NATURAL RESOURCES

Aquatic Resources Program
Endangered Species Act
Compliance Project

Potential Effects and Expected Outcomes Technical Paper

November 2007

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

This page intentionally left blank

Acknowledgements

Department of Natural Resources

Francea McNair, *Aquatic Steward*

Aquatic Resources Program, Endangered Species Act Compliance Project

Carol Cloen, *Lead Scientist - Freshwater*

Philip Bloch, *Scientist - Marine*

Carol Piening, Linda Wagoner, Marc Daily - *Planners*

Ginger Shoemaker, *Research Scientist*

Aquatic Resources Program

Robert Brenner, Dave Kiehle, Nancy Lopez, Michal Rechner

Additional contributors

Washington State Department of Fish and Wildlife - Bob Bicknell, Bon Burke, John Carleton, Randy Carman

Prepared by

ENTRIX
ENVIRONMENTAL CONSULTANTS

Greg Reub, *Project Manager* Cody Fleece, *Asst. Project Manager*
Leo Lentsch, *ESA Planning*

GIS and Database Support: Shruti Mukhtyar and Kevin Gabel

Potential Effects Analysis: Greg Reub, Cody Fleece, Todd Goodsell, Michael Kyte, Darin Waller and Brianna Shrier

Conservation Measures Analysis: Greg Reub, Jeff Fisher, Cody Fleece, Todd Goodsell, Darin Waller

Battelle
The Business *of* Innovation

Ron Thom, *Project Manager*
GIS Support: Amy Borde

Potential Effects Analysis: Roy Kropp and John Vavrinec

Conservation Measures: Greg Williams, Ron Thom, Amy Borde, Roy Kropp

Photo courtesy P. Bloch

Aquatic Resources Program
Endangered Species Act
Compliance Project

Potential Effects and Expected Outcomes Technical Paper

November 2007

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

This page intentionally left blank

Contents

1. Introduction

This Potential Effects and Expected Outcomes Technical Paper is one of several documents developed to assist the Washington State Department of Natural Resources (Washington DNR) Aquatic Resources Program with its Endangered Species Act (ESA) compliance efforts. The purpose of this document is to quantify the direct and indirect impacts of Washington DNR authorized activities on state-owned aquatic lands and their associated habitats for species considered endangered, threatened, of concern, or rare. This information is provided for use within the framework of an ESA compliance process. Utilizing the more formal language of Section 10 of the ESA, Washington DNR's goal for ESA compliance is to:

> *Reduce ESA liability associated with authorizing the use of state-owned aquatic lands, while enhancing efforts to conserve and recover endangered, threatened, and imperiled species.*

The United States Fish and Wildlife Service (U.S. Fish and Wildlife) and National Oceanographic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) (collectively, the Services) require a standard information base for determining compliance with ESA. Washington DNR has developed a process that accumulates, synthesizes, and presents this information in an efficient and compartmentalized manner for use in a final ESA compliance document. The information for direct application as part of an ESA compliance document, is provided in separate documents (technical papers) and includes the following.

- Covered Species - Identifies species that would benefit from ESA compliance activities and their legal status (Washington DNR 2007).
- Covered Area/Habitat - Identifies the location being evaluated and describes baseline habitat conditions (Washington DNR 2005a).
- Covered Activities - Identifies Washington DNR management activities that may cause take of covered species (Washington DNR 2005b).
- Potential Effects and Expected Outcomes - Describes and quantifies the direct and indirect effects of covered activities on covered species and habitats; evaluates the actions that could be taken to avoid, minimize, and mitigate potential effects; and quantifies the expected outcome of implementing conservation measures (this paper).

The analysis presented in this paper is an initial assessment of the potential for "take" that is based on knowledge about the species, their habitat use and their interactions with activities authorized by Washington DNR. When an animal is listed by the Services, the ESA prohibits "taking" of the species, with "take" defined as:

> *To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (Public Law (P.L.) 93-205 (3)19;* 16 United States Code (U.S.C.) 35 (1532)19).

Definitions of "harass" and "harm" are also provided in Federal regulations, with harass defined as "...an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." (50 Code of Federal Regulations (CFR) 17.3); and harm as "...an act that directly or indirectly kills or injures wildlife. Such acts may include significant habitat modifications or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3).

Congress amended the ESA in 1984 to include provisions for the issuance of permits to allow the taking of listed species that are incidental to, but not the purpose of, otherwise lawful activities. An application for a Section 10(a) incidental take permit must be accompanied by a Habitat Conservation Plan (HCP) that adheres to Federal regulations and guidelines prepared by the Services.

In meeting the requirements of the ESA Section 10(a) permit, the description of effects from authorized activities must comply with certain ESA standards. Information submitted by the applicant related to take is required to describe:

- How incidental take will be calculated.
- The level of take and related impacts that will result from the activities.
- The level of take that the Section 10(a) Permit will actually authorize (U.S. Fish and Wildlife and NOAA Fisheries 1996).

While there are no absolute "rules" for specific conservation measures or mitigation programs in either the Services' HCP guidance or the Incidental Take Permitting process, such programs should reflect sound science and recognize the underlying regulatory standards outlined in section 10 paragraph (a)(2)(B) of the ESA. In order for a permit to be issued the Services must find that:

- The applicant will avoid, minimize, and/or mitigate the impacts of authorized incidental take of Covered Species to the maximum extent practicable.
- The authorized taking will not appreciably reduce the likelihood of survival and recovery of such species in the wild (i.e., takings will not result in species jeopardy).

Reflecting Washington DNR's role as the manager of the submerged lands and associated biological communities (e.g., seagrass, benthic infauna) owned by the state of Washington, this analysis does not calculate take as the number of animals killed, harmed, or harassed by authorized uses but, rather calculates the area of potentially affected habitat for each species. The methods used to determine the area of potentially affected habitat and the expected outcomes from applying conservation measures are described in Chapter 2 of this document, with the level of take (affected habitat) presented in Chapter 5 (Effected Habitat and Species) and the potential reductions in take upon implementation of selected conservation measures in Chapter 6 (Conservation Measures and Expected Outcomes).

2. Analysis Methods

This chapter is divided into two sections - the methods used in analyzing and quantifying potential effects from activities authorized by Washington DNR on aquatic habitats and species; and the methods used in the selection of applicable conservation measures and quantifying the expected outcomes from applying the measures.

2-1 Potential Effects Analysis

While the baseline effects analysis presented here includes eight activity groups (Table 2-1) and 42 species (Table 2-2), Washington DNR is seeking ESA coverage for only the three activity groups addressed in Chapter 4 of this paper (Aquaculture – finfish, shellfish; Log booming and storage; Overwater structures) and the 22 species defined as Covered in Table 2-2. Additional information on the potential effects of activities for which Washington DNR is not seeking coverage may be obtained by contacting the Aquatic Resources Program.

Potential effect calculations are based on the physical, chemical and biological impacts associated with currently authorized activities and do not factor in effects from historic activities, the construction of new uses, or effects from unauthorized and/or illegal activities occurring on state-owned aquatic lands.

Table 2-1 - Activities included in the potential effects analysis.

Activity Group	Sub-group	Covered Activity
Overwater Structures – single element	Boat ramps, launches, hoists; Docks & wharves; Rafts & floats; Floating homes; Mooring buoys; Nearshore buildings	All
Overwater Structures – multiple element	Marinas; Shipyards & terminals	All
Outfalls	Combined sewer overflows; Desalinization; Stormwater; Industrial, Municipal	None
Utilities	Power and cable lines; Oil/Gas, Sewer and Water pipelines; Water intake	None
Transportation	Bridges; Ferries; Railroads; Roads and Highways	None
Flood/Wave/Erosion Control	Dike & Dams; Fill and bank armoring; Breakwaters	None

Activity Group	Sub-group	Covered Activity
Aquaculture	Netpens; Shellfish; Commercial Geoduck Harvest; Sand shrimp	Netpens; Shellfish
Mitigation and Enhancement	Artificial habitat; Conservation/Preservation; Contamination remediation; Invasive Species Management; Derelict Vessel Removal	None
Miscellaneous Nearshore	Public Access; Sediment removal; Log booming and storage	Log booming and storage

Table 2-2 - Species included in the potential effects analysis.

Species Group	Common Name	Covered Species	
		X	No
Amphibians & Reptiles	Coastal tailed frog		X
	Columbia spotted frog	X	
	Northern leopard frog	X	
	Oregon spotted frog		X
	Western pond turtle	X	
	Western toad	X	
Birds	Bald eagle	X	
	Black tern	X	
	Brown pelican	X	
	Common loon	X	
	Common murre		X
	Eared grebe		X
	Harlequin duck	X	
	Marbled murrelet	X	
	Tufted puffin		X
	Western snowy plover	X	
Fish	Brown rockfish		X
	Bull trout/Dolly varden	X	
	Chinook salmon	X	
	Chum salmon	X	
	Coastal cutthroat	X	
	Coho salmon	X	
	Copper rockfish		X
	Green sturgeon	X	
	Olympic mudminnow		X
	Pacific cod		X
	Pacific hake		X

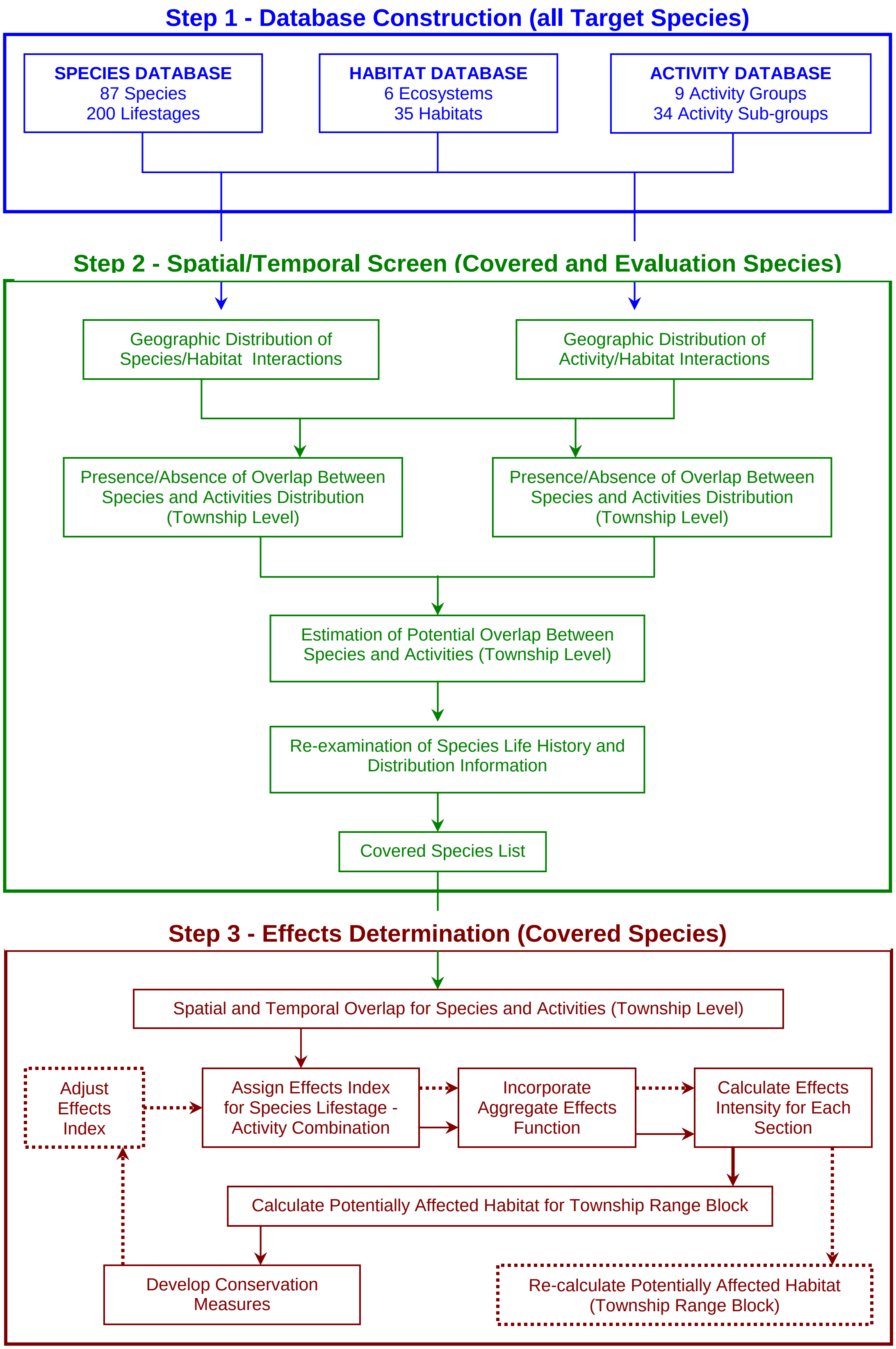
Species Group	Common Name	Covered Species	
		X	No
	Pacific herring		X
	Pink salmon	X	
	Pygmy whitefish		X
	Quillback rockfish		X
	Sockeye salmon-Kokanee	X	
	Steelhead	X	
	Walleye pollock		X
	White sturgeon	X	
Invertebrates	Olympia oyster		X
	Pinto (Northern) abalone		X
Marine Mammals	Humpback whale		X
	Southern resident orca	X	
	Northern sea otter		X
Plants	Persistentsepal yellowcress		X
	Water howellia		X
	Water lobelia	X	

The Potential Effects Analysis described here is comprised of three major steps:

- Database Construction - Compilation of the relevant information on the distribution of species, habitats and activities (Washington DNR 2007, 2005a, 2005a) and standardization of data sources (Section 2-1.1).
- Spatial and Temporal Screening - Identification of potential interactions between species and activities in both space and time (Section 2-1.2).
- Determination of Effect - Review of the available literature characterizing each activity sub-group, identification of potential controlling factors for ecosystem function, and quantification of the impacts to species habitat (Section 2-1.3).

