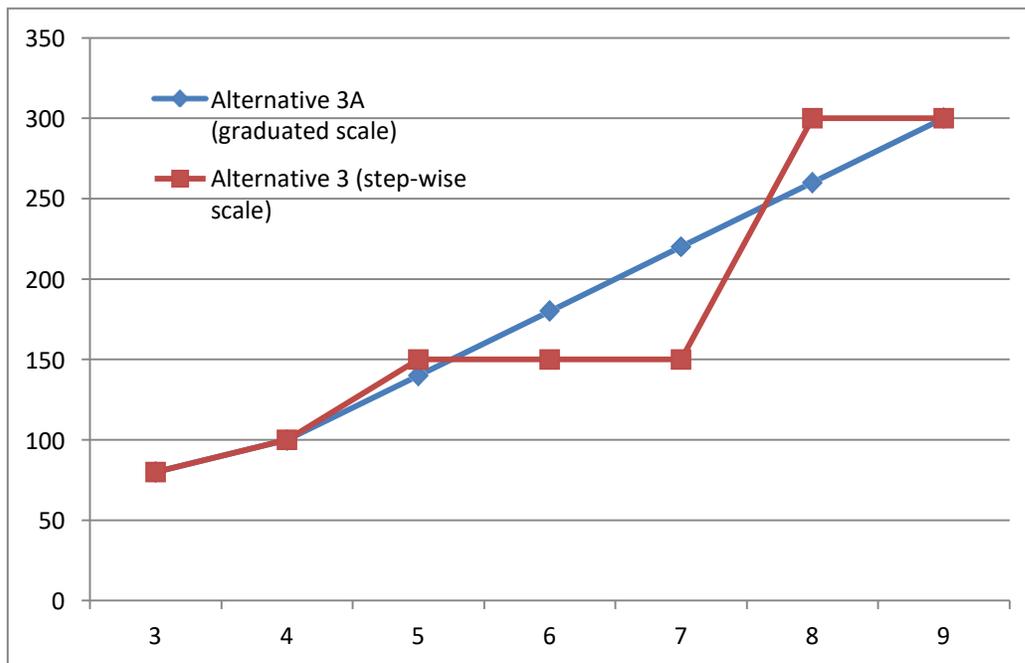
Alternative 3 contains recommendations for protecting the habitat functions of wetlands using only three groupings of scores (3-4, 5-7, 8-9). As a result, a one-point difference between 4 and 5 and between 7 and 8 can result in a 50-foot increase in the width of a buffer around a wetland. The habitat scores were divided into three groups to simplify the regulations based on this guidance.

Such a large increase in width with a one-point increase in the habitat score may be contentious. A jurisdiction may wish to reduce the increments in the widths for buffers by developing a more graduated (but inherently more complicated) scale based on the scores for habitat. Table 8C-9 provides one example of a graduated scale for widths of buffers where the width increases for every one point increase in the habitat score.

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Table 8C-9. Comparison of widths for buffers in Alternatives 3 (step-wise scale) and 3A (graduated scale) for proposed land uses with high impacts based on the score for habitat functions in western Washington

Points for Habitat from Wetland Rating Form	3	4	5	6	7	8	9
Alternative 3	80	100	150	150	150	300	300
Alternative 3A	80	100	140	180	220	260	300



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Other scales are possible as long as they keep within the limits established from the scientific information currently available: wetlands with scores for habitat that are higher than 7 points need buffers that are at least 300 feet wide; wetlands with a score of 5-7 points need buffers of at least 150 feet; and wetlands with a score 3-4 points need buffers that are at least 80 feet wide.

These buffer widths can be further reduced by 25 percent if a proposed project with high impacts implements the mitigation measures such as those described in Table 8C-8. The measures are part of “Condition 1” in Section 8C.2.4 (Special Conditions for a Possible Reduction in Buffer Widths). The buffer widths under Buffer Alternatives 3 and 3A, and the corresponding 25 percent reduction (per buffer reduction condition 1) are shown in Table 8C-10.

Table 8C-10. Comparison of widths for buffers in Alternatives 3 (step-wise scale) and 3A (graduated scale) for proposed land uses with high impacts based on the score for habitat functions in western Washington if the impacts are mitigated.

Points for Habitat from Wetland Rating Form	3	4	5	6	7	8	9
Alternative 3 (with impact-reducing measures)	60	75	110	110	110	225	225
Alternative 3A (with impact-reducing measures)	60	75	105	135	165	195	225

Alternatives 3 and 3A represent two separate approaches for determining widths of buffers for wetlands scoring between 5 and 8 points for the habitat functions. Local governments should select one of the two approaches and should not hybridize the approaches or adopt both at the same time.

8C.3 Ratios for Compensatory Mitigation

When the acreage required for compensatory mitigation is divided by the acreage of impact, the result is a number known variously as a *replacement*, *compensation*, or *mitigation* ratio. Compensatory mitigation ratios are used to help ensure that compensatory mitigation actions are adequate to offset unavoidable wetland impacts by requiring a greater amount of mitigation area than the area of impact. Requiring greater mitigation area helps compensate for the risk that a mitigation action will fail and for the time lag that occurs between the wetland impact and achieving a fully functioning mitigation site.

8C.3.1 Definitions of Types of Compensatory Mitigation

The ratios presented are based on the type of compensatory mitigation proposed (e.g., restoration, creation, and enhancement). In its *Regulatory Guidance Letter 02-02*, the U.S. Army Corps of Engineers provided definitions for these types of compensatory mitigation. For consistency, the authors of this document use the same definitions which are provided below.

Restoration: The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former or degraded wetland. For the purpose of tracking net gains in wetland acres, restoration is divided into:

- **Re-establishment.** The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a **former** wetland. Re-establishment results in a gain in wetland acres (and functions). Activities could include removing fill material, plugging ditches, or breaking drain tiles.
- **Rehabilitation.** The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural or historic functions of a **degraded** wetland. Rehabilitation results in a gain in wetland function but does not result in a gain in wetland acres. Activities could involve breaching a dike to reconnect wetlands to a floodplain or return tidal influence to a wetland.

Creation (Establishment): The manipulation of the physical, chemical, or biological characteristics present to develop a wetland on an upland or deepwater site where a wetland did not previously exist. Establishment results in a gain in wetland acres. Activities typically involve excavation of upland soils to elevations that will produce a wetland hydroperiod, create hydric soils, and support the growth of hydrophytic plant species.

Enhancement: The manipulation of the physical, chemical, or biological characteristics of a wetland site to heighten, intensify, or improve specific function(s) or to change the growth stage or composition of the vegetation present. Enhancement is undertaken for specified purposes such as water quality improvement, flood water retention, or wildlife

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habitat. Enhancement results in a change in some wetland functions and can lead to a decline in other wetland functions, but does not result in a gain in wetland acres. Activities typically consist of planting vegetation, controlling non-native or invasive species, modifying site elevations or the proportion of open water to influence hydroperiods, or some combination of these activities.

Protection/Maintenance (Preservation): Removing a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland. This includes the purchase of land or easements, repairing water control structures or fences, or structural protection such as repairing a barrier island. This term also includes activities commonly associated with the term *preservation*. Preservation does not result in a gain of wetland acres, may result in a gain in functions, and will be used only in exceptional circumstances.

Distinction between rehabilitation and enhancement

The distinction between rehabilitation and enhancement as defined above is not clear-cut and can be hard to understand. Actions that rehabilitate or enhance wetlands span a continuum of activities that cannot be defined by specific criteria.

Rehabilitation ←————→ *Enhancement*

In general, rehabilitation involves actions that are more sustainable and that reinstate environmental processes, both at the site and landscape scale (e.g., reinstating hydrologic processes in a diked floodplain by breaching the dikes). Rehabilitation actions often focus on restoring environmental processes that have been disturbed or altered by previous or ongoing, human activity. Ecology further defines *rehabilitation* as:

- Actions that restore the original hydrogeomorphic (HGM) class, or subclass, to a wetland whose current HGM class, or subclass, has been changed by human activities
- Actions that restore the water regime that was present and maintained the wetland before human activities changed it

Any other actions taken in existing wetlands would be considered *enhancement*. Enhancement typically involves actions that provide gains in only one or a few functions and can lead to a decline in other functions. Enhancement actions often focus on structural or superficial improvements to a site and generally do not address larger-scale environmental processes.