Figure 2-1 illustrates the steps involved in the analysis, including how conservation measures were incorporated into the model and how potentially affected habitat is recalculated with the implementation of conservation measures.

Figure 2-1 – Illustration of the steps used in the Potential Effects Analysis. Dashed lines indicate the feedback loop for implementation of conservation measures.



2-1.1 Database construction (Step one)

Three key data types were used in constructing the database:

- Species Data – Information regarding the spatial and temporal distribution of species.
- Habitat Data – Spatial distribution of ecosystems and associated habitats.
- Activities Data – Information about the spatial and temporal distribution of authorized activities on state-owned aquatic lands.

Each data type and its associated databases are discussed below, with Figure 2-2 providing a conceptual illustration of the database content, organization and initial output.

SPECIES DATABASE

The species database was developed as part of the literature review conducted for the 87 species (and 200 lifestages) addressed in the Covered Species Technical Paper (Washington DNR 2007). Using the reviews, worksheets documenting the timing of lifestage occurrence (Appendix A) and habitat usage (Appendix B) were compiled and incorporated into the species database (Figure 2-2). A limitation to this approach is that we were unable to describe the life history and habitat use for some species and life stages because their behavioral characteristics (e.g., deep water residency, extensive migrations) make them difficult to study thereby contributing to knowledge gaps. For example, very little is known about juvenile habitat use for certain rockfish (*Sebastes spp.*) and the spawning behavior of the Umatilla dace (*Rhinicthys umatilla*) is unknown but presumed similar to that of other dace species (*Rhinicthys spp.*).

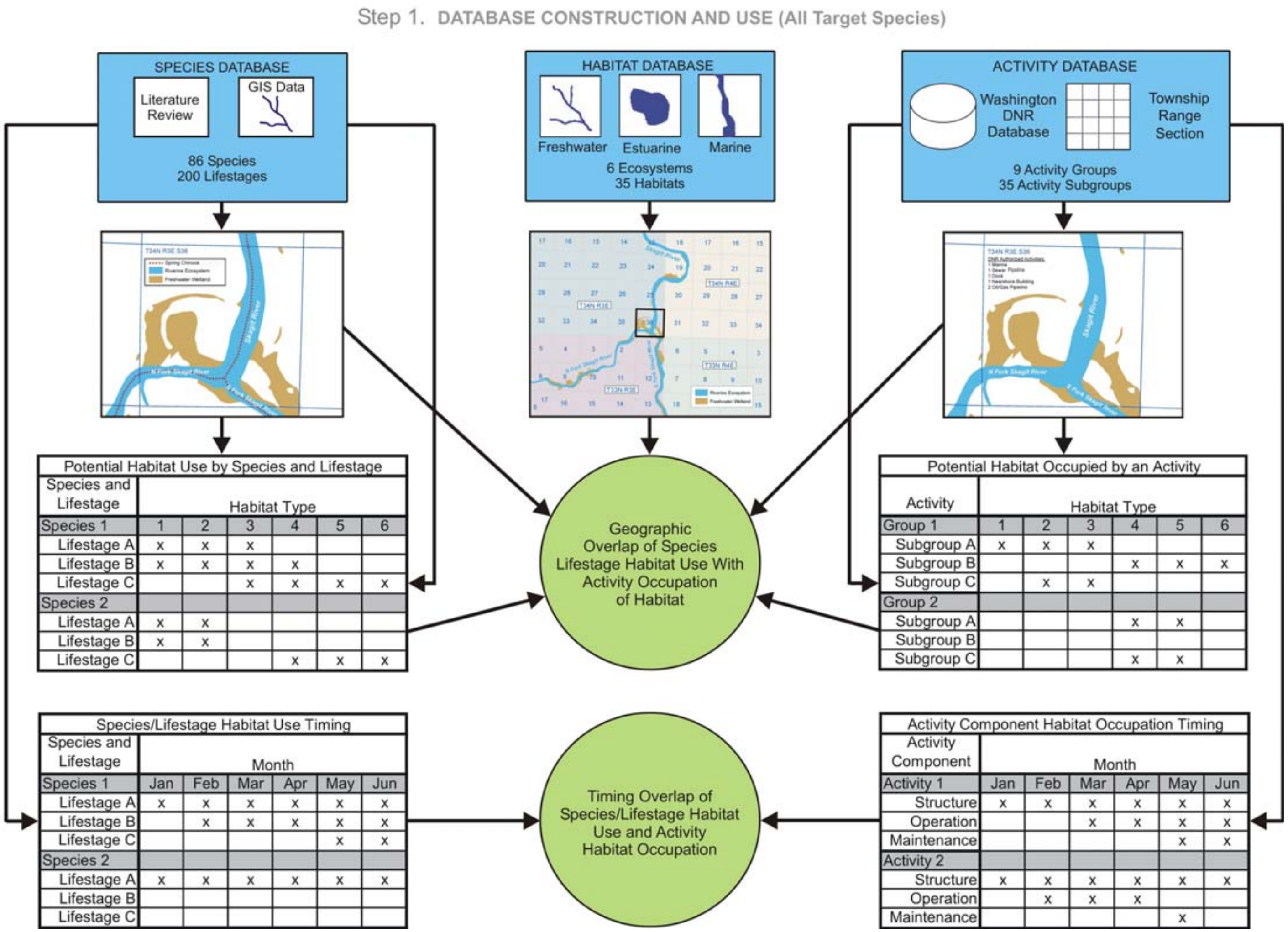
The spatial distribution of species was obtained in a geographic information system (GIS) shapefile or coverage format compatible with Environmental Systems Research Institute (ESRI) ArcGIS® mapping software. Because of the broad scope of this project we focused on using widely available, standardized information. Data sources included the Washington Gap Analysis Project, the Washington State Department of Fish and Wildlife (Washington Fish and Wildlife), Washington DNR, the Washington Nature Mapping Program, the Interior Columbia Basin Ecosystem Management Project, and others. For a number of the species reviewed, we were unable to obtain data that adequately portrayed the species distribution for the entire life history (e.g., salmonid use of saltwater environments). For all species, potentially suitable habitats identified in the literature reviews were selected from our GIS habitat classification datasets to spatially represent areas where the species may occur. Any additional modifying information (e.g., a species only occurs in eastern Washington) was also incorporated into the potential habitat selection.

For many of the species reviewed, distribution information is portrayed as discrete point data reflecting actual field observations which likely understate the true range and movement of the species. To overcome this limitation in our input data sets, we used life history information for 8 of the 87 species reviewed to create species distribution buffers around observation points (Table 2-3). For species that lacked sufficient information to conservatively estimate the species' distribution, no distribution map was created and no screening or potential effect determination was performed.

Table 2-3 – Buffer distances for species distributions.

Species	Species Group	Data Source	Buffer Distance
Bald eagle	Bird	▪ Species Predicted Distribution: Interior Columbia Basin Monitoring Program ▪ Species Observations: Washington Fish and Wildlife, Wildlife Heritage	100 km
Brown Pelican	Bird	▪ Species Observations: Washington Fish and Wildlife, Puget Sound Ambient Monitoring Program, Wildlife Heritage	75 km
Common loon	Bird	▪ Species Predicted Distribution: Washington Gap Analysis Program ▪ Species Observations: Washington Fish and Wildlife, Puget Sound Ambient Monitoring Program	100 km
Common murre	Bird	▪ Species Predicted Distribution: Washington Gap Analysis Program ▪ Species Observations: Puget Sound Ambient Monitoring Program	100 km
Harlequin duck	Bird	▪ Species Observations: Washington Fish and Wildlife, Wildlife Heritage	2 km
Marbled murrelet	Bird	▪ Species Observations: Washington Fish and Wildlife, Puget Sound Ambient Monitoring Program, Wildlife Heritage	5 km
Tufted puffin	Bird	▪ Species Breeding Distribution: Washington Gap Analysis Program	100 km
Eared grebe	Bird	▪ Species Predicted Distribution: Washington Gap Analysis Program ▪ Species Generalized Distribution: Interior Columbia Basin Monitoring Program	5 km
Northern sea otter	Mammal	▪ Species Observations: Washington Fish and Wildlife, Natural Heritage Program, Puget Sound Ambient Monitoring Program	2 km

Figure 2-2 – Conceptual illustration of database content, organization (squares) and initial output (circles).



Habitat Database

Washington DNR used an ecosystem-based approach for organization of information, leading to a habitat-based perspective for addressing the conservation needs of species. As mentioned previously, this analysis calculates take for each species as potentially affected habitat and is measured in hectares. By relating species and lifestages to habitat-type, existing spatial and temporal aspects of habitat use can more directly relate to activities authorized by Washington DNR. The Covered Habitat Technical Paper (Washington DNR 2005a) provides definitions of ecosystems and associated habitats used in the Washington DNR ESA compliance process. Although the definitions were founded on scientifically based and commonly used classification systems, they were simplified to address the broad geographic scope of state-owned aquatic lands (2.4 million acres or approximately 970,000 hectares); the large number and variability of both species and activities; and the differences in the resolution of available data. The Covered Habitat Technical Paper also provides a perspective of how Washington DNR's simplified use of the terms "ecosystem" and "habitat" within the ESA compliance process compares to current use in ecology and systematic biology.

Six ecosystems (Saltwater-Offshore, Saltwater-Nearshore, Tidal Wetland, Riverine, Lakes, and Freshwater Wetlands) and 35 associated habitats were ultimately identified (Appendix C), with five basic criteria employed in their selection:

- The habitat types must have biological relevance to a broad array of species including amphibians, aquatic invertebrates, birds, fish, and reptiles.
- The habitat types must be based on physical processes.
- The habitat types must be based on a widely accepted classification system.
- It must be possible to categorize habitat types from existing data that are easily obtainable.
- The spatial resolution of the habitat types must be consistent and compatible with other data sources used in the analysis (e.g., Washington DNR authorized activities), as well as adaptable to future refinements.

To assess the accuracy of the classifications, the GIS dataset was compared with field habitat observations and a report was generated (Washington DNR 2005c). While the number of observation was small when compared to the overall dataset, there was a high degree of agreement with that projected in the GIS database.

Activities Database

Activities data used in the Potential Effects Analysis were derived from the Washington DNR Revenue, Timber and Assets (RTA) systems database. The Potential Covered Activities Technical Paper (Washington DNR 2005b) provides detailed descriptions of activities authorized by Washington DNR, the RTA systems and the Activities Database developed from it, and the assumptions used to develop the information required for the Potential Effects Analysis. The Activities Database used in this analysis consists of two main datasets - a spatially explicit representation of the locations of authorized activities on state-owned aquatic lands, and descriptive information about temporal and spatial components of the activities (Figure 2-2).

SPATIAL DATA

While the spatial data for the Activities Database is GIS based, for financial purposes Washington DNR currently tracks activities to individual Sections within a township and range block, rather than by the exact location (i.e., GPS coordinate or equivalent) of the authorized activities. This means that the activity can occur anywhere within a particular section. A regular township is 6 miles on a side, and is bounded on the north and south by township lines, and on the east and west by range lines. Each township is divided into 36 sections of 1 square mile ($mile^2$), and comprises about 640 acres (≈260 hectares). However, sections are a component of the Public Land Survey System and most sections end along the shoreline of navigable waterways and do not extend into the water. Sections indicated in the dataset are typically a waterward extension of the section nearest to the activity occurring on state-owned aquatic lands. Further, some activities extend across section lines and by extrapolation may also cross township and range blocks. The resulting level of geographic accuracy in the Activities Database created limitations for the analysis of effects from activities on the environment. While we assume that all species, habitats and activities occurring in the same section co-occur or overlap in their distribution, overlaps which were identified as unlikely (e.g., fill and bank armoring in the deepwater ecosystem) were eliminated.

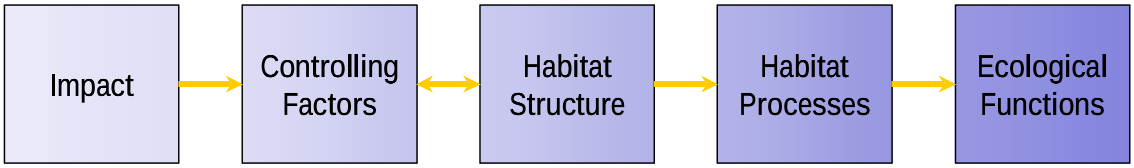
DESCRIPTIVE DATA

The original data contained in the RTA systems are also limited by the lack of a standardized approach for how Washington DNR characterizes individual use authorizations. Consequently, two individual use authorizations that are similar in nature may have markedly different size or use characteristics, with some entries lacking size descriptors and/or a description beyond a billing code (Washington DNR 2005b). Addressing the lack of reliable spatial and temporal characteristics for over 4,000 individual use authorizations is beyond both the scope and the ability of Washington DNR's ESA Compliance Project. As a result, a "typical activity" was defined for each of the 34 activity sub-groups that incorporates the average characteristics of a broad spectrum of use authorizations thereby facilitating the development of descriptive statistics at the sub-group level. Typical activity assumptions are described in greater detail in Chapter 4 (Potential Effects), with the descriptive data placed in one of two categories - data related to the size of the activity sub-groups (size descriptors), and data characterizing the temporal aspect of the sub-groups (temporal descriptors).

Size Descriptors

There are two elements of an activity that influence the spatial extent of effects on a species or habitat - the activity's "footprint" and the "area of alteration" that results from the activity's broader area of influence. To simplify the estimation of the area of alteration, it was assumed that habitat structure is correlated with ecological function, as illustrated in Figure 2-3. This allows spatial impacts to habitats to be extrapolated to impacts on ecological functions and on the species of interest.

Figure 2-3 - General conceptual model linking impacts to ecological functions (from Williams et al. 2003).



The area of alteration was estimated for each typical activity through review of the literature (Chapter 4), field examination (Washington DNR 2005c), and professional opinion. To characterize the area of alteration, the footprint of the activity was first estimated based on a description of a "typical" structure, with the structures characteristics drawn from a review of current leases in the RTA systems and supplemented by input from Washington DNR land managers and ESA Compliance Project scientists familiar with the activities. Following an examination of the sources and controlling factors (mechanisms) for potential effects, the extent of habitat alteration (structure or process) was defined using one or more of the factors identified in Table 2-4 and estimated based on the area of the "typical activity" footprint. For example, bark deposits associated with log booming and storage may extend outward from the site used for up to 60 meters (Pease 1974) - based on an assumed area of almost 20 acres (~ 8 hectares) for individual log booming and storage sites (Chapter 4, Table 4-21), the total area of alteration becomes almost 45 acres (18 hectares).

Table 2-4 - Controlling factors potentially affecting ecosystem function.

Controlling Mechanisms*	
▪ Loss of natural shade	▪ Wave energy
▪ Increased artificial shade	▪ Sediment supply
▪ Pollution (toxins, nutrients, thermal)	▪ Substrate type
▪ Physical disturbance (recurring human activity)	▪ Depth/slope
▪ Hydrology	

* Adapted from Thom et al. 2005.

Temporal Descriptors

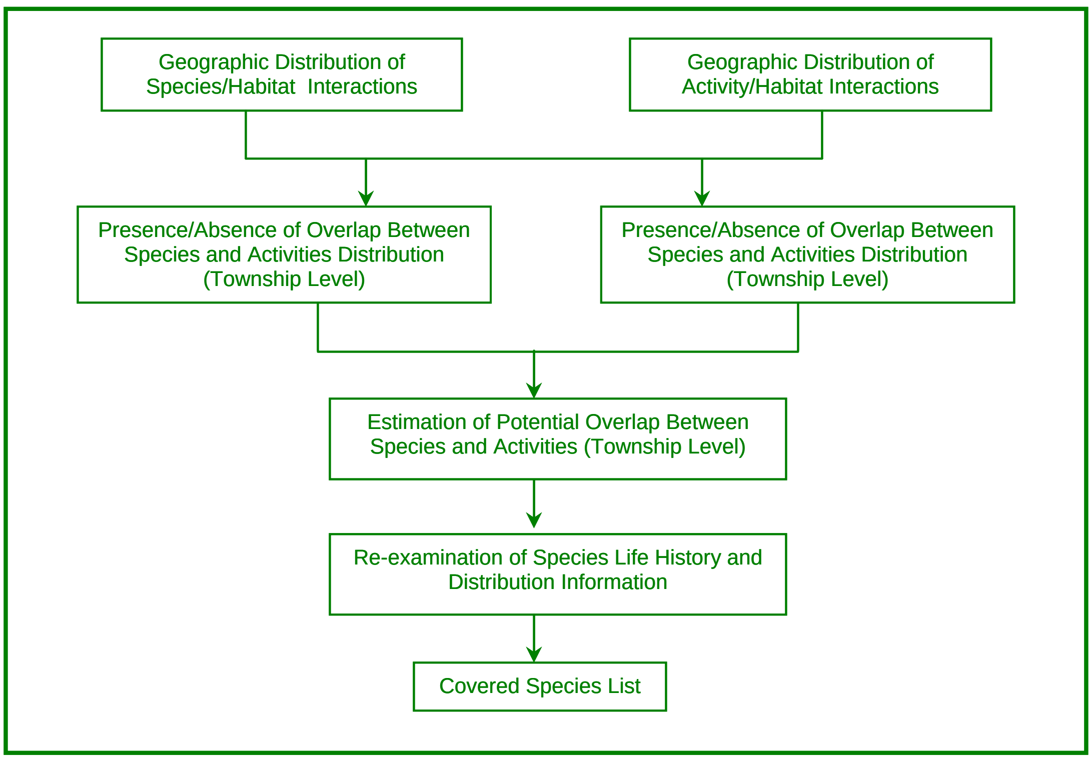
Temporal descriptors for "typical" activity sub-groups are presented in Chapter 3 and include the following information:

- The type of structures present in aquatic habitats (e.g., log rafts, creosote pilings, rip-rap).
- The time period during which the structure and/or activity occurs.
- A description of the operational conditions associated with the activity.
- The period of time in which the maintenance activities occur.

2-1.2 Screening analysis (Step two)

The second step in the Potential Effects Analysis was the screening analysis (Screen) used to identify intersections between species, habitats, and activities authorized by Washington DNR (Figure 2-4). To complete this analysis it was necessary to divide the landscape into analysis units and determine which species, activities and habitats occur within each analysis unit.,. As Washington DNR currently characterizes authorized activities by section, township and range, the Public Land Survey System was used as the analysis unit and intersected with species distribution data, habitat distribution data, and activity data to identify overlaps. Appendix D illustrates activity and habitat overlap.

Figure 2-4 - Step 2 of the Potential Effects Analysis (spatial/temporal screen).



Information generated in the Screen was used to confirm or deny any assumptions regarding overlap between species, lifestages and activities and provides the basic information required for the calculation of potentially affected habitat (Section 2-1.3, Potential Effects Determination). What follows is a description of the role of the Screen in determining the likelihood of potential interaction between species/lifestages and Washington DNR activities, as well as the role of the Screen in the selection of Covered Species.

Spatial Overlap Analysis

The objective of the Screen was to determine the degree to which the distribution of authorized uses potentially interact with Covered and Evaluation species. This was accomplished using two techniques. First, we developed a metric that describes the number of activities authorized by Washington DNR that co-occur with each species evaluated. The number of activities overlapping with a species' distribution was then converted into a rank score of low (1), medium (2) or high (3) as described in Table 2-5. Second, the Screen data were used to examine the spatial extent of the species distribution relative to the spatial extent of all authorized uses of state-owned aquatic lands. The calculated percentage of each species distribution coinciding with activities authorized by Washington DNR is referred to as "coincident habitat" and is used as an indicator of the likelihood of interaction. Table 2-5 illustrates the ranking criteria and metrics used for the species/lifestage and activity overlap and coincident habitat metrics. The two metrics were used to assess the potential for activities authorized by Washington DNR to effect species by averaging the two ranks (Table 2-6).

The results of this analysis were used to re-evaluate the preliminary coverage recommendations presented in the Covered Species Technical Paper (Washington DNR 2007). When the results indicated a higher or lower potential for effect than originally recommended, professional judgment was used to re-assess the information presented in the species paper (status and rank, range, habitat use, population trends, known threats) and arrive at a final recommendation. Results from the Spatial Overlap Analysis are presented in Chapter 5 (Affected Habitat and Species) of this document.

Table 2-5 – Ranking criteria for species and activity overlap and coincident habitat metrics.

Species/lifestage and Activity Overlap		Coincident Habitat	
Count	**Rank**	**Percent of Townships**	**Rank**
0 – 22	Low (1)	0 – 34	Low (1)
23 – 30	Medium (2)	35 – 66	Medium (2)
31 – 34	High (3)	67–100	High (3)

Table 2-6 –Potential to Affect rank.

Species/Activity Overlap Rank	Coincident Habitat Rank	Potential to Affect Rank
Low (1)	Low (1)	Low (1)
Medium (2)	Low (1)	Low (1.5)
High (3)	Low (1)	Medium (2.5)
Low (1)	Medium (2)	Low (1.5)
Medium (2)	Medium (2)	Medium (2)
High (3)	Medium (2)	Medium (2.5)

Species/Activity Overlap Rank	Coincident Habitat Rank	Potential to Affect Rank
Low (1)	High (3)	Medium (2)
Medium (2)	High (3)	Medium (2.5)
High (3)	High (3)	High (3)

Evaluation of Coverage Status

Of the original 87 species reviewed, 14 were listed as federally endangered or threatened, 4 were candidates for federal listing, and 26 were federal or state species of concern, with the remaining 43 having no federal status. Thirty-three of the species were determined to have a high potential to be adversely affected by activities authorized by Washington DNR, with 35 having a moderate potential, 14 low potential, and 5 having no potential to be affected. Using the coverage definitions presented in the Covered Species Technical Paper (Washington DNR 2007), as well as information related to population trends and data gaps, we recommended a preliminary status of "Covered" for 20 species, "Evaluation" for 51 species, and "Watch-list" for sixteen. Data gaps for the species can be described by five general categories: 1) insufficient information on distribution within the state of Washington; 2) insufficient information on life history or habitat use; 3) insufficient information on population trends; 4) insufficient information on threats; and 5) taxonomic uncertainty.

The distribution data described in the preceding sub-section (Spatial Overlap Analysis) was queried to confirm or deny the assumed overlap between species (by lifestage) and activities (by sub-group) and used to revise the initial species coverage categories. When the spatial overlap queries indicated a higher or lower potential to interact than that originally assigned, the selection matrix (Table 2-7) was reapplied with the change factored in. In total, 41 of the species that were initially categorized as either "Covered" or "Evaluation" were addressed in this analysis.