For example, a wetland that was once a forested, riverine wetland was changed to a depressional, emergent wetland by the construction of a dike and through grazing. Rehabilitating the wetland would involve breaching the dike so the wetland becomes a riverine wetland again, discontinuing the grazing, and reforesting the area. Discontinuing the grazing and reforesting the wetland without re-establishing the links to the riverine system would be considered enhancement.

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Basic assumptions for using the guidance on ratios

- The ratios are for a compensatory mitigation project that is concurrent with impacts to wetlands. If impacts are to be mitigated by using an approved and established mitigation bank, the rules and ratios applicable to the bank should be used.
- The ratios are based on the assumption that the category (based on the rating system for western Washington) and hydrogeomorphic (HGM) class or subclass of the wetland proposed as compensation are the same as the category and HGM class or subclass of the affected wetland (e.g., impacts to a Category II riverine wetland are compensated by creating, restoring, or enhancing a Category II riverine wetland).
- Ratios for projects in which the category and HGM class or subclass of wetlands proposed as compensation is not the same as that of the wetland affected will be determined on a case-by-case basis using the recommended ratios as a starting point. The ratios could be higher in such cases.
- The ratio for using rehabilitation as compensation is 2 times that for using re-establishment or creation (R/C) (2 acres of rehabilitation are equivalent to 1 acre of R/C). The ratio for using enhancement as compensation is 4 times that for using R/C (4 acres of enhancement are equivalent to 1 acre of R/C).
- Re-establishment or creation can be used in combination with rehabilitation or enhancement. For example, 1 acre of impact to a Category III wetland would require 2 acres of R/C. If an applicant provides 1 acre of R/C (i.e., replacing the lost acreage at a 1:1 ratio), the remaining 1 acre of R/C necessary to compensate for the impact could be substituted with 2 acres of rehabilitation or 4 acres of enhancement.
- Generally the use of enhancement alone as compensation is discouraged. Using enhancement in combination with the replacement of wetland area at a minimum of 1:1 through re-establishment or creation is preferred.

These ratios were developed to provide a starting point for further discussions with each proponent of compensatory mitigation. They are based on the observations of the success and risk of compensatory mitigation, as reviewed in Volume 1, and do not represent the specific risk or opportunities of any individual project.

As noted above, the ratios for compensatory mitigation are based on the assumption that the category and hydrogeomorphic (HGM) class or subclass of the affected wetland and the mitigation wetland are the same. The ratios may be adjusted either up or down if the category or HGM class or subclass of the wetland proposed for compensation is different. For example, ratios may be lower if impacts to a Category IV wetland are to be mitigated by creating a Category II wetland. The same is true for impacts to wetlands that currently would be considered *atypical* (see definition below).

Also, compensatory mitigation should not result in the creation, restoration, or enhancement of an atypical wetland. An atypical wetland is defined as a wetland whose

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design does not match the type of wetland that would be found in the geomorphic setting of the proposed site (i.e., the water source(s) and hydroperiod proposed for the mitigation site are not typical for the geomorphic setting). In addition, any designs that provide exaggerated morphology or require a berm or other engineered structures to hold back water would be considered atypical. For example, excavating a permanently inundated pond in an existing seasonally saturated or inundated wetland is one example of an enhancement project that could result in an atypical wetland. Another example would be excavating depressions in an existing wetland on a slope that required the construction of berms to impound water.

On a case-by-case basis, it is possible to use the scores from the Washington State wetland rating system to compare functions between the mitigation wetland and the impacted wetland. This information may also be used to adjust replacement ratios. Scores from the methods for assessing wetland functions (Hruby et al. 1999) provide another option to establish whether the functions lost will be replaced if both the affected wetland and the wetland used for compensation are of the same HGM class and subclass.

Mitigation ratios for projects in western Washington are shown in Table 8C-11. Refer to the text box on the basic assumptions on the previous page before reading the table. As mentioned previously, these ratios were developed to provide a starting point for further discussions with each proponent of compensatory mitigation. They only factor in the observations of mitigation success and risk at a programmatic level, and do not represent the specific risk or opportunity of any individual project.

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Table 8C-11. Mitigation ratios for projects in western Washington.

Category and Type of Wetland Impacts	Re-establishment or Creation	Rehabilitation Only ⁴	Re-establishment or Creation (R/C) and Rehabilitation (RH) ⁴	Re-establishment or Creation (R/C) and Enhancement (E) ⁴	Enhancement Only ⁴
All Category IV	1.5:1	3:1	1:1 R/C and 1:1RH	1:1 R/C and 2:1 E	6:1
All Category III	2:1	4:1	1:1 R/C and 2:1 RH	1:1 R/C and 4:1 E	8:1
Category II Estuarine	Case-by-case	4:1 Rehabilitation of an estuarine	Case-by-case	Case-by-case	Case-by-case
Category II Interdunal	2:1 Compensation has to be interdunal wetland	4:1 Compensation has to be interdunal wetland	1:1 R/C and 2:1 RH Compensation has to be interdunal wetland	Not considered an option ⁵	Not considered an option ⁵
All other Category II	3:1	6:1	1:1 R/C and 4:1 RH	1:1 R/C and 8:1 E	12:1
Category I Forested	6:1	12:1	1:1 R/C and 10:1 RH	1:1 R/C and 20:1 E	24:1
Category I based on score for functions	4:1	8:1	1:1 R/C and 6:1 RH	1:1 R/C and 12:1 E	16:1
Category I Natural Heritage site	Not considered possible ⁶	6:1 Rehabilitation of a Natural Heritage site	R/C Not considered possible ⁶	R/C Not considered possible ⁶	Case-by-case
Category I Coastal Lagoon	Not considered possible ⁶	6:1 Rehabilitation of a coastal lagoon	R/C not considered possible ⁶	R/C not considered possible ⁶	Case-by-case
Category I Bog	Not considered possible ⁶	6:1 Rehabilitation of a bog	R/C Not considered possible ⁶	R/C Not considered possible ⁶	Case-by-case
Category I Estuarine	Case-by-case	6:1 Rehabilitation of an estuarine	Case-by-case	Case-by-case	Case-by-case

NOTE: Preservation is discussed in the following section.

⁴ These ratios are based on the assumption that the rehabilitation or enhancement actions implemented represent the average degree of improvement possible for the site. Proposals to implement more effective rehabilitation or enhancement actions may result in a lower ratio, while less effective actions may result in a higher ratio. The distinction between rehabilitation and enhancement is not clear-cut. Instead, rehabilitation and enhancement actions span a continuum. Proposals that fall within the gray area between rehabilitation and enhancement will result in a ratio that lies between the ratios for rehabilitation and the ratios for enhancement.

⁵ Due to the dynamic nature of interdunal systems, enhancement is not considered an ecologically appropriate action.

⁶ Natural Heritage sites, coastal lagoons, and bogs are considered irreplaceable wetlands because they perform some special functions that cannot be replaced through compensatory mitigation. Impacts to such wetlands would therefore result in a net loss of some functions no matter what kind of compensation is proposed.

8C.3.2 Conditions for Increasing or Reducing Replacement Ratios

Increases in replacement ratios are appropriate under the following circumstances:

- Success of the proposed restoration or creation is uncertain
- A long time will elapse between impact and establishment of wetland functions at the mitigation site
- Proposed mitigation will result in a lower category wetland or reduced functions relative to the wetland being impacted
- The impact was unauthorized

Reductions in replacement ratios are appropriate under the following circumstances:

- Documentation by a qualified wetland specialist (see Appendix 8-H) demonstrates that the proposed mitigation actions have a very high likelihood of success based on prior experience
- Documentation by a qualified wetland specialist demonstrates that the proposed actions for compensation will provide functions and values that are significantly greater than the wetland being affected
- The proposed actions for compensation are conducted in advance of the impact and are shown to be successful
- In wetlands where several HGM classes are found within one delineated boundary, the areas of the wetlands within each HGM class can be scored and rated separately and the ratios adjusted accordingly, if **all of the following** apply:
 - The wetland does not meet any of the criteria for wetlands with “Special Characteristics” as defined in the rating system
 - The rating and score for the entire wetland is provided along with the scores and ratings for each area with a different HGM class.
 - Impacts to the wetland are all within an area that has a different HGM class from the one used to establish the initial category
 - The proponents provide adequate hydrologic and geomorphic data to establish that the boundary between HGM classes lies at least 50 feet outside of the footprint of the impacts

8C.3.3 Replacement Ratios for Preservation

In some cases, preservation of existing wetlands may be acceptable as compensation for wetland losses. Acceptable sites for preservation include those that:

- Are important due to their landscape position
- Are rare or limited wetland types
- Provide high levels of functions

Ratios for preservation in combination with other forms of mitigation generally range from 10:1 to 20:1, as determined on a case-by-case basis, depending on the quality of the wetlands being impacted and the quality of the wetlands being preserved. Ratios for preservation as the sole means of mitigation generally start at 20:1. Specific ratios will depend upon the significance of the preservation project and the quality of the wetland resources lost.

See Chapter 8 (Section 8.3.7.2) and Appendix 8-B for more information on preservation and the criteria for its use as compensation.

8C.3.4 Replacement Ratios for Temporal Impacts and Conversions

When impacts to wetlands are not permanent, local governments often require some compensation for the temporal loss of wetland functions. *Temporal impacts* refer to impacts to those functions that will eventually be replaced but cannot achieve similar functionality in a short time. For example, clearing forested wetland vegetation for pipeline construction could result in the temporal loss of functions, such as song bird habitat provided by the tree canopy. It may take over 20 years to re-establish the level of function lost as a result of clearing the trees. Although the wetlands will be re-vegetated and over time it is anticipated that their previous level of functioning will be re-established, a temporal loss of functions will occur. There is also some risk of failure associated with the impacts or alterations, especially when soil is compacted by equipment, deep excavation is required, and pipeline trenches alter the water regime at the site.

Therefore, in addition to restoring the affected wetland to its previous condition, local governments should consider requiring compensation to account for the risk and temporal loss of wetland functions. Generally, the ratios for temporal impacts to forested and scrub-shrub wetlands are one-quarter of the recommended ratios for permanent impacts (refer to Table 8C-11), provided that the following measures are satisfied:

- An explanation of how hydric soil, especially deep organic soil, is stored and handled in the areas where the soil profile will be severely disturbed for a fairly significant depth or time

July 2018 Modified Habitat Score Ranges

- Surface and groundwater flow patterns are maintained or can be restored immediately following construction
- A 10-year monitoring and maintenance plan is developed and implemented for the restored forest and scrub-shrub wetlands
- Disturbed buffers are re-vegetated and monitored
- Where appropriate, the hydroseed mix to be applied on re-establishment areas is identified

When impacts are to a native emergent community and there is a potential risk that its re-establishment will be unsuccessful, compensation for temporal loss and the potential risk should be required in addition to restoring the affected wetland and monitoring the site. If the impacts are to wetlands dominated by non-native vegetation (e.g., blackberry, reed canarygrass, or pasture grasses), restoration of the affected wetland with native species and monitoring after construction is generally all that is required.

Loss of functions due to the permanent conversion of wetlands from one type to another also requires compensation. When wetlands are not completely lost but are converted to another type, such as a forested wetland converted to an emergent or shrub wetland (e.g., for a utility right-of-way), some functions are lost or reduced.

The ratios for conversion of wetlands from one type to another will vary based on the degree of the alteration, but they are generally one-half of the recommended ratios for permanent impacts (refer to Table 8C-11).

Refer to Appendix 8-F for the rationale for the ratios provided in this appendix.

Specific guidance has been developed for conversions of wetlands to cranberry bogs. Please refer to the 1998 *Guidelines for Implementation of Compensatory Mitigation Requirements for Conversion of Wetlands to Cranberry Bogs* for information on ratios associated with this activity (Washington State Department of Ecology, U.S. Environmental Protection Agency Region 10, U.S. Army Corps of Engineers Seattle District, and U.S. Fish and Wildlife Service. 1998. Special Public Notice: <http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/ACF101C.pdf>).

Robby Eckroth

From: Jake Koopmans <jakekoopmansbl@gmail.com>
Sent: Monday, July 28, 2025 3:35 PM
To: Commissioners; PDS comments
Subject: Koopmans Written and Presented Comments to Commissioners Critical Areas Ordinance Public Hearing 7-28-2025
Attachments: Koopmans Written and Presented Comments to Commissioners Critical Areas Ordinance Public Hearing 7-28-2025.pdf

Hello Team,

I attach my combined written and presented comments to the Commissioners Critical Areas Ordinance Public Hearing on July 28, 2025. Please let me know if you have any questions.

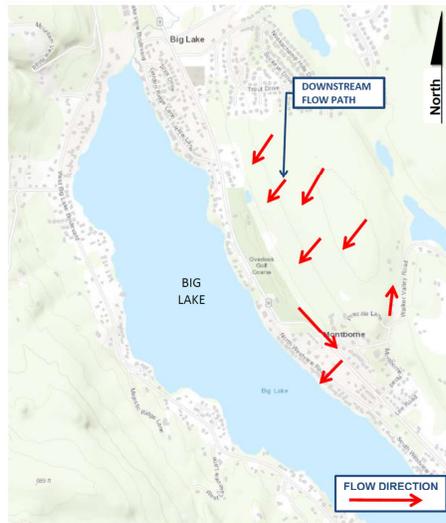
Thanks,
Jake Koopmans
360-391-4146

COA Comments for Commissioners Public Hearing

Jake Koopmans
23904 N West View Rd Mount Vernon WA

July 28, 2025

**For Example: 4 SEPA Reviews over 16 Years – NO CRITICAL AREA ASSESSMENTS
2024 Approval would have piped to Big Lake untreated polluted stormwater from
18+ acres new impervious area**



No LID BMPs
**Runoff going in one
big pipe to Big Lake.**

**By: Wa State
Certified P.E. to
comply with 2019
Stormwater
Manual.**

**BUT, water doesn't stop
at 200 feet downhill.**



Here is an example of an active project that was approved under the 200' critical areas assessment but never considered impacts on Big Lake because Big Lake was more than 200' away. No Critical Areas Assessment to capture Big Lake impacts.

Approved without low impact development (LID) to mitigate for future stormwater discharges

STORMWATER CODE DOES NOT ASSURE PROTECTION OF CRITICAL AREAS



PCA Tract 2 receiving sediment-laden water with sheen visible from Overlook Crest detention pond



Big Lake Outfall receiving sediment-laden water from Overlook Crest

From 'upgraded' stormwater ponds to PCA wetlands to ditches to pipes to Big Lake

"Prepared in full compliance 2019 stormwater manual"

By: Wa State Certified P.E.

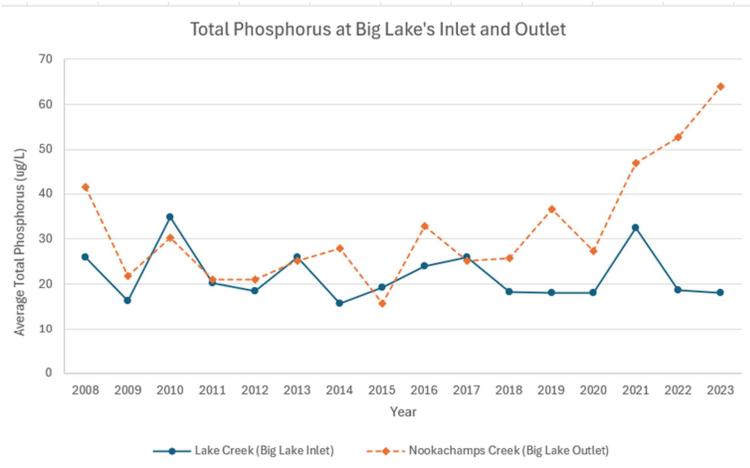
Photo taken on February 1, 2025

Note: 2025 Revisions to Land Division and Engineering. Pipe replaced with on-site dispersion and treatment. Approved by Planning with NO opportunity for public scrutiny or participation. Under appeal.

As of February 2025, this is the current quality of the water discharge to Big Lake...
Sediment Laden Water!

Looking forward, we got lucky on this development because of a GMA settlement where from these specific parcels, there would be no pollution or degradation to Big Lake. Strange that this pollution was allowed to happen, but regardless no future project within the Big Lake basin will be held to this standard unless the limited 200' critical area is expanded.

BIG LAKE CASE STUDY– Total Phosphorus 1999 - 2023



Water Quality Criteria: 20 ug/l

1999: 18.7 ug/l (Ecology)

2023: 65 ug/l annual average
(Skagit Monitoring)

Chart from Skagit Water
Quality Monitoring.

Blue line measured at inlet.

Orange line measured at outlet.

Total Phosphorus data collected and provided by Public Works. The quality of water discharging from the lake has continued to degrade.

The beginning of our 2025 annual algae bloom has visibility started this weekend!