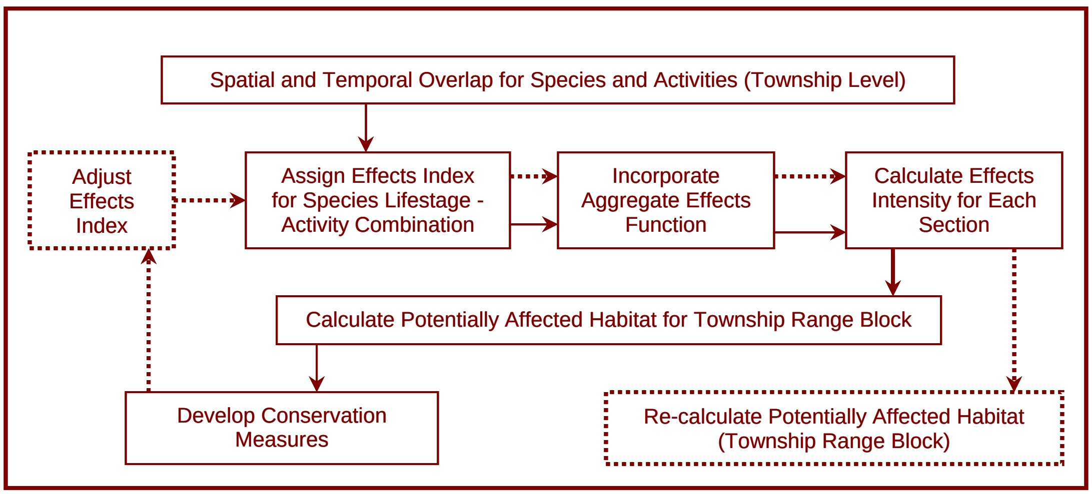
Table 2-7 - Decision matrix for determining preliminary designation of species to be considered for an ESA take authorization associated with authorized activities.

Preliminary Selection Criteria	Species Status – Level that Federal ESA Protection is Warranted			
Potential Effect	**Currently Listed**	**Species of Concern**	**Designated Imperiled**	**Not Designated**
High	**Covered**	**Covered**	Evaluation	Evaluation
Medium	Evaluation	Evaluation	Evaluation	*Watch List*
Low	Evaluation	Evaluation	*Watch List*	*Watch List*

2-1.3 Potential effects determination (Step three)

The Potential Effects Determination is the final step in the Potential Effects Analysis and was used to estimate the extent, magnitude and intensity of effects from activities authorized by Washington DNR on habitats occupied by Covered Species and lifestages. Only Covered Species were analyzed in Step 3 (Figure 2-5) because incidental take permits were not likely to be sought for those species defined as Evaluation or Watch-List species.

Figure 2-5 - Step 3 of the Potential Effects Analysis (effects determination for Covered Species).



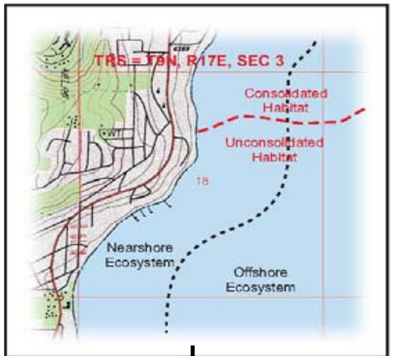
The determination of effects consists of four basic components:

- Magnitude of Effect – A qualitative ranking of the magnitude of direct and indirect effects resulting from the physical presence, operation, and maintenance of each activity sub-group on Covered species and lifestages.
- Intensity of Effect – The adjustment of the magnitude of effect to reflect any additional impacts that may occur as a result of the density of authorized uses within a given area.
- Potentially Affected Habitat – The total habitat area affected by authorized uses. Potentially affected habitat is a function of the extent of alteration as well as the magnitude and intensity of the effect.
- Intensity of Effect Distribution – A spatially explicit representation of the Intensity of Effect for all species, lifestages, and activity sub-groups within each Section.

Detailed discussions of the components of the potential effects model are presented in the following sub-sections, with Figure 2-6 illustrating the process used.

Figure 2-6 - Conceptual illustration of the process for determining potential effects.

Determine geographic overlap of habitat for species lifestage and activity$_x$



(Area of Alteration)
x
(Number of Activities in Section)

Calculation of Potentially Affected Habitat$_{Axtivity\ X}$

1[ST] Potentially Affected Area$_{Activity\ X}$ = Intensity of Effects x Area of Alteration

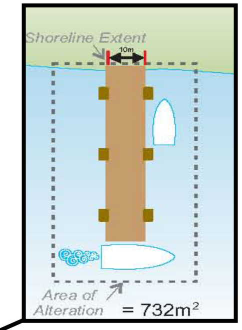
2[ND] Σ Potentially Affected Area$_{Activity\ x}$ for all Sections in Township Range

3[RD] Using habitat types associated with activity, assign habitat area to Potentially Affected Area proportional to habitat found in Township Range

4[TH] Σ for Habitat

5[TH] Σ for Ecosystem

Determine footprint, shoreline extent and extent of alteration for typical activity$_x$



Calculate Intensity of Effect for each activity by Section

$$\text{Intensity of Effects} = \frac{\text{Magnitude of Effects}_x}{1 - f_x}$$

Intensity of Effects Illustration (map): Sum of the Intensity of Effects for <u>all</u> activities in a section for a specific species lifestage

Assign Magnitude of Effects for each species lifestage & activity combination

Species X Lifestage Y	Activity 1 Effects Index	Activity 2 Effects Index	Activity 3 Effects Index
Direct Effect			
Species level			
Increased activity	x	x	x
Impair behavior/timing patterns	x	x	x
Physical harm or harassment	x	x	--
Assigned Effect Index Value	0.75	0.75	0.5
Habitat level			
Air quality impairment (acute levels)	--	--	--
Water impairment (acute levels)	--	--	--
Sediment quality impairment (acute levels)	--	--	--
Permanent habitat destruction/displacement	x	x	x
Permanently inaccessible habitat	x	x	x
Assigned Effect Index Value	0.75	0.75	0.75
Indirect Effect			
Habitat loss			
Temporary destruction/displacement	x	x	x
Temporarily inaccessible	x	x	x
Assigned Effect Index Value	0.75	0.75	0.75
Habitat degradation			
Energy resource reduction	x	x	x
Air quality impairment (chronic levels)	--	--	--
Water quality impairment (chronic levels)	x	--	x
Sediment quality impairment (chronic levels)	x	--	x
Reduction of structural habitat quality metrics	x	x	--
Assigned Effect Index Value	0.75	0.75	0.75
Average Direct Effects	0.75	0.75	0.63
Average Effects Index	[illegible]	[illegible]	[illegible]
Magnitude of Effects	**0.75**	**0.75**	**0.69**

* Scale: 1= total loss; 0.75 = high effect; 0.5 = moderate effect; 0.25 = low effect; 0 = trace effect

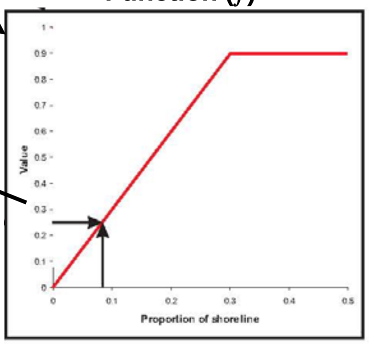
** Scale: 1= No effectiveness; 0.75 = low effectiveness; 0.5 = moderate effectiveness; 0.25 = high effectivenesst; 0 = Total effectiveness

x = Sources of effect

-- = Absence of effect

NA = Absence of interaction

Integrate Aggregate Effects Function (f)



Magnitude of Effect

The Magnitude of Effect is a qualitative ranking of the direct and indirect effects resulting from an authorized activity including the physical presence of any structures, operation of facilities and infrastructure, and maintenance. Magnitude is determined by first having experts follow an ordinal ranking system ranging from 0 (no or trace effect) to 1.0 (total loss) for ranking direct and indirect effects and then calculating the magnitude as the greater of either the average of individually ranked direct and indirect effects or the direct effect rank. Rankings for effects were created using Effect Indices for each of the Covered Species and lifestage for each activity sub-group (e.g., docks and wharves) with the indices providing a standardized method across species and activities to estimate the relative severity of effects associated with activity structure, operation, and maintenance.

REGULATORY BASIS FOR DETERMINING MAGNITUDE OF EFFECT

In meeting the requirements of a Section 10 permit, the effects from the covered activities must meet both the Section 10 (not appreciably reduce the likelihood of survival and recovery of the species in the wild) and Section 7 standards (not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated habitat). The effects of covered activities are typically described as direct or indirect, with direct effects including the immediate impacts of an activity on the species or its habitat (e.g., entrainment in surface water diversions), as well as the destruction of habitat (e.g., elimination due to the placement of a structure). Indirect effects are those "...that are caused by, or will result from, the proposed action and are later in time, but still are reasonably certain to occur..." (50 CFR 402.02) and include chronic exposure to contaminants and reductions in prey.

PROCESS FOR DETERMINING MAGNITUDE OF EFFECT

Effect Indices were prepared for each unique species, lifestage, and activity sub-group combination and composite scores characterizing the magnitude of effect were derived from individual rankings of direct and indirect effects. Fifteen mechanisms for potential effects were identified, with the mechanisms assigned to two categories for both direct (species and habitat level) and indirect effects (habitat loss and habitat degradation) (Figure 2-7). For each mechanism, an "X" was used to indicate an overlap between the effect category, the species/lifestage being considered, and the particular activity. Justifications for the assumed overlap and the interpretation of the magnitude of the effect were based on a review of the literature and supplemented by professional judgment (see Chapter 3, Potential Effect Analysis).

Figure 2-7 - Example effect index.

Species X			
Lifestage Y	**Activity 1**	**Activity 2**	**Activity 3**
Direct Effect			
Species level			
Increased activity	x	x	x
Impair behavior/timing patterns	x	x	x
Physical harm or harassment	x	x	--
Assigned Effects Index Value	0.5	0.5	0.25
Habitat level			
Air quality impairment (acute levels)	--	--	--
Water impairment (acute levels)	x	x	x
Sediment quality impairment (acute levels)	x	x	x
Permanent habitat destruction/displacement	x	x	--
Permanently inaccessible habitat	--	--	--
Assigned Effects Index Value	0.25	0.25	0.5
Indirect Effect			
Habitat loss			
Temporary destruction/displacement	x	x	x
Temporarily inaccessible	x	x	--
Assigned Effects Index Value	0.5	0.5	0.25
Habitat degradation			
Energy resource reduction	x	x	x
Air quality impairment (chronic levels)	--	--	--
Water quality impairment (chronic levels)	x	x	x
Sediment quality impairment (chronic levels)	x	x	x
Reduction of structural habitat quality metrics	x	x	x
Assigned Effects Index Value	0.5	0.5	0.25
Average Direct Effects Index	**0.38**	**0.38**	**0.38**
Average Effects Index	**0.44**	**0.44**	**0.31**
Magnitude of Effects	**0.44**	**0.44**	**0.38**
Scale: 1= total loss; 0.75 = high effect; 0.5 = moderate effect;			
0.25 = low effect; 0 = trace effect			
x = Sources of effect			
-- = Absence of effect			
NA = Absence of interaction			
[1] Use direct effect value if greater			

Once it was determined that a category had a nexus and the potential magnitude of effect was identified, the potential effect value (score) for each of the four types of effect (direct - species and habitat level; indirect - habitat loss and habitat degradation) was estimated. Effects were evaluated in relation to the area of alteration and the severity of the potential impact and assigned scores of 0 (“trace” effect), 0.25 (“low” effect), 0.5 (“moderate” effect), 0.75 (“high” effect), and 1 (“total loss”). Since the total area affected by a given activity is the product of the area of alteration and the magnitude of effect, activities with very large areas of alteration may have relatively low magnitude of effects values because the impacts are spread over a large total area. For example, if the entire area of alteration was considered a complete loss due to the specified mechanism, it was rated a “1” for that effects component. If half of the entire area of alteration was considered a complete loss with regard to a mechanism, it was scored a 0.5. Similarly, if it was determined that the entire area of alteration was moderately affected by the mechanism then the assigned Effect Index (EI) value would equal 0.5.

The Magnitude of Effect (ME) is a composite score that is derived from the assigned effect index values for direct and indirect effects. The Magnitude of Effect for each activity sub-group and species lifestage is the greater of either the average of the two direct effect category scores or the average of the scores for all four categories. For example, the Magnitude of Effect for Activities 1 and 2 in Figure 2-7 is equal to 0.44 - the average of all four categories; whereas the Magnitude of Effect for Activity 3 is 0.38 – the direct effect value.

Intensity of Effect

The Intensity of Effect (IE) is a metric that is calculated as the ratio of the Magnitude of Effect over an aggregate effects function, with the metric designed to reflect additional impacts that may occur as a result of the concentration or aggregation of authorized uses within a given area.