Phosphorus comes to our lake from nutrient loading within the stormwater. The Current SCC 14.24 and proposed changes within in conjunction with Stormwater Manual are not protecting Big Lake from pollutant loaded stormwater runoff. Where is the enforcement to help combat this? Receiving critical area water bodies need to require impacts assessment.

Robby Eckroth

From: Alison Studley <astudley@skagitfisheries.org>
Sent: Monday, July 28, 2025 3:43 PM
To: PDS comments
Subject: CAO update Comments

To Skagit County Planning department

The Skagit Fisheries Enhancement Group (SFEG) is submitting comments related to the draft updates to Skagit County's Critical Areas Ordinance specifically section 14.24.070.

This section indicates a list of activities that can take place in critical areas and are "allowed without standard review".

Only one activity of the long list of activities that are "allowed without standard review" requires "Director Notification" and that activity is "Nature Enhancement". It makes no sense that the only activity on this list that is "enhancing or improving" critical areas requires Director Notification, when the entire purpose of the Skagit County CAO is to ensure Skagit County's critical areas are adequately protected to ensure functioning critical areas.

While "Nature Enhancement" activities are improving critical areas and require "Director Notification" to occur, no "Director notification" is required for any other "activity allowed without standard review" including the following:

- Landscaping (such as mowing);
- ongoing agricultural activities;
- maintenance of existing structures, utilities, water systems, drainage facilities, retention ponds and public and private driveways;
- modification of an existing single family residence that does not change footprint;
- maintenance of existing public and private diking operations;
- existing irrigation activities

It does not make sense to require an additional "Director Notification" step to participate in activities that "Enhance Nature" in critical areas. This step to Notify the Director, seems especially unnecessary given that many of the other activities allowed in critical areas "without standard review" could potentially result in harm to critical areas while "nature enhancement" activities will improve critical areas. This Director Notification will increase costs and cause possible delays for important riparian projects to occur. The County is a valued partner in riparian enhancement projects with many organizations throughout Skagit County. We ask that the County remove the "Director Notification" step for "Nature Enhancement" activities cited as "not requiring standard review" as part of section 14.24.070.

Thank you

Alison Studley

Executive Director

Skagit Fisheries Enhancement Group

PO Box 2497, Mount Vernon, WA 98273

Office 360-336-0172 ext 300

Cell 360-708-1573

Email astudley@skagitfisheries.org

[Website](#) **[Facebook](#)** **[Volunteer](#)** **[Donate](#)**

Skagit Fisheries Enhancement Group is a 501c3 nonprofit organization

Robby Eckroth

From: Kim Matthews <kmatthews@westag.org>
Sent: Monday, July 28, 2025 3:52 PM
To: PDS comments
Subject: Skagit County 2025 Critical Areas Ordinance Update
Attachments: 2025_7.28 WWAA Comments on CAO Updates_Final.pdf

Thank you for the opportunity to submit our comments, which are included below and in the attached signed copy. We hope these suggestions will support the Critical Areas Ordinance (CAO) update in protecting both our farmland and natural resources, while also ensuring that regulations do not create undue challenges for our agricultural producers. Thoughtful consideration in this process is essential to maintain the viability of local farming as without it, working lands could face greater pressure to convert to non-agricultural uses - a trend we have already seen elsewhere along the I-5 corridor.

In appreciation and gratitude,

Kim Matthews – WWAA Executive Director

July 28th, 2025

Skagit County Planning & Development Services
 1800 Continental Place
 Mount Vernon, WA 98273

RE: Comments on Skagit County's 2025 Draft Comprehensive Plan Update – Critical Areas Ordinance

Dear Skagit County Planning & Development Services,

On behalf of the Western Washington Agricultural Association (WWAA), thank you for the opportunity to provide comments on the draft update to Skagit County's Critical Areas Ordinance (CAO).

Agriculture is a cornerstone of Skagit County's economy, heritage, and landscape. WWAA supports the protection of natural resources in tandem with preserving the viability of working farmland and the critical infrastructure - such as drainage, diking, and irrigation systems - that sustains it.

Below we express specific concerns and include recommended code revisions.

Against the Adoption of Riparian Management Zones instead of Riparian Buffers.

WWAA recommends that only the term *riparian buffer* be used, and that the term *riparian management zone* be removed from the CAO document, as the latter represents a fundamental shift from traditional buffer-based regulations to ecosystem-based critical area designation.

The term *riparian buffer*, as defined by the Washington Department of Fish and Wildlife (WDFW), is a regulatory designation with fixed widths established through policy decisions designed to protect streams. In contrast, a *riparian management zone* (RMZ) is a scientifically based description of the area adjacent to

streams that has the potential to provide full function based on the Site Potential Tree Height (SPTH) framework.

The WDFW states that RMZs are designated as critical areas unto themselves, not merely buffer zones around critical areas. As a critical area, an RMZ requires enhanced regulatory oversight, including site-specific critical area reports that must demonstrate no net loss of ecological functions for any proposed changes within the zone.

The WDFW's definition of an RMZ includes the riparian ecosystem, which is comprised of:

- The riparian zone – vegetation immediately adjacent to water
- The active floodplain, including riverine wetland
- The zone of influence – the terraces and adjacent uplands that directly contribute matter and energy to the stream

Current agricultural operations are impacted, as building any structures near an RMZ could trigger significantly more complex and costly permitting requirements compared to traditional riparian buffer approaches, such as:

- Mandatory Critical Areas Report – prepared by a qualified professional;
- Site-Specific Analysis – unlike fixed-width buffers, RMZ assessments require detailed, site-specific professional evaluation; and
- WDFW Mapping Tool Requirements – reports must include findings from the WDFW mapping tool

Protecting farmland without fully considering the potential impact of increased regulatory pressures on the business of farming - especially in one of the most expensive places in the United States to farm - may unintentionally contribute to the loss of the very things we are all working together to try to protect: our beautiful landscape and our pristine farmland.

Against the Adoption of WDFW's Buffer Guidance

In response to concerns raised by Planning Commissioners during the entire CAO revision process and as outlined in Section 6.4 of the GAP Analysis, the Western Washington Agricultural Association (WWAA) recommends against adopting the Washington Department of Fish and Wildlife's (WDFW) 2020 Riparian Management Zone (RMZ) guidance for Fish and Wildlife Habitat Conservation Areas and related recommendations presented by FACET Consultants in Section 6.4 of the GAP Analysis. Instead, WWAA recommends maintaining the current CAO buffer standards.

While WWAA supports using best science as tool to guide policy, the RMZ framework based on Site Potential Tree Height (SPTH), and the related buffer increases recommended made by FACET Consulting, imposes uniform, one-size-fits-all buffer requirements. This approach does not reflect the practical realities of agricultural landscapes and poses a direct threat to the viability of farms that rely on man-made drainage systems. In Skagit County, many of these watercourses - maintained under RCW Title 85 - are at risk of being misclassified as natural streams, despite serving as essential infrastructure for crop production and flood management.

While Best Available Science is a required compass to be applied to CAO revision, it should be recognized that WDFW's own literature is contradictory and does not just recommend setting a one-size-fits-all standard. In fact, WDFW's Volume 2 Management Recommendations clearly state using site-specific strategies for policy:

“The most efficient way to protect riparian functions is to adopt protections that recognize [site] differences, rather than uniform-width RMZs... which may result in over-protection in some places and under-protection in others. (p. 11)”

The site-specific Volume 2 recommendation is based on conclusions formed throughout Science Synthesis (Volume 1) that clearly articulates the uncertainty of outcomes associated with SPTH-based buffers. The agency notes:

- “Despite the large quantity of research... no widely accepted recommendations have emerged on minimum buffer widths needed to protect water quality. (p. 142)”
- “Riparian vegetation height and density may be more closely associated with shade than width... (p. 89)”
- “Models cannot predict exactly how much shade reduction will result in a specific temperature increase. (p.89)”
- **“The SPTH-based approach does not guarantee improved salmon returns. (p. 274)”**

Further, WDFW staff have clarified that Volume 2 represents policy preferences and acknowledged that land use decisions must also weigh human needs, such as food production and farm viability.

WWAA has quantified the real-world consequences of SPTH adoption. One member farm in south Mount Vernon would lose 40% of a single field - an 86-acre area currently producing 4.3 million pounds of potatoes, 103,000 pounds of spinach seed, and 175,000 pounds of grass seed annually. The long-term impacts to local agriculture and food security would be significant. We urge the County to reject the application of WDFW’s SPTH Framework.

Conclusion

We thank you for the opportunity to comment and urge the County to revise the ordinance in a manner that respects both environmental protection and agricultural sustainability. We remain committed to being a collaborative partner throughout this process.

Sincerely,

Kim Matthews
WWAA Executive Director

Board of Directors

Dan Gundersen | Aaron Taylor | Jennifer Smith | Brandon Hansen | Tyler Breum | Jacob Slosberg | Torey Wilson | Troy Hansen | Mikala Staples Hughes | Owen Peth |

Attachments: WWAA Chapter 14.24 Critical Areas Ordinance: Recommended Revisions

Chapter 14.24 Critical Areas Ordinance: Recommended Revisions

SCC 14.24.530 and Related Subsections – Riparian Buffer Concerns

We recommend that Skagit County Planning & Development Services explicitly clarify within SCC 14.24.530 and related subsections that the proposed riparian buffers and riparian management zones are located outside of designated Agricultural-Natural Resource Lands (Ag-NRL) and will not impact existing agricultural operations.

Additionally, we strongly urge the County to restore the riparian buffer standards to those previously codified. Our concern stems from the potential for unintended precedent that could open the door to future policy applications negatively affecting Ag-NRL lands—particularly those in active production today.

Protecting riparian function is a shared goal, but it must be pursued in a manner that avoids regulatory uncertainty for farmers and ensures continued agricultural viability. As such, we advocate for language and policy decisions that uphold the integrity of working farmland and provide clarity for long-term land use planning.



July 28th, 2025

Skagit County Planning & Development Services
1800 Continental Place
Mount Vernon, WA 98273

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Robby Eckroth

From: Jovian Finch <jovianfinch@gmail.com>
Sent: Monday, July 28, 2025 4:08 PM
To: PDS comments
Subject: Skagit County 2025 Critical Areas Ordinance Update
Attachments: Nordgren - Comments on "Skagit County 2025 Critical Areas Ordinance Update".docx

Please find attached my comments regarding the Skagit County 2025 Critical Areas Ordinance Update. In it, I referenced my previous comments on the Skagit County 2025 Comprehensive Plan and Development Regulations Update. Should I also attach that or will it be sufficient to list the date that I submitted those?

Thank you,

- Jovian Finch Nordgren

July 28, 2025

Planning and Development Services
Comments on “Skagit County 2025 Critical Areas Ordinance Update”
1800 Continental Place
Mount Vernon WA 98273

Dear Planning and Development Services and other interested parties,

I submitted comments previously to the Comprehensive Plan Update on June 16, 2025, but will repeat some of it here as it is more relevant to the Critical Areas Ordinance Update. I recommend reading it for more nuance and context but below is a more distilled version.

I, like many others of my generation, am trying to find an alternate path to homeownership and independence because the traditional pathways are becoming more and more inaccessible. I looked to our ancestors for inspiration; the countless generations before us who blazed new trails – the kind of people who founded and continue to look after Skagit County. I took a leap and acquired a piece of land that I could afford and that I could start a small homestead on – one that had been overlooked for previous development due to the potential for wetlands present. Before I finalized the purchase, I researched Skagit County Code to be sure I was going to be able to achieve my goals, and based on what was in the CAO at the time it was possible. Now those goalposts are moving and creating more roadblocks and I’m not sure I can do it anymore.

When faced with the challenges of adhering to the code, peers and elders have offered the advice, “Just do it and ask for forgiveness later if they find out”. This worries me, because if the spirit of the ordinance is to protect these critical areas, then making it harder for owner-builders, homesteaders, and DIYers like myself to apply them will backfire and do more harm because people will ignore the regulations.

Overall, I believe the change to the Reasonable Use Exception and Variance process is a positive one. It does simplify the process greatly. However there are a few details that will make it even harder for others in circumstances similar to mine, and, I believe, end up creating more harm.

12.24.140(5)

(a) RUE will only be applicable to sites that do not have an area of 4000 square feet or more **available for development** outside the standard buffer

(b) When buffer impacts are allowed through RUE the maximum total combined development area outside the buffer **and** within the critical area or critical area buffer will be 4000 square feet. All **area available for development** outside the standard buffer **must be utilized** before any buffer impacts can be approved.

...

(d) To the maximum extent feasible, the disturbance area must be located away from the critical area and critical buffer and to avoid the removal of existing native vegetation with emphasis on preservation of conifers greater than or equal to 24 inches diameter at

breast height (dbh), deciduous trees greater than or equal to 20 inches dbh, and forested areas with an established duff layer.

In my case, the entirety of the “area available for development outside the standard buffer” is within 100 feet of the neighbor’s well, such that I would not be able to install a septic drain field. It is also within a hazard zone of a deciduous tree greater than 20 inches dbh, so I could not safely build a residence without having to remove that tree. It is also one of the few areas where native vegetation has recovered from previous clearing practices before these ordinances existed, whereas other portions of the parcel that are within the wetland buffers have been inundated with invasive vegetation that create very little habitat support function.

Given that my choices for development are either in a forested area with an established duff layer, native vegetation, and trees that are preferred for preservation, OR in a wetland buffer with none of those things, it is unclear what the preference is here since the provision does not establish one. Given that my goal is to steward and restore the land, I’d much rather develop with minimal impact in the area that has already seen 50+ years of human impact than to further impact the area that has actually begun to recover.

I do not consider that non-buffered area developable, but it seems that the code as written restricts me to utilizing that full area before expanding into the buffer will be considered. Additionally, that area is counted toward the 4000 sqft total impact area, so that leaves me very little options due to the extensive requirements for a septic field and related buffers that will take up the rest of the 4000.

Ideally, I would propose that the cap on impact area would only consider what is within the critical areas and buffers, rather than including the area outside of the buffers as well, and the cap could be reduced if needed in that case. The provision already limits this option to those with less than 4000 sq ft of area available for development, and the Director must already approve the intrusion based on conditions of the site with the criteria laid out in subsection (d). By further counting the non-buffer area against the total impact area, this provision will be unfairly restrictive in many situations where the non-buffer area size is close to the impact area cap, and the Director will be unable to grant the RUE even if it makes much more sense to do so.

Example: My “area available for development” is 3500 sq ft, so I qualify to apply the RUE (and must do so instead of a variance). However within that 3500 is a neighboring well buffer and dense native vegetation containing large trees.

- With the current standard, I would be forced to build the home in the dense native vegetation, cut down large trees, create a long driveway through a wetland to access it, *and then* I can use the remaining 500 sq feet of impact area for the septic field (which may not be enough) after I’ve exhausted the 3500.
- With the proposal, I could design a site plan that works with the existing vegetation/topography/access, make a case to the Director, and they could approve up to, *for example*, a 2000 sq ft impact area within the already low habitat function buffer and allow for preservation of a substantial portion of the forested area.

In lieu of (or addition to) that proposed change, I would like to see the “area available for

development” be better defined and clarified in a way that accounts for other development limitations separate from critical areas such as: distances between wells and septic drain fields, soil erosion hazard, topography, vegetation, or position relative to property access such that a longer driveway that impacts a wetland is not necessary.

While the variance process is still available if the RUE is not able to provide reasonable use, it is now even more restrictive and an even higher barrier. Further, that the variance is only possible if the RUE is *not*, I could be forced to do more harm by adhering to the RUE’s requirement to utilize the full “area available for development” instead of being allowed to get a variance instead that will work better for the parcel’s unique needs.

I do not foresee that the majority of people in my situation are going to follow through with the increased restrictions, creating the risk of further harm to the critical areas this ordinance is meant to protect.

One possible approach recommended by Dept of Ecology (pub no. 05-06-008) that could address this gap is in 8C.2.4.3 Condition 3: Reduction in Buffer Widths Through an Individual Rural Stewardship Plan:

A Rural Stewardship Plan (RSP) is the product of a collaborative effort between rural property owners and a local government to tailor a management plan specific for a rural parcel of land. The goal of the RSP is better management of wetlands than what would be achieved through strict adherence to regulations. In exchange, the landowner gains flexibility in the widths of buffers required, in clearing limits, and in other requirements found in the regulations. For example, dense development in rural residential areas can be treated as having a low level of impact when the development of the site is managed through a locally approved RSP. The voluntary agreement includes provisions for restoration, maintenance, and long-term monitoring and specifies the widths of buffers needed to protect each wetland within the RSP.