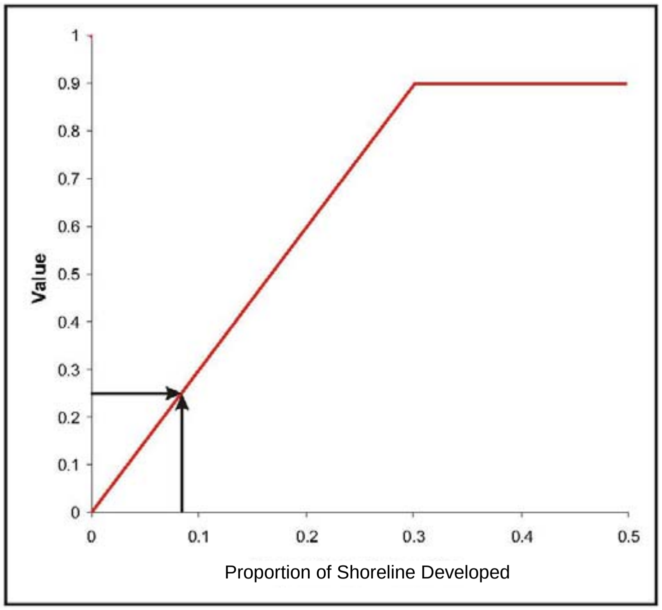
BASIS FOR THE INCORPORATION OF AGGREGATE EFFECTS

In estimating potentially affected habitat, it was important to incorporate an aggregate effects factor to account for an increase in the magnitude of impacts in areas where activities authorized by Washington DNR are concentrated. For example, a single dock authorization may not significantly impact nearshore sediment supply and transport processes, but in all likelihood the combined presence of many docks along a shoreline will.

The role of aggregate effects in aquatic ecosystems is not well studied. However, research in upland watersheds indicates that it is a combination of factors that influence the ecological integrity (physical, chemical, and biological measures) of aquatic resources. These factors cover a range of spatial and temporal scales, with research (Horner et al. 1996, Booth and Jackson 1997), indicating that there are no distinct thresholds of degradation, but rather a continuous decline in water quality, biological integrity, and habitat complexity as natural vegetation-soil structure are lost to development leading to a loss of ecosystem function. Most research in the Pacific Northwest and elsewhere in the country indicates that when native forest cover drops below the 60 to 70 percent range for a sub-basin and/or the level of imperviousness rises over 10 percent, noticeable changes in ecological integrity can be observed. Several forest management studies also indicate that road density is another clear metric of landscape change that is directly correlated to ecological degradation on a watershed scale. Degradation may occur as forests are cleared during timber harvest operations, when forest and wetlands are converted to agricultural or grazing lands, or when native cover (vegetation and soils) is removed as part of the development (urbanization) process. Recent research (see Alberti and Bidwell in prep) also indicates that these same landscape-scale factors have a negative influence on water quality (specifically bacterial pollution levels), biological integrity, and physical habitat conditions in nearshore-shoreline areas.

A science panel convened to evaluate ecological conditions in Puget Sound and the Georgia Basin concluded that ecosystem value declines rapidly with the percentage of developed shoreline (Puget Sound Action Team 2005). The aggregate effects function used in this analysis (Figure 2-8) is based on the conclusions of the panel regarding nearshore ecosystem function and upon a weight of evidence approach (Diefenderfer et al. 2005). This function suggests that ecosystem value declines rapidly as the percentage of shoreline development increases until a threshold is reached (≈30 percent), following which no additional density effect is observed and activities achieve their maximal impacts.

Figure 2-8 - Aggregate Effects function.



The Aggregate Effects function is based upon the density of uses authorized by Washington DNR per length of shoreline, and is therefore not a cumulative effect function. This approach was chosen partly in response to practical considerations. While data on shoreline length and the number of use authorizations per section were readily available, other indicators of aggregate impacts (e.g., percent impervious surface, land cover) were either not readily available for the entire state; did not allow us to easily discriminate between uses authorized by Washington DNR and those that were not; and/or required significant modification and commitment of resources that were beyond the scope of this project.

PROCESS FOR INCORPORATION OF AGGREGATE EFFECTS

Aggregate effects were incorporated into the analysis by calculating the ratio of the length of shoreline encumbered by uses authorized by Washington DNR versus the total length of shoreline. This calculation was performed for each activity sub-group and was based on the assumed dimensions of each “typical” activity. The function consists of a line associated with the proportion of shoreline affected on the X-axis and an aggregate effect value of between 0 and 1 on the Y-axis (Figure 2-8). The line rises at a 45 degree angle from 0 for both axis until 30 percent of the shoreline was estimated to be affected and an aggregate effect of 0.9 was reached. The lack of further increases in the function is designed to reflect observations that substantial and increasing degradation of ecosystem function occurs when 0 to 30 percent of a shoreline is developed, after which ecosystem function changes very little.

Next, the Aggregate Effects function was used to arrive at the intensity of effect, with the Intensity of Effect (IE) equal to the ratio of the Magnitude of Effect (ME) and the Aggregate Effects function (AE) (Equation1). The ratio is used in determining the Potentially Affected Area for each activity (Equation 2).

Equation 1

$$IE = \frac{ME}{(1 - AE)}$$

Equation 2

$$PAA = (AA) \times \left(\frac{ME}{(1 - AE)} \right)$$

The value derived from the Aggregate Effects function increases with the percentage of shoreline development, decreasing the value of the denominator in the Effects Intensity ratio and resulting in a higher Intensity of Effect. When shoreline development is small the Intensity of Effect is roughly equal to the Magnitude of Effect.

For example, assuming that approximately 5 percent of the shoreline in Section X is disturbed, the Aggregate Effects (AE) function (see Figure 2-8) is equal to 0.1. If the Area of Alteration (AA) from activity Y is 100 meters^2, and the activity has a moderate (0.5) Magnitude of Effect (ME) on species B, the Potentially Affected Area (PAA) is:

$$PAA = (100 meters^2) \times \left(\frac{0.5}{(1 - 0.1)} \right) = 55 meters^2$$

In contrast, if 25 percent of the shoreline is disturbed the Aggregate Effects function is equal to 0.75 and the Potentially Affected Area would quadruple:

$$PAA = (100 meters^2) \times \left(\frac{0.5}{(1 - 0.75)} \right) = 200 meters^2$$

Potentially Affected Habitat

As described in Section 2-1.1 (Database Construction), the ecosystem and habitat data were referenced to the township and range block, while activities were referenced to a section with the exact location of the activity within the section unknown. Therefore, the estimation of potentially affected habitat was calculated on the township/range scale. This was done by calculating the potentially affected area for a specific activity by section, adding all of the areas in a township and range block, and simply proportioning the habitat by the percentage of that habitat type found in the township and range (Figure 2-9). As described above in the Screening Analysis, only those habitats potentially associated with a particular activity are included in the habitat area calculation. For example, since finfish net pen aquaculture in Puget Sound only occurs in offshore saltwater habitats, the habitats associated with that ecosystem are proportioned to this type of aquaculture.

Figure 2-9 – Conceptual illustration of the calculation of Potentially Affected Habitat.

Calculation of Potentially Affected Habitat$_{\text{Axtivity X}}$

1ST: Potentially Affected Area$_{\text{Activity X}}$ = Intensity of Effects X Area of Alteration

2ND: Σ Potentially Affected Area$_{\text{Activity x}}$ for all Sections in Township Range

3RD: Using habitat types associated with activity, assign habitat area to Potentially Affected Area proportional to habitat found in Township Range

4TH: Σ for Habitat

5TH: Σ for Ecosystem

This also enables estimation of the percent of an ecosystem or habitat that is potentially affected by Washington DNR activities in relation to that available in the region/state. The data summaries assist in determining 1) what activities are having the greatest impacts on habitats and the species/lifestages they support; 2) what ecosystems and habitats affected by Washington DNR authorized activities are contributing to, or limiting recovery of, a species on a regional scale; and 3) what conservation measures should be emphasized for an activity, ecosystem, habitat, and species/lifestage to encourage recovery.

Intensity of Effects Distribution

As described above, potentially affected habitat was summarized by activity, activity sub-group, ecosystem, habitat, and species/lifestage (Chapter 5 - Affected Habitat and Species). Although the coarseness of the locational datasets for habitats and activities prohibited defining the precise geographic distribution of affected habitat, the summaries provide an understanding of where potentially affected habitat occurs and where activities are concentrated, as well as a basis for developing appropriate conservation measures.

The summary was accomplished by examining the Intensity of Effect values for all species-lifestage-activity combinations on a regional basis. Using the Intensity of Effect equation (Equation 1), the theoretical maximum Intensity of Effect value for an individual species-lifestage-activity combination in a section equals 10 and would occur only when both the Magnitude of Effect was very high (i.e., 1.0 = total loss) and the density of activities authorized by Washington DNR comprised at least 30 percent of the shoreline (AE = 0.9).

$$IE_{Maximum} = \frac{ME}{(1-AE)} = \frac{1}{1-0.9} = 10$$

As part of the potential effect analysis, 51 species-lifestage combinations and 34 activity sub-groups were examined, thus the theoretical maximum Intensity of Effect value for all species-lifestage and activity sub-groups in a given section is 17,340 and the minimum is zero. The analysis of the distribution of the intensity of effects was based on the combined influence of activities authorized by Washington DNR within a given section on all species present. The Intensity of Effects Distribution (IED) was calculated by adding the Intensity of Effect values for each species-lifestage-activity combination (SLAC) within a section (Equation 3).

Equation 3

$$IED_{SecrtionX} = \sum_{SLAC=1}^{n} IE_{SLAC}$$

Examination of the Intensity of Effect Distribution values for individual sections is a useful and convenient method to identify specific locations within the state where numerous species-lifestages and activities interact. To illustrate the relative effect intensity distribution on a map, the range of scores observed were divided into three equally sized groups and assigned a symbol corresponding to low, medium or high. As part of the examination of regional differences, the state of Washington was divided into a grid that consisted of 28 equal area blocks (Blocks) that were 1 degree by 1 degree in length. Basic statistics were generated to examine the number of sections where effect intensity scores were observed as well as the range of scores observed within Blocks. Full results for the Intensity of Effect Distribution analysis for all activities analyzed are presented in Chapter 5.

2-2 Conservation Measures and Expected Outcomes

The potentially applicable conservation measures evaluated here were identified from a number of sources (e.g., B.C. Ministry of Agriculture and Lands, Washington Department of Transportation, U.S. Army Corps of Engineers) and varied considerably in terms of specificity for addressing threats to Covered Species; their potential for use as mitigation measures; and their potential to benefit species and reduce potential impacts to state-owned aquatic lands. The analysis of the measures and their expected outcomes focused on identifying and evaluating actions that would avoid and minimize potential effects to Covered Species in cost-effective manner. Because the conservation measures were general in nature and applied across a wide range of activities, this analysis was restricted to examining activity (or sub-groups if substantially different) and species groups rather than individual species.

Only avoidance and minimization conservation measures were included in the analysis because mitigation would be more effective if addressed across all activities and in a strategic manner based on species-specific “likelihood of survival and recovery.” The results of this analysis will allow Washington DNR to work with the services and pertinent stakeholders to determine the most efficient approach for any required mitigation.

The measures ultimately selected by the consulting team for each activity group/sub-group can generally be described as conditions or best management practices (BMPs) that would likely be required as part of current permitting processes for new facilities. Ranking criteria (Sub-section 2-2.1) were employed to ensure that each of the measures were:

- Effective in avoiding or minimizing potential effects on Covered Species and lifestages (reduce threats).
- Applicable across a wide range of Washington DNR authorized activities.
- Addressed operation and maintenance aspects of Washington DNR authorized activities (scope of the potential effects analyses).

This approach enabled us to characterize the reduction in potential effects to Covered Species from the application of a common environmental protection standard to all the authorizations within an activity group . It also provides a basis for examining how different activities can contribute to “a reasonable possibility of not jeopardizing the continued existence of a species” and assist in the recovery of that species with standard BMPs applied. The conservation measures selected here may also be used as the basis of a leasing best management practices manual.

2-2.1 Selection of conservation measures

A three-step filtering process was used to select the conservation measures:

- Identification and ranking of the initial pool of potentially applicable conservation measures for each of the nine activity groups defined in the Potential Covered Activities Technical paper (Washington DNR 2005b).
- Categorization and screening of the pool of identified conservation measures to determine whether measures could be classified as those which avoid, minimize, or mitigate potential effects. Avoidance and minimization measures were retained for possible inclusion in the expected outcomes analysis with those measures identified as mitigation retained as potential programmatic measures to be negotiated with the Services.
- Evaluation of the identified avoidance and minimization measures to determine if they would reduce identified direct or indirect effects to Covered Species (Chapter 4, Potential Effects).