While Skagit County has adopted the Voluntary Stewardship Program, it does not serve the same purpose that the Ecology RSP outlines. It only applies to agriculture, and does not offset the CAO regulations. But a RSP as described in Ecology would work with land owners like myself who care about protecting and stewarding the land and want to build in symbiosis, not opposition to it. The current regulations do a great job at protecting the critical areas from developers who would otherwise pave it over. But there is no carve-out for more ecologically minded land owners who want to build sustainably but have limited options with the regulations. I would love to see Skagit adopt a similar provision.

Jovian Nordgren
111 Woodworth St #301
Sedro Woolley, WA 98284
(425) 239-8167

Robby Eckroth

From: Lora Claus <lorac@skagitonians.org>
Sent: Monday, July 28, 2025 4:29 PM
To: PDS comments
Subject: RE: Comments on the 2025 Critical Areas Ordinance (CAO) update
Attachments: 2025 0728 CAO_SPF Comments.pdf

Letter attached in addition to text below.

Thank you,

Lora Claus
Executive Director
LoraC@skagitonians.org
360-336-3974 office
603-703-2247 cell

Skagitonians to Preserve Farmland
Pavement is Forever

From: Lora Claus <lorac@skagitonians.org>
Sent: Monday, July 28, 2025 4:26 PM
To: pdscomments@co.skagit.wa.us; ljanicki@co.skagit.wa.us; Commissioner Peter Browning <pbrowning@co.skagit.wa.us>; Commissioner Ron Wesen <ronw@co.skagit.wa.us>
Cc: Lora Claus <lorac@skagitonians.org>; Bryony Angell <BryonyA@skagitonians.org>; Kim Rubenstein <kimkce@aim.com>; Tim Knue <timknue@gmail.com>; John Roozen <John@wabulb.com>; John <hayman0405@me.com>; Audrey Gravley <audreygravley97@gmail.com>
Subject: RE: Comments on the 2025 Critical Areas Ordinance (CAO) update

TO:
Skagit County Board of Commissioners
1800 Continental Place
Mount Vernon, WA 98273

FROM:
Skagitonians to Preserve Farmland
414A Snoqualmie St
Mount Vernon, WA 98273

July 28, 2025

RE: Public Comment on Proposed Amendments to the Critical Areas Ordinance (CAO)

Dear Commissioners,
On behalf of Skagitonians to Preserve Farmland (SPF), thank you for the time and effort invested by County staff, the Planning Commission, and the Board of County Commissioners to review and consider updates to the Critical Areas Ordinance (CAO). We appreciate the opportunity to comment.
SPF has been working to protect farmland since our founding in 1989. The CAO rules are complex and impact farmland.

Comment #1: Support for Consortium Recommendations

We voice our strong support of proposed changes made by the Skagit County Drainage and Irrigation District Consortium, LLC (Consortium), in their July 25, 2025, letter. The diking and drainage infrastructure makes agriculture possible across Skagit County, and we defer to the Consortium’s technical expertise on needed changes to the CAO regarding that infrastructure. We appreciate that many of the Consortium’s comments earlier in this process were implemented, and we ask that Skagit County continue to adopt their recommendations.

Comment #2: Concerns with Buffer Expansion in Section 14.24.530

Section 14.24.530, which addresses Riparian Management Zones, contains proposed changes to double buffer widths from 50 feet to 100 feet for DNR Water Types Np and Ns.

Our organization is deeply concerned about the proposed expansion of riparian buffer widths, particularly within the Agricultural-Natural Resource Land (Ag-NRL) zone, where farmland is often adjacent to rivers and streams. While Section 14.24.070(2)(b) allows “Existing Agricultural Activities” (page 9) without standard critical areas review, this exemption should not suggest that the proposed changes do not impact agriculture. They do—and we should be concerned.

14.24.070(2)(b) Existing Agricultural Activities

(i) Existing activities defined as ongoing agriculture on designated agricultural land, including related existing development and activities which do not result in expansion into a critical area or its buffer and which do not result in significant adverse impacts to a critical area or its buffer; provided, that such activities comply with the provisions of SCC 14.24.120.

(ii) **New development and/or expansion of existing agricultural operations must comply with both the substantive and procedural provisions of this Chapter.** Existing and ongoing agricultural activities that result in significant adverse impacts to a critical area or its buffer will not be allowed without standard review under this Chapter. **[Emphasis added]**

The practical effect of increasing the buffer size from 50 to 100 feet is a significant expansion of the area removed from agricultural use—doubling the setback imposed on farms that are expanding or using land not classified as “ongoing agriculture.” This change creates a new barrier to farming in areas that should remain available for agricultural production. It is particularly burdensome for smaller farms, where limited acreage means every bit of land counts. This proposal is at odds with the **Comprehensive Plan’s** guiding principles, which call on the County to *preserve agricultural land for agricultural uses* and to *resolve conflicts between agricultural and environmental objectives* (Comprehensive Plan 2024–2025, page 104).

Furthermore, the Washington Supreme Court, in *King County v. Friends of Sammamish Valley*, stated: “Agricultural land that is specifically designated must be maintained and enhanced for potential future use under the GMA, even if the land is not being used for agricultural production currently.”

Reducing the available footprint a farmer can utilize can significantly impact the profitability of farming. When farming becomes less profitable, we see a rise in alternative uses of farmland: event centers, battery energy storage systems, solar farms—the list goes on.

Agriculture stands strong in Skagit County because of the people who stand with it, aware that a diverse and local food supply feeds our children, combats climate change, and preserves open space. In the 2024 Skagit County survey supporting the Comprehensive Plan process, respondents identified the **preservation of farmland as their #1 priority**.

The **Voluntary Stewardship Program (VSP)** is the preferred tool for protecting critical areas on agricultural lands while maintaining viable farming. Since its adoption, meaningful work has been accomplished in partnership with farmers to improve riparian function without imposing blanket regulations.

Sustaining agriculture in Skagit County requires all of us—especially policymakers—to recognize and support the complex realities farmers navigate every day. Policies that result in the loss of productive ground or impose costly restoration mandates without clarity or flexibility jeopardize the long-term sustainability of agriculture—one of the key land uses the Comprehensive Plan is designed to protect.

We urge the Board **not** to adopt the proposed buffer width increases at this time. While 100 feet may appear to be a convenient and uniform standard, it does not reflect the complex realities of either ecological function or agricultural production. Skagit County can—and must—support the protection of riparian areas **and** the preservation of farmland. These goals are not mutually exclusive.

We respectfully request that the proposed changes to buffer widths in Section 14.24.530 be removed from the current draft and reconsidered through the lens of the **Voluntary Stewardship Program** and the values enshrined in our **Comprehensive Plan**.

Thank you for your consideration and for your enduring support of Skagit County agriculture.

Lora Claus

Executive Director

LoraC@skagitonians.org

360-336-3974 office

603-703-2247 cell

Skagitonians to Preserve Farmland

Pavement is Forever



July 28, 2025

Board of Commissioners
Skagit County
1800 Continental Place, Suite 100
Mount Vernon WA 98273

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Thank you for your consideration and for your enduring support of Skagit County agriculture.

A handwritten signature in black ink, appearing to read "Lora Claus".

Lora Claus
Executive Director



July 28, 2025

Skagit County Planning and Development Services
"Skagit County 2025 Critical Areas Ordinance Update" 1800 Continental Place
Mount Vernon WA 98273

Provided
during 11:00 a.m.
Public Hearing

Comments submitted by Kirk Johnson
Board President
Skagit Land Trust
1020 S. Third St.
Mount Vernon, WA 98273

Thank you for the opportunity to comment on the latest draft of Skagit County's Critical Areas Ordinance (CAO). We appreciate the hard work by staff, consultants and the Planning Commission to update the code and incorporate Best Available Science.

Please find below our comments and recommendations on specific sections, both where we support the revisions and where we continue to have concerns.

• **Section 14.24.020 Title and Purpose**

Please clarify that in meeting the legal requirement to protect critical areas under the No Net Loss standard, mitigation will not be substituted for protecting critical areas whose ecological functions and values are intact. We suggest adding wording on page 4 as underlined below:

"(1) This Chapter shall be known as the Skagit County Critical Areas Ordinance and is adopted to assist in conserving the value of property, safeguarding the public welfare, ensuring no net loss of ecological functions and providing protection for the following critical areas. Under the No Net Loss standard, given mitigation's uncertain success, mitigation will not be substituted for protecting critical areas whose ecological functions and values are intact."

On page 5 under "Fish and Wildlife Habitat Conservation Areas," please correct a significant omission from the general description of these areas by adding wording such as the following underlined phrase:

"In addition to their intrinsic value, certain species of fish and wildlife represent important historic, cultural, recreational and economic resources and may have special protection under state and/or federal law. It is the purpose of this Chapter to protect fish and wildlife populations and their associated habitats and provide special consideration to conservation or protection measures necessary to preserve or enhance anadromous species."