Identification and Ranking of Possible Conservation Measures (Step 1)

An array of possibly applicable conservation measures were identified by Washington DNR scientists using relevant literature and professional judgment (B.C. Ministry of Agriculture and Lands 2005; EPA 2000; Hanson et al. 2003; Pacific Coast Shellfish Growers Association 2001; Pentec Environmental 2000; G3 Consulting Ltd. 2003; Title 220 Washington Administrative Code; Washington Department of Transportation 2004 and 2005; U.S. Fish and Wildlife Service 2003; United States Army Corps of Engineers 2005; Washington Department of Fish and Wildlife 1999). Conservation measures were retained for further analysis if they focused on the operations and maintenance of activity groups authorized by Washington DNR, with measures designed for specific projects modified to remove site-specific constraints and make them more generally applicable to the activity groups used throughout this project (e.g., Aquaculture, Overwater Structures).

The biological effectiveness of each measure was ranked by Washington Fish and Wildlife scientists using professional judgment, with each measure assigned an ordinal score of high (3), medium (2), or low (1), based upon the measures' ability to avoid, minimize, or mitigate direct or indirect effects to Covered Species. To reduce the subjectivity of ordinal scores, each conservation measure was reviewed and ranked by multiple Washington Fish and Wildlife biologists. The Biological Effectiveness Rank (BER) for each conservation measure was then calculated by summing the scores in each category (i.e., avoid, minimize) for each activity sub-group and then dividing by the number of Washington Fish and Wildlife scientists who ranked the effectiveness of the measure. Washington DNR scientists chose not to further analyze conservation measures with Biological Effectiveness Ranks of less than 1.5 due to their limited potential to provide biological benefit. Conservation measures that were limited to monitoring practices were also removed from the analysis at this point.

Categorization and Screening of Measures (Step 2)

In step 2, the consulting team screened the conservation measures to ensure they:

- Were general enough for standard application across the range of groups or sub-groups developed for the Potential Effects Analysis.
- Could be applied to the operation and maintenance of existing structures and facilities authorized by Washington DNR on state-owned aquatic lands.
- Addressed avoidance and minimization of effects rather than compensatory mitigation.

As discussed in Section 2-2, standard BMPs were desirable as they provided a mechanism to examine changes in effects across activity groups from the application of a common environmental protection standard. If conservation measures were considered too specific or oriented toward compensatory mitigation rather than avoidance or minimization, they were identified as "applicable to mitigation only".

Some conservation measures were slightly reworded by the consulting team to make them more broadly applicable, or changed to include operation or maintenance activities (rather than construction) so they could be used in the analysis. Other measures were very similar in content and were combined to create a single measure to assist in organization and consistency. If a measure was applicable only as mitigation, then it was neither carried forward in the pool of possibly applicable conservation measures nor included in the calculation of potentially affected habitat for the Expected Outcomes analysis (Chapter 6).

Evaluation of Measures Potential to Reduce Direct or Indirect (Step 3)

In Step 3, the remaining conservation measures were evaluated to determine whether the threats and potential direct and/or indirect effects identified in Chapter 4 of this paper could be reduced for each Covered Activity and Covered Species. As with the Potential Effects Analysis, this analysis focused on species threats as indicated by the magnitude of direct and indirect effects (ME) and ultimately the Intensity of Effects (IE). Because the conservation measures were general in nature, the analysis addressed species groups (e.g. birds) and activity groups (e.g. overwater structures) or sub-groups (e.g. docks and wharves within the overwater structures activity group) if the difference in the potential to reduce effects was substantial.

These "risk pathway" evaluations were based on the literature reviews conducted for the Covered Species Paper, Potential Covered Activities Technical Paper, Covered Habitat Technical Paper (Washington DNR 2007, 2005b, and 2005a), and the Potential Effects chapter of this paper (Chapter 4), as well as the professional opinion and experience of the consulting team. The codes in Table 2-8 were used to simplify the process of linking the conservation measures with the mechanisms for direct and indirect effects identified in the potential effects determination (sub-section 2-1.3). The Conservation Measure Ranks calculated in Step 1 were used as decision points in the final selection of conservation measures.

Table 2-8 - Direct and indirect effects analyzed by activity group and sub-group for Covered Species and lifestages

Mechanism	Assigned Code
Direct Effects	
Species Level	
Increased activity	DE1
Impair behavior/timing patterns	DE2
Physical harm or harassment	DE3
Habitat Level	
Air quality impairment (acute)	DE4
Water impairment (acute)	DE5
Sediment quality impairment (acute)	DE6
Permanent habitat destruction/displacement	DE7
Permanently inaccessible habitat	DE8
Indirect Effects	
Habitat loss	
Temporary destruction/displacement	IE1
Temporarily inaccessible	IE2
Habitat degradation	
Energy resource reduction	IE3

Mechanism	Assigned Code
Air quality impairment (chronic)	IE4
Water quality impairment (chronic)	IE5
Sediment quality impairment (chronic)	IE6
Reduction of structural habitat quality metrics	IE7

Before proceeding with the selection of conservation measures to be used in the Expected Outcomes Analysis (Chapter 6), both the total affected habitat and the percent of total habitat affected by each activity group for each Covered Species were reviewed from the Potential Effects Analysis (Chapter 4). If there was no indication of a significant overlap between an activity and a Covered Species lifestage, then the species was eliminated from further consideration in the Expected Outcomes Analysis for that activity. An initial review indicated that only a very small amount of pinto abalone habitat (≈ 25 acres) was affected by activities authorized by Washington DNR, therefore this species was excluded from further evaluation.

2-2.2 Characterizing expected outcomes

To characterize the Expected Outcomes of implementing the applicable conservation measures, the amount of Potentially Affected Habitat for each Covered Species was recalculated to account for the expected benefits of the conservation measures. The matrices used for determining the magnitude of effect (Sub-section 2-1.3) were expanded to include an estimate of the effectiveness of the chosen conservation measures using a net conservation measures index (NCMI) for *all* the applicable conservation measures that would be applied to each activity sub-group. The Net Conservation Measure Index was determined using a weight of evidence approach based on relevant literature and the analysts' professional experience as to whether the measure(s) could legitimately reduce the risks of direct and indirect effects. Like the assigned Effects Index values, the Net Conservation Measure Index was ranked on a 0 to 1 ordinal scale in 0.25 increments, however the scale was reversed with 0 equal to the measure being completely effective at eliminating all threats associated with a particular type of effect (e.g., habitat loss), 0.25 equal to a high level of effectiveness, 0.50 moderate effectiveness, 0.75 low effectiveness and 1 no effectiveness (Figure 2-11).

The Adjusted Effects Index (AEI) was then calculated by multiplying the assigned Effects Index for each activity group and applicable Covered Species' life stage by the Net Conservation Measure Index (NCMI) for the same activity and species (Equation 5). With lower Net Conservation Measure values leading to a greater reduction in the

Equation 5:

$$AEI = (EffectsIndex) x (NCMI)$$

magnitude of effects. Using the direct effect value for Sub-group A in Figure 2-11 as an example, if prior to applying conservation measures the Effects Index was 0.25 (low effect) and the estimated Net Conservation Measure Index was estimated as 0.75 (low effectiveness in eliminating effects), the Adjusted Effects Index becomes 0.19:

$$AEI = (0.25)x(0.75) = 0.19$$

The resulting Adjusted Effects Index was then used to recalculate the Magnitude of Effect for each species-lifestage-activity combination and the Potentially Affected Area (PAA) using Equation 2 and the adjusted Magnitude of Effect (ME).

Figure 2-11 - Typical example of effect index worksheet with net conservation measures index.

Species X	Sub-group A			Sub-group B		
Lifestage Y	Effects Index	Net Conservation Measure Index	Adjusted Effects Index	Effects Index	Net Conservation Measure Index	Adjusted Effects Index
Direct Effect						
Species level						
Increased activity	x			x		
Impair behavior/timing patterns	x			x		
Physical harm or harassment	x			--		
Assigned Effects Index Value	0.25	0.75	0.19	0.25	0.75	0.19
Habitat level						
Air quality impairment (acute levels)	--			--		
Water impairment (acute levels)	--			--		
Sediment quality impairment (acute levels)	--			--		
Permanent habitat destruction/displacement	x			--		
Permanently inaccessible habitat	x			--		
Assigned Effect Index Value	0.25	0.75	0.19	0	0.75	0.00
Indirect Effect						
Habitat loss						
Temporary destruction/displacement	x			x		
Temporarily inaccessible	x			x		
Assigned Effect Index Value	0.25	1	0.25	0.25	1	0.25
Habitat degradation						
Energy resource reduction	x			--		
Air quality impairment (chronic levels)	--			--		
Water quality impairment (chronic levels)	--			--		
Sediment quality impairment (chronic levels)	--			--		
Reduction of structural habitat quality metrics	x			--		
Assigned Effect Index Value	0.25	0.75	0.19	0	0.75	0.00
Average Direct Effects Index	**0.25**		**0.19**	**0.13**		**0.09**
Average Effects Index	**0.25**		**0.20**	**0.13**		**0.11**
Magnitude of Effects	**0.25**		**0.20**	**0.13**		**0.11**
Effects Index Scale		**Conservation Measures Effectiveness Scale**				
Scale: 1= total loss; 0.75 = high effect; 0.5 = moderate effect;		1 = Trace or no Effectiveness				
0.25 = low effect; 0 = trace effect		0.75 = Low Effectiveness				
x = Sources of effect		0.5 = Medium Effectiveness				
-- = Absence of effect		0.25 = High Effectiveness				
NA = Absence of interaction		0 = Elimination of Effect				
[1] Use direct effect value if greater						

2-3 Database improvements

While the Potential Effects Model was created using typical activity descriptions and size estimates (Section 2-1.1, Descriptive Data), it was also designed to use explicit spatial data as more became available and to allow the inclusion of additional authorizations.

To improve the precision of the Potentially Affected Area estimates used in Washington DNR's ESA decision making process, several refinements were made to the spatial data. In addition, an updated version of the database was created that includes only those species and activities proposed for coverage under Washington DNR's Aquatic Lands

Habitat Conservation Plan (HCP). The following specific improvements were made to the original database:

- All use authorization data has been updated and is current as of June 2007.
- Ecosystem and water body names have been added for all use authorizations.
- Wherever possible, typical activity size estimates have been replaced by explicit size information for all Covered Activities.
- Unauthorized docks digitized during the creation of a state-wide GIS "Overwater Structures" data layer were added.

The resulting information is the basis of the affected habitat estimates presented in Chapter 5.

3. Spatial and Temporal Screen Results

This section describes the results of the Spatial and Temporal Screen conducted as Step Two of the Potential Effects Analysis (Figure 2-1). Although a total of 42 species were deemed to have sufficient information to undergo the screening analysis, only 35 of those species have sufficient state or federal protection to be addressed here. Table 3-1 provides a summary of the coverage category recommendations and the changes in coverage resulting from the screen analysis, with 22 species assigned to the Evaluation category and 20 species assigned to the Covered category. In 2006, the Northern pinto abalone was removed from the list of covered species due to the small amount of habitat potentially affected by covered activities and the inability of Washington DNR to address the species primary threat – overfishing. At the same time three additional species were added either as a result of discussions with the Services or due to changes in their listing status. Appendix E illustrates the spatial overlap between activity sub-groups and species habitat (by lifestage) and includes the numeric rank for the overlap; with Appendix F providing the percentage of townships with habitat that are potentially affected by at least one activity sub-group for each species lifestage and the corresponding numeric rank. Potential to affect ranks are presented at the end of this chapter in Table 3-2.

Table 3-1 - Screen results for the species coverage recommendations. Species not addressed in this chapter are indicated in italics, with changes in coverage as a result of the analysis indicated in bold.