- **Section 14.24.070 Activities allowed without standard review.**
Please modify the requirements regarding notification of restoration and enhancement activities in critical areas.

“(i) Fish, wildlife, wetland and/or riparian buffer enhancement activities not required as mitigation, such as native plant and mulch installation and/or reasonable removal of non-native vegetation, provided all of the following apply:

- (A) The project is consistent with the chapter and does not harm critical areas or their buffers;
- (B) The subject property is not located in a high landslide hazard area; and
- (C) Notification of the enhancement activities must be submitted to the Director.”

We strongly recommend removing (C) notification to the director of enhancement activities. Alternatively, enhancement activities undertaken by conservation and restoration entities and governmental agencies, including tribes, or activities funded by state, local or federal grants attached to fish and wildlife or watershed programs and plans should be exempted.

The proposed notification requirement which is only for “Nature Enhancement” activities would be more burdensome than for other allowed activities in a PCA and more burdensome than the current code. This is despite the fact nature enhancement, which is typically undertaken by a conservation group, agency, tribe or landowner assisted by local, state or federal conservation funding, is the one activity listed in 14.24.070 that is specifically intended to be beneficial for a critical area. No other listed activity would now require notification, including existing agricultural activities; related existing development activities; maintenance and repair of existing structures, utilities, sewage disposal, detention/retention ponds, private roads and driveways; modification of an existing single-family residence that does not change use or footprint; maintenance of existing public and private diking operations along shorelines; existing irrigation activities etc.

Skagit Land Trust and most restoration entities routinely use motorized tools, such as weed eaters and mowers, to control invasive species prior to planting native trees and shrubs and for maintenance for many years afterwards. Mowing, for example, controls invasive reed canary grass so native species can be established. Required notification would result in PDS having to review countless pages of weed-eating and mowing activities annually or conversely delay enhancement activities which are time sensitive and beneficial to the environment. It seems counter-productive to make enhancement activities that seek to improve critical areas, more burdensome.

- **14.24.090 Protected critical areas (PCA) requirements.**

We appreciate the specific, statements about maintaining the integrity and function of PCAs as on page 18:

“(e) PCA Maintenance. The PCA is to be left undisturbed in its natural state. No clearing, grading, filling, logging, agricultural or landscape mowing, or removal of woody material; building; construction or road construction of any kind; planting of non-native vegetation or occupation by livestock is allowed within the PCA areas except as specifically permitted by Skagit County on a case-by-case basis.”

However, we note that this wording assumes critical areas are high quality natural areas. In fact, many critical areas are degraded and take years of enhancement and maintenance to return to health. Thus, we suggest adding **“Revegetation with appropriate native species at natural densities is allowed and encouraged in conjunction with removal of invasive plant species.”**

- **14.24.080 Standard critical areas review and site assessment procedures.**

We appreciate that the CAO draft includes requirements for critical area assessment to consider direct and indirect impacts to critical areas and buffers (p.13):

“(5)(D) An assessment of the probable direct and indirect impacts to the critical area(s) and buffer(s) as well as the cumulative impacts to critical areas resulting from the existing development of the site and the proposed development ...”

We support this addition and understand it to mean that impacts originating beyond 200 or 300 feet from the critical area would have to be taken into consideration when determining whether to permit a development. We assume this would mean, for example, that untreated stormwater runoff into a lake from a development more than 300 feet away from the lake would not be permissible.

- **14.24.130 (2)(b) Hazard tree removal.**

Given the importance of dead or dying trees to a variety of wildlife species, we appreciate the priority given to leaving dead trees as snags rather than cutting them down and leaving them as logs or removing them (p. 26):

“If standing dead trees and snags can reasonably and safely be left in place they should be prioritized over the retention of logs in order to accommodate the preservation of wildlife habitat; ...”

- **14.24.230(7) Wetland Protection Standards.**

We appreciate the efforts to tighten up the exemptions for small wetlands. However, we continue to have concerns about the gaps in protection for wetlands less than 1,000 square feet and Category IV wetlands of less than 4,000 square feet.

Small, isolated wetlands create significant diversity of habitat across the landscape and are important for songbirds and native amphibians; they serve important water quality and storage functions as well. Even small, isolated wetlands can provide important refugia during extreme weather events and may play an oversized ecological role as the climate changes. Exempting these wetlands from protection will not achieve no net loss

of ecological function and is inconsistent with WA Department of Ecology guidelines and with the County's own consultant's Best Available Science analysis.

- **14.24.410 Geologically hazardous areas known or suspected risk.**

We suggest adding the following underlined wording to make the statement more fully reflective of Skagit County experience:

“(2)(e) Potentially unstable areas resulting from rapid stream incision, stream bank erosion, ponding due to landslides or other natural conditions, and undercutting by wave action.” (p.62)

Also, we note this reference in (2)(i) to the Skagit County Alluvial Fan Study Orthophoto Maps:

“(2)(i) Areas designated on the Skagit County Alluvial Fan Study Orthophoto Maps as alluvial fans or as identified by the Director during site inspection.”

We are concerned about the adequacy of these maps. When available, Skagit County should use the most recent available data, including from the Washington Geological Survey.

As in our comment letter of May 8, 2025, we again suggest inclusion of wording such as appears in Whatcom County's CAO concerning development on alluvial fans:

“Permanent residential structures and commercial developments shall be allowed in alluvial fan hazard areas only if the fan has undergone a county-approved study to assess potential hazards, determine risks, and identify mitigation measures and is deemed suitable for development. **The technical administrator shall make this determination based on a detailed assessment by a qualified professional that identifies the risks associated with a 500-year return period debris flow or the maximum credible event that could impact the alluvial fan.**”

We strongly recommend that Skagit County give direction to professionals about the time period or level of event that their study and recommendations should be based on. This will increase the safety for local communities and individuals in an era of climate change impacts. Skagit County's draft CAO does not give this information for development on or near alluvial fans.

- **14.24.500 Fish and wildlife habitat conservation area designations.**

We appreciate the addition of the following underlined wording to (p.66)

“(1)(k) State priority habitats and areas associated with State priority species as defined in WAC 365- 190-080 or documented in the Washington State Department of Fish and Wildlife Priority Habitats and Species List; ...”

We see that the reference to forage fish habitat at (1)(d) is still incomplete despite the recommendations of multiple commenting organizations in addition to Skagit Land Trust

(e.g. Skagit River System Cooperative, Skagit Audubon). Please amend (1)(d) by adding the underlined wording:

“Kelp and eelgrass beds, herring, smelt and other forage fish spawning areas; ...”
Sand Lance, for example, are an important forage fish species which spawn in Fidalgo Bay among other places in Skagit County. They are essential in the diets of various seabird species and fish, including salmon.

We would also like to repeat the request in our May 8, 2025, comment letter for the following added language at (4)(a):

“Great blue heron nest sites and foraging areas.”

The areas where great blue herons forage are integral to their habitat. Communal nesting areas meeting certain criteria are essential to survival of this species, but they are not sufficient in themselves. Foraging areas and nest sites are inseparable parts of the great blue heron’s necessary habitat.

As owner of the greater part of the March Point heronry, with a larger number of heron nests than any other West Coast heronry, Skagit Land Trust has a special responsibility for ensuring continued protection of this habitat. For this reason, our May 8, 2025, comment letter included suggestions on how this protection might be improved; for example, by making the County CAO consistent with the relevant Anacortes CAO sections given that a portion of the heronry lies in each jurisdiction. We urge the inclusion of this goal in the county’s CAO. We would note that the Anacortes approach to protecting heronries more closely follows the recommendations of WDFW than does Skagit County’s. Importantly, the Anacortes CAO includes this language:

“iv. For the March Point colony, given the observed and documented sensitivity of this mega-colony to human intrusion and the fact that the colony is in a rare, isolated, but tight location, a year-round buffer of 984 feet.”

- **14.24.530 Fish and wildlife habitat conservation area protection standards.**

We appreciate the new provision for wildlife corridors in developments with or near streams or wetlands.

“(5) On development proposal sites involving land division, short plat, long plat, and/or a binding site plan, that contain streams and/or wetlands with a high habitat score greater than or equal to six, that are also located within 200 feet of an on-site or off-site a stream and/or wetland with a high habitat score greater than or equal to six a fish and wildlife habitat corridor shall be set aside and protected as follows: ...”