Group	Species	Coverage Recommendation		Listing Status/Rank	
		Original	Screen	Federal	State
Amphibians & Reptile	*Coastal tailed frog*	*Evaluation*	*Evaluation*	*None*	*None*
	Columbia spotted frog	Covered	Covered	Concern	Candidate
	Northern leopard frog	Covered	Covered	Concern	Endangered
	Oregon spotted frog	Evaluation	Evaluation	Candidate	Endangered
	Western toad	**Evaluation**	**Covered**	**Concern**	**Candidate**
	Western pond turtle	**Evaluation**	**Covered**	**Concern**	**Endangered**
Birds	Bald Eagle	Covered	Covered	Delisted	Threatened
	Black tern	Covered	Covered	Concern	None

Group	Species	Coverage Recommendation		Listing Status/Rank	
		Original	Screen	Federal	State
	Brown pelican	Evaluation	Evaluation[1]	Endangered	Endangered
	Common loon	Covered	Covered	None	Sensitive
	Common murre	**Covered**	**Evaluation**	**None**	**Candidate**
	Eared grebe	*Evaluation*	*Evaluation*	*None*	*None*
	Harlequin duck	Covered	Covered	None	None
	Marbled murrelet	Covered	Covered	Threatened	Threatened
	Tufted puffin	**Covered**	**Evaluation**	**Concern**	**Candidate**
	Western snowy plover	Covered	Covered	Threatened	Endangered
Fish	Brown rockfish	Evaluation	Evaluation	Concern	Candidate
	Bull trout/Dolly Varden	Covered	Covered	Threatened	Candidate
	Chinook salmon	Covered	Covered	Endangered or Threatened	Candidate
	Chum salmon	Covered	Covered	Threatened	Candidate
	Coastal cutthroat	Covered	Covered	None	None
	Coho salmon	Covered	Covered	Concern	None
	Copper rockfish	Evaluation	Evaluation	Concern	Candidate
	Olympic mudminnow	*Evaluation*	*Evaluation*	*None*	*Sensitive*
	Pacific cod	Evaluation	Evaluation	Concern	Candidate
	Pacific hake	Evaluation	Evaluation	Concern	Candidate
	Pacific herring (Cherry Point, Discovery Bay)	Evaluation	Evaluation	Candidate	Candidate
	Pink salmon	**Evaluation**	**Covered**	**None**	**None**
	Pygmy whitefish	*Evaluation*	*Evaluation*	*None*	*Sensitive*
	Quillback rockfish	Evaluation	Evaluation	Concern	Candidate
	Sockeye salmon (inc. kokanee)	Covered	Covered	Endangered	Candidate

[1] The brown pelican and white sturgeon were upgraded to Covered Species after the Potential Effects Analysis was completed.

Group	Species	Coverage Recommendation		Listing Status/Rank	
		Original	Screen	Federal	State
	Steelhead	Covered	Covered	Endangered or Threatened	Candidate
	Walleye pollock	Evaluation	Evaluation	Concern	Candidate
	White sturgeon	*Evaluation*	*Evaluation*[1]	*None*	*None*
	Green sturgeon (Southern DPS)	*Watch*	*Watch*[2]	*Endangered*	*None*
Invertebrates	Olympia oyster	Evaluation	Evaluation	None	Candidate
	Pinto (Northern) abalone	Covered	Covered[3]	Concern	Candidate
Marine Mammals	Humpback Whale	Evaluation	Evaluation	Endangered	Endangered
	Southern resident orca	Covered	Covered	Endangered	Endangered
	Northern sea otter	Evaluation	Evaluation	Concern	Endangered
Plants	*Persistentsepal yellowcress*	*Evaluation*	*Evaluation*	*None*	*None*
	Water lobelia	*Evaluation*	*Evaluation*	*None*	*None*
	Water howellia	**Covered**	**Evaluation**	**Threatened**	**Threatened**

3-1 Amphibians and Reptile

3-1.1 Covered Species

COLUMBIA SPOTTED FROG

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 23 activity sub-groups that have the potential to overlap spatially with Columbia spotted frog habitat during all lifestages

[2] Green sturgeon were added as Covered Species after their listing in 2006.

[3] Northern pinto abalone were downgraded to Evaluation Species after the Potential Effects Analysis was completed due to minimal spatial overlap with covered activities and Washington DNR's inability to address the primary threat for this species – overfishing.

(Appendix E), resulting in a “medium” species/activity overlap rank. Of the 358 townships where Columbia spotted frogs occur, 120 (34%) overlap spatially with at least one Washington DNR activity (Appendix F). This results in a “low” coincident habitat rank and a “low” potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern (over part of its range)
- State: Candidate
- Natural Heritage Program: Apparently secure globally; Apparently secure in Washington, with many occurrences

Population Trends

Populations are currently stable within Washington State, but are in decline in neighboring states.

Coverage Category Status

While the Covered Species paper determined a “high” potential effect from authorized activities resulting in the recommendation to treat the Columbia spotted frog as a Covered Species, the screen analysis indicate a “low” potential to affect. However, Columbia spotted frogs are highly dependent upon freshwater wetlands, which have a “high” potential to be affected by activity sub-groups and similar species are recommended as Covered in this analysis (northern leopard frog, western toad) and as a result the Columbia spotted frog would likely benefit from inclusion with little to no additional effort or cost. Therefore, professional judgment justifies a “high” potential for effect and the continued recommendation of the Columbia spotted frog as a Covered Species.

NORTHERN LEOPARD FROG

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 15 activity sub-groups that spatially overlap with northern leopard frog habitat for the adult migration and spawning lifestages (Appendix E), resulting in a “low” species/activity overlap rank. Although the screen analysis did not identify any spatial overlap between authorized activities and habitat during the remaining lifestages, because of the coarseness of the screen analysis and the difficulties associated with determining amphibian presence, it is possible that potential overlap was understated.

Of the 122 townships where northern leopard frogs occur, 65 (or 53%) have overlap with at least one activity sub-group (Appendix F). This results in a coincident habitat rank of “medium” and a “low” potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Endangered

- Natural Heritage Program: Demonstrably secure globally; critically imperiled (5 or fewer occurrences) in the state of Washington.

Population Trends

Populations are declining and there are currently only two areas within Washington where presence of northern leopard frogs has been confirmed.

Coverage Category Status

While the Covered Species paper determined a “high” potential effect from Washington DNR activities and recommended the northern leopard frog as a Covered Species, the screen analysis indicates a “low” potential to affect. However, similarly to other amphibians addressed in this analysis, northern leopard frogs are highly dependent upon freshwater wetlands, which have a “high” potential to be affected by Washington DNR activities. Furthermore, the northern leopard frog is extremely rare in Washington and is currently listed as endangered by Washington Fish and Wildlife and critically imperiled by the Washington Natural Heritage Program. As a result, professional judgment justifies a utilizing a “high” potential for effect and continuing to recommend the northern leopard frog as a Covered Species

WESTERN TOAD

Spatial Overlap and Coincident Habitat Ranks

There are 30 activity sub-groups that spatially overlap with western toad habitat during all three lifestages (Appendix E), resulting in a “medium” species/activity overlap rank. Of the 833 townships in which western toads occur (all three lifestage groups), 359 (43%) overlap spatially with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of “medium” and a “medium” potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Secure globally; rare or uncommon in the state.

Populations Trends

Western toad populations are declining throughout its range in Western Washington, with trends in Eastern Washington unknown.

Coverage Category Status

The screen analysis confirms this species original categorization as an Evaluation Species because of a “medium” potential for activities authorized by Washington DNR to affect its habitat. However, due to the low resolution of the data used in the screen analysis and population trends qualitative metrics potentially affecting the species were examined further. Upon review, professional judgment determined that declining populations and a heightened sensitivity to anthropogenic effects justify categorizing the western toad as a Covered Species.

WESTERN POND TURTLE

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 28 activity sub-groups that have coincide with western pond turtle habitat during the adult foraging and overwintering lifestages (Appendix E), resulting in a "medium" species/activity rank. Of the townships that are utilized during the more sensitive foraging/nesting lifestage, 64% have overlap with at least one activity sub-group (Appendix F). This results in a coincident habitat rank of "medium" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Endangered
- Natural Heritage Program: Globally very rare or local throughout its range; or found locally in a restricted range (21-100 occurrences). This species is also critically imperiled in Washington (5 or fewer occurrences).

Population Trends

Western pond turtle populations are declining throughout their range.

Coverage Category Status

Because Washington DNR activities were determined to have a "medium" potential to affect the habitat of the Western pond turtle; this species was originally classified as an Evaluation Species. Although the numerical ranking criteria derived from the screen analysis supports the initial classification, the low resolution of the screen analysis and the organisms decreasing populations led to further examination of qualitative metrics potentially affecting the species. Upon review, it has been determined that declining populations and a heightened sensitivity to anthropogenic effects justify categorizing western pond turtle as a Covered Species.

3-1.2 Evaluation Species

OREGON SPOTTED FROG

Spatial Overlap and Coincident Habitat Ranks

As determined by the screen analysis, there are no activity sub-groups that have the potential to spatially overlap with Oregon spotted frog habitat (Appendix E). However, because this species is highly aquatic, occurs in a variety of freshwater habitats, and amphibian presence is difficult to determine, there is a possibility of missed activity/habitat overlap. As a result a "low" species/activity overlap and coincident habitat rank was assigned, with the potential for activities authorized by Washington DNR also ranked "low" (Table 3-2).

Status and Rank

- Federal: Candidate
- State: Endangered

- Natural Heritage Program: Imperiled globally (6 to 20 occurrences); critically imperiled in the state (5 or fewer occurrences)

Population Trends
The few existing populations in Washington are decreasing.

Coverage Category Status
This species was originally categorized as an Evaluation Species, in part due to a "medium" potential for effect from activities authorized by Washington DNR. While the numerical ranking criteria derived from the screen analysis indicate a "low" potential to affect, it appears that there is little to no overlap of Washington DNR activities and habitat. Therefore, professional judgment justifies utilizing a "low" potential for effect and continuing to recommend the Oregon spotted frog should remain an Evaluation Species.

3-2 Birds

3-2.1 Covered Species

BALD EAGLE

Spatial Overlap and Coincident Habitat Ranks
The species-activity overlap analysis identified 33 activity sub-groups that have the potential to overlap spatially with bald eagle habitat during both lifestages (Appendix E), resulting in a "high" species/activity rank. Of the 1,016 townships where bald eagles occur, 489 (48%) overlap with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of "medium" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank
- Federal: Delisted
- State: Threatened
- Natural Heritage Program: Apparently secure globally; apparently secure, with many occurrences in Washington.

Population Trends
Bald eagles populations are increasing and the species was proposed for delisting in 1999.

Coverage Category Status
The species paper determined a "high" potential effect from Washington DNR activities resulting in the recommendation to treat bald eagles as a Covered Species. The screen analysis also indicates a "high" potential to affect, which combined with the species federal status, as threatened confirms the original coverage recommendation.

BLACK TERN

Spatial Overlap and Coincident Habitat Ranks

There are 22 activity sub-groups that spatially overlap with black tern habitat during both lifestages (Appendix E), resulting in a "low" species/activity rank. Of the 396 townships where black terns occur, 128 (32%) have overlap with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of "low" and a "low" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Monitored
- Natural Heritage Program: Apparently secure globally; imperiled (6 to 20 occurrences), very vulnerable to extirpation in Washington.

Population Trends

Population levels are currently unclear within the state of Washington but are in decline throughout its range.

Coverage Category Status

The species paper determined a "high" potential effect from Washington DNR activities resulting in the recommendation to treat the black tern as a Covered Species. The numerical ranking criteria derived from the screen analysis indicate a "low" potential to affect. However, due to low data resolution used in the screen, population trends and other qualitative metrics were examined further. Black terns are highly dependent upon freshwater wetlands, which have a "high" potential to be affected by Washington DNR activities. In addition, populations are decreasing and non-breeding adults are currently ranked as imperiled with a "high" risk of extirpation by the Natural Heritage Program. Therefore, professional judgment justifies continuing the recommendation that black terns be treated as a Covered Species is confirmed.

BROWN PELICAN

Spatial Overlap and Coincident Habitat Ranks

There are 33 activity sub-groups that overlap spatially with brown pelican habitat during the non-breeding lifestage, resulting in a "high" species/activity overlap rank (Appendix E). Because brown pelicans do not breed in Washington State, there is no potential for spatial overlap between activities and habitat during the nesting lifestage. Of the 228 townships that post-breeding and non-breeding adult and juvenile brown pelicans occur in, 171 (75%) overlap with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of "high" and a "high" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Endangered

Note: currently the entire brown pelican species, *Pelicanus occidentalis*, and the California subspecies, *Pelicanus occidentalis californicus*, the brown pelicans most likely occurring in Washington, are under U.S. Fish and Wildlife Service status review for delisting (71 Federal Register 100:29908-29910, May 24, 2006).

- State: Endangered

- Natural Heritage Program: Apparently secure globally; rare and regularly occurring post-breeding and non-breeding adults and juveniles in Washington. Note: there may be indications that brown pelicans are "on the verge of nesting in the Columbia River estuary" (Wright et al. 2002 cited in Wahl et al. 2005).