It is not clear how the 100-foot corridor requirement relates to the larger requirement for buffers around wetlands and streams. We note that the Planning Commission recommends exempting short plats from the wildlife corridor requirement. This would create gaps in any corridors and could significantly degrade their functioning for the

intended purpose. For this reason, we disagree with the Commission's recommendation; short plats should not be exempted.

In addition, paragraph 5(c) of this section states: "A management plan for the wildlife corridor contained within a tract or tracts shall be prepared that specifies the permissible extent of recreation, forestry or other uses compatible with preserving and enhancing the wildlife habitat value of the tract or tracts. The management plan shall be reviewed and approved by the Department." However, there does not appear to be any criteria or specific requirements for said management plan.

We recommend adding language requiring the "habitat management plan follow at a minimum the guidelines provided by WDFW's Management Recommendations for Washington's Priority Species for those species expected to occur in the wildlife corridor."

- **14.24.540 Fish and wildlife habitat conservation area performance-based buffer alternatives and mitigation standards.**

We appreciate the addition of the following provision addressing corridors in both riparian and non-riparian areas (p.72 & 73):

"(1) Buffer Width Increasing. The Director may require the standard buffer width to be increased or to establish habitat corridors, when such buffers are necessary for 1 of the following: ...

(iv) To protect habitat corridor connections between open spaces and critical areas inside and outside the county."

- **14.24.540 Fish and wildlife habitat conservation area performance-based buffer alternatives and mitigation standards.**

We note that, if certain criteria are met, timber harvest is permitted in critical area buffers (pg. 75, 14.24.540 (g)). We also note that the current CAO draft has added, "No net loss of ecological functions must be demonstrated through the critical area report process." Despite this reassurance, we strongly agree with the comment from Washington Department of Fish and Wildlife in its May 8, 2025, comment letter (#27):

"Allowing timber harvest within riparian buffers, regardless of conditions or proposed performance standards, compromises the critical ecological functions and values these areas are intended to protect....For these reasons, we strongly recommend eliminating this provision and reinforcing protections for intact riparian vegetation to maintain water quality, fish habitat, and the long-term resilience of riparian ecosystems." (p.9)

We also note that WDFW's *Skagit County Riparian Buffer Evaluation* (Whittaker & Fuchs, July 1, 2025) found that county's 2006 buffers have resulted in the loss of thousands of

acres of riparian tree cover and consequently have not been ensuring no net loss of ecological functions (pgs. 16 & 17). It is inappropriate to then allow reducing forest cover in riparian areas.

* * * *

Creation of a Climate/Environment Advisory Board

Although this recommendation is not a part of the proposed Critical Areas Ordinance, it would help the County with implementation of the Critical Areas Ordinance and with development of future environmental policies.

This past fall, in response to the Planning Department’s call for public participation, 59 of the 90 comments submitted to PDS recommended the revised 2025 Periodic Comprehensive Plan Update draft support the creation of an Environmental/Climate Advisory Board.

An EAB would help the Skagit County Commissioners, the Planning Department and the Planning Commission broaden their understanding of our county’s unique **interconnecting ecosystems that work together to support biodiversity, mitigate climate impacts, store and purify water, reduce flood risk naturally, and enable low carbon solutions.** No current advisory board is charged with taking a comprehensive, best available science-based view of these natural systems.

An EAB would complement the focus on the commercial aspects of natural resources of the County’s existing natural resource boards—the Agricultural, Forestry and Conservation Futures Advisory Boards—with a **specific focus on the protection and stewardship of Skagit County’s natural ecosystems and their critical role in climate adaptation and resilience.**

The Skagit Land Trust’s full recommendation for an EAB is included below. We look forward to discussing this important issue with you further in the near future.

**Creation of an Environmental Advisory Board (EAB)
(or Climate and Environment Advisory Board)**

Submitted by Skagit Land Trust, July 2025

This past fall, in response to the Planning Department’s call for public participation, 59 of the 90 comments submitted to PDS recommended the revised 2025 Periodic Comprehensive Plan Update draft support the creation of an Environmental/Climate Advisory Board.

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Why an Environmental Advisory Board (EAB) Is Needed

An EAB would help the Skagit County Commissioners, the Planning Department and the Planning Commission broaden their understanding of our county's unique **interconnecting ecosystems that work together to support biodiversity, mitigate climate impacts, store and purify water, reduce flood risk naturally, and enable low carbon solutions.** No current advisory board is charged with taking a comprehensive, best available science-based view of these natural systems.

An EAB would help local government make evidence based, informed judgements, about:

- How to best protect and connect natural lands, waterways, wildlife habitat and open space.
- How to thoughtfully plan for, dealing with the challenges, and adapting to issues caused by the intensifications of climate change's impacts on our county far into the future. These include water shortages, extreme weather events, sea level rise, increased landslides etc.

while at the same time:

- Building community support for climate preparedness and carbon reduction.
- Promoting environmental stewardship.
- Integrating best available science into land use and conservation decisions.
- Acting as a bridge with the public.

Proposed Functions of the EAB

The Environmental Advisory Board could evaluate and advise the County Commissioners, Planning Commission, and Planning Department on the following areas:

Environmental and Open Space Policy Development and Planning

- Relevant aspects of planning documents (e.g., Comp Plan), particularly in the areas of fish and wildlife habitat, habitat restoration, wildlife corridors, climate impacts and mitigations.

- The County's Open Space Plan to incorporate updates that include projected climate impacts; fairness and equity; support for green urbanization (multi-use trails connecting cities and towns through a rural landscape); wildlife corridors etc.
- Proposed land use impacts on ecological processes (e.g., rivers, shorelines)

Climate Change Adaptation Strategies

- Solutions, including natural solutions, for climate resilience that prepare for the impacts of climate change, such as sea-level rise, extreme weather events, and water shortages.
- Emerging legislation and best available science affecting natural systems.

Climate Change Mitigation

- Strategies for reducing greenhouse gas emissions, promoting renewable energy, and improving energy efficiency as well as helping to educate the community on these strategies.

The EAB could also:

Foster Collaboration

- Work with local governments, as well as non-profit organizations, on environmental initiatives and information sharing.
- Facilitate communication and coordination between different county departments on environmental issues.

Engage and Educate the Community

- Educate the public about environmental and climate issues and encourage participation in sustainability initiatives.
- Facilitate dialogue between the government, residents, businesses, and other parties on environmental matters.

Board Composition would represent a broad range of community perspectives and technical knowledge with the ability to provide specialized expertise on challenges and opportunities.

Appointments could include:

- Scientists with an environmental, geology/geomorphology, hydrology or climate focus.
- Fish & Wildlife, Conservation & Restoration professionals.
- Technical experts who offer data-driven insights.
- Representatives from education and research programs with an environmental or climate focus.
- Sector expertise such as: land use planning, energy management, waste management, sustainable natural resource management, and climate solution-oriented businesses.
- Community members and landowners with an environmental or climate interest, including youth and those from underserved populations.

Local governments, Tribal and public agency management representatives would be consulted and included to the extent desired.



7/28/25

RE: Critical Areas Ordinance Update

Provided during 11:00 am.
Public Hearing

Happy World Conservation Day! World Conservation Day is celebrated today, on July 28, each year to remind everyone about the importance of protecting nature and maintaining biodiversity.

The Critical Areas Ordinance requires us to protect, not just minimize damage to our vital areas. Skagit Co is, and has been, proactive at protecting farmland in our amazing area. We choose to protect the farmland, not just minimize losing it. We need to remember that the State requirements are the minimum requirements. Skagit Co can be proactive in ensuring protection of critical areas through increased requirements, just as we have done while protecting farmland. With the climate crisis escalating, it is time to be just as proactive on protecting our critical areas.

The demonstrated degradation of the water quality of Big Lake over the last decade shows the current rules are not sufficient to protect the water quality (see Dr. Horner's report), and in fact aren't doing much to even minimize the impacts of increased development.

The 200' distance required for determining if new development impacts a critical area should just be a minimum distance, not an absolute boundary outside of which it doesn't matter what development occurs without serious mitigations to protect a nearby critical area. By only focusing on the area within the 200', we create an artificial bubble of environmental concern.

Critical areas are not magical stand-alone areas, the whole surrounding environment created what we call the critical area. We also know that we are facing serious climate changes. We will have strong weather events impacting our critical areas. With this in mind, we should require even stronger mitigations, expand all buffers, and truly try to shore up protections of our critical areas. It will be an investment that will be vital to our future.

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