Population Trends
Populations are increasing in Washington State.

Coverage Category Status
The brown pelican was originally categorized as an Evaluation Species because the species paper described a "medium" potential effect from Washington DNR activities. However, screen analysis indicates a "high" potential for activities to affect brown pelican habitat. Post-breeding and non-breeding adults and juveniles are primarily found on the outer coast or within the Straits. Potential effects are generally related to pollution, disturbance (displacement or attraction) from foraging or roosting habitats, and to prey abundance. As a result, brown pelican are considered as a Covered Species.

COMMON LOON

Spatial Overlap and Coincident Habitat Ranks
The species-activity overlap analysis identified 33 activity sub-groups that have the potential to overlap spatially with common loon habitat during the non-breeding lifestage and 30 activity sub-groups during the nesting lifestage (Appendix E), resulting in "high" (non-breeding) and "medium" (nesting) spatial activity/habitat overlap ranks. Common loons are found in 1,016 townships with non-breeding adults potentially interacting with Washington DNR managed activities in 406 (40%) townships, and the nesting life stage 141 (14%) (Appendix F). This results in coincident habitat ranks of "medium" and "low" respectively, with the potential for activities authorized by Washington DNR to affect this species also ranked "medium" and "low"(Table 3-2).

Status and Rank
- Federal: Not listed

- State: Candidate

- Natural Heritage Program: Breeding birds are imperiled (6 to 20 occurrences) and very vulnerable to extirpation in Washington; Non-breeding birds are globally secure and demonstrably secure in the state.

Population Trends
Common loon populations are decreasing globally, with no clear trend within the state of Washington.

Coverage Category Status

Although the Covered Species paper determined a “high” potential effect from Washington DNR activities, the screen analysis indicates a “medium” potential to affect. However, because common loon populations are decreasing globally and breeding adults are listed as imperiled within Washington State, professional judgment justifies a “high” potential for effect and continuing to recommend covered loons as a Covered Species.

HARLEQUIN DUCK

Spatial Overlap and Coincident Habitat Ranks

There are 33 activity sub-groups that overlap spatially with harlequin duck habitat during the non-breeding lifestage and 20 activity sub-groups that overlap spatially during the nesting lifestage (Appendix E), resulting in “high” and “medium” species/activity ranks respectively. Harlequin ducks are found in 204 townships with non-breeding adults overlapping with Washington DNR activities in 132 (65%) and 73 (36%) townships during the nesting lifestage (Appendix F). This results in coincident habitat ranks of “medium” and “low” respectively, with the potential for activities authorized by Washington DNR to affect the species ranked “medium” for the wintering form and “low” for the nesting form (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Not listed
- Natural Heritage Program: Apparently secure globally; breeding birds are imperiled in Washington (6 to 20 occurrences) and very vulnerable to extirpation, with non-breeding birds rare or uncommon (21 to 100 occurrences).

Population Trends

Populations are increasing in Washington.

Coverage Category Status

Although the Covered Species paper determined a “high” potential effect from Washington DNR activities, the screen analysis indicates a “medium” potential to affect. However, harlequin ducks utilize most aquatic habitat types in the state of Washington and may therefore have a higher potential for effect than the resolution of the screen data supports. In addition, breeding harlequins are listed as imperiled by the Washington Natural Heritage Program due to a small population in Washington. Therefore professional judgment justifies continuing to utilize a “high” potential for effect and leaving harlequin duck as a Covered Species.

MARBLED MURRELET

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 33 activity sub-groups that have the potential to overlap spatially with marbled murrelet habitat during both lifestages (Appendix E), resulting in a “high” species/activity overlap rank. Of the 420 townships where marbled murrelets occur, 174 (41%) overlap with at least one activity sub-group (Appendix F). This results in a coincident habitat rank of “low” and a “medium” potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Threatened
- State: Threatened
- Natural Heritage Program: Either very rare throughout its range or found locally in a restricted range (21 to 100 occurrences) globally; rare or uncommon (21 to 100 occurrences) in Washington.

Population Trends

Murrelet populations are decreasing throughout California, Oregon and Washington.

Coverage Category Status

The screen analysis confirms the Covered Species paper's preliminary determination of "high" potential effect to murrelets from activities authorized on state-owned aquatic lands. Based on the birds listing status and the screen analysis, marbled murrelet should remain a Covered Species.

WESTERN SNOWY PLOVER

Spatial Overlap and Coincident Habitat Ranks

Due to the limited range of the western snowy plovers, the species-activity overlap analysis identified 11 activity sub-groups that have the potential to overlap spatially with western snowy plover habitat during both lifestages (Appendix E), resulting in a "low" species/activity overlap rank. Of the 13 townships where western snowy plovers are known to occur, 12 (92%) overlap with at least one activity sub-group (Appendix F). This results in a coincident habitat rank of "high" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Threatened
- State: Endangered
- Natural Heritage Program: Apparently secure globally; critically imperiled (5 or fewer occurrences) in the state of Washington.

Population Trends

Populations are declining throughout the species' range.

Coverage Category Status

While the Covered Species paper determined a "high" potential effect from activities authorized by Washington DNR, the screen analysis indicates activities have a "medium" potential to affect the species. While it is clear that there are only a few types of activities that have the potential to effect plovers, 92 percent of their habitat may be affected by those activities. As a result of the high percentage of habitat potentially affected and the bird's federal and state status as Endangered the western snowy plover is recommended to remain a Covered Species.

3-2.2 Evaluation Species

COMMON MURRE

Spatial Overlap and Coincident Habitat Ranks

All 33 activity sub-groups spatially overlap with common murre habitat during both lifestages (Appendix E), resulting in a "high" species/activity overlap rank. Of the 514 townships in which both lifestages of common murres occur, only 162 (32%) have overlap with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of "low" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Demonstrably secure globally; apparently secure with many occurrences of breeding birds and demonstrably secure nesting birds in the state of Washington.

Populations Trends

Although difficult to assess due to year -to -year variability, populations appear to be declining slightly throughout the common murre's range in Washington.

Covered Category Status

This species was originally categorized as a Covered Species because the Covered Species paper determined that activities authorized by Washington DNR have a "high" potential to affect its habitat. However, the numerical ranking criteria derived from the screen analysis indicate only a "medium" potential to affect. While the low resolution of the data used in the screen analysis may lead to an underestimation of the spatial overlap, common murres nest on cliff tops that are well protected from potential effects from Washington DNR activities and it is assumed that even with a "high" potential overlap effects will primarily involve prey abundance. In addition, five of the six murre colonies in Washington are located in marine sanctuaries offering a high level of protection. As a result, professional judgment was utilized in reclassifying the common murre as an Evaluation Species.

TUFTED PUFFIN

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 17 activity sub-groups that have the potential to spatially overlap with tufted puffin habitat during the nesting lifestage, and only one activity sub-group that has the potential to affect the wintering lifestage (Appendix E). As a result, the species/activity overlap rank is "low" for both lifestages. Tufted puffins are found in 208 townships with nesting life stages interacting with authorized activities in 112 (54%) and wintering puffins in 2 (1%) townships (Appendix

F). This results in coincident habitat ranks of “medium” and “low” respectively, with a “low” potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Candidate
- Natural Heritage Program: Demonstrably secure globally; apparently secure with many occurrences of breeding and wintering birds in Washington State.

Population Trends

Populations are declining in the state of Washington.

Coverage Category Status

The tufted puffin was originally categorized as a Covered Species because the species was determined to have a “high” potential to be affected by activities authorized by Washington DNR. However, the numerical ranking criteria derived from the screen analysis indicated a “low” potential to affect. While the resolution of the screen data may lead to an underestimation of the potential to affect, puffins nest primarily on the outer coast or within the Straits and rarely venture inland. As a result, potential effects would primarily involve prey abundance rather than direct interactions with activity sub-groups and professional judgement was used to reclassify the tufted puffin as an Evaluation Species.

3-3 Fish

3-3.1 Covered Species

PACIFIC SALMON, TROUT, AND CHAR (BULL TROUT / DOLLY VARDEN, CHINOOK, CHUM, COASTAL CUTTHROAT TROUT, SOCKEYE, STEELHEAD)

Although each of the species addressed in this section were evaluated separately during the screen analysis, similar results enable them to be treated together. All seven species also exhibit similar habitat use and life histories, including identical lifestage divisions adult migration/spawning/marine rearing; freshwater rearing/outmigration; and incubation/emergence. In addition, each of the species were originally treated as Covered in the Covered Species Technical Paper (Washington DNR 2005a). Pink salmon are not included in the Pacific Salmon, Trout, and Char complex because they were originally treated as Evaluation Species.

Spatial Overlap and Coincident Habitat Ranks

Thirty-three activity sub-groups overlap spatially with the adult and juvenile lifestages of this species complex, with the overlap for the incubation/emergence lifestage ranging from 22 to 29. As a result, the adult and juvenile phases have a species/activity overlap rank of “high”, with the overlap for the incubation/emergence lifestage ranked “medium”.

The percentage of potential habitat affected for each species during the incubation/emergence lifestage ranges from 16 to 30 percent, resulting in “low” coincident habitat ranks. Coincident habitat by township for each species during the adult migration/spawning/marine rearing and freshwater rearing/outmigration lifestages ranges from 39 to 65 percent (Appendix F). This results in coincident habitat ranks that range from “low” to “medium”, with the potential for activities authorized by Washington DNR to affect this species ranked “medium” for adults and juveniles and “low” for incubation/emergence lifestages (Table 3-2).

Status and Rank

- Federal: Threatened - Bull trout/Dolly Varden, Chum, Steelhead; Threatened/Endangered - Chinook , Sockeye; Species of Concern - Coho; Not listed - Coastal Cutthroat.
- State: Candidate Species - Bull trout/Dolly Varden, Chinook, Chum, Sockeye, and Steelhead; Not listed – Coho, Coastal Cutthroat.
- Natural Heritage Program: Although bull trout are globally ranked as either very rare and local throughout its range or found locally in a restricted range (21 to 100 occurrences), all other species are globally ranked as apparently or demonstrably secure throughout their respective ranges. Within Washington Chinook, chum, coho, sockeye and bull trout are considered rare or uncommon (21 to 100 occurrences); Steelhead are ranked as demonstrably secure; and coastal cutthroats as uncertain

For more detailed information concerning the status and rank for each species, refer to the Covered Species Technical Paper (Washington DNR 2005a).

Population Trends

Population trends for pacific salmon, trout and char are as follows:

- Bull trout - For many stocks in Washington population, trends are unclear.
- Chinook, chum, coastal cutthroat, sockeye, and steelhead - General populations are considered to be declining.
- Coho salmon - Although some stocks are considered to be depressed but stable, in general, populations are considered to be declining.

Coverage Category Status

The species paper determined a “high” potential effect from Washington DNR activities, resulting in the recommendation to treat all species considered pacific salmon, trout, and char as Covered Species. The numerical ranking criteria derived from the screen analysis indicates a “high” potential to affect two of three lifestages for all species. Because most of the species are listed under the Endangered Species Act and all populations are either depressed or declining, the seven species in this group should remain as Covered Species.

PINK SALMON

Spatial Overlap and Coincident Habitat Ranks

Similarly to the Pacific Salmon, Trout, and Char group, the species-activity overlap analysis identified 33 activity sub-groups that overlap spatially with pink salmon habitat during both the adult and juvenile lifestages, resulting in a "high" species/activity rank (Appendix E). While there are no activity sub-groups with a spatial overlap for the incubation and egg lifestage, the low resolution of the screen data may not capture some degree of spatial overlap for this sensitive lifestage.

Of the 332 townships that are utilized by the adults and juveniles, 171 (52%) have overlap with least one activity sub-group (Appendix F). This results in a coincident habitat rank of "medium" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: No rank
- Natural Heritage Program: Globally secure; Imperiled in Washington, vulnerable to extirpation

Population Trends

Populations are stable in Washington State, except for those found in drainages along the Strait of Juan de Fuca.

Coverage Category Status

Because pink salmon are not federally listed and Washington DNR activities were determined to have a "medium" potential to affect, they were originally categorized as an Evaluation Species. However, the screen results indicate a "high" potential for activities authorized by Washington DNR to affect two of three lifestages for pink salmon. In addition, similar species are Covered (Chinook, chum, coho, and sockeye salmon) and pink salmon would gain benefits from inclusion with little to no additional effort or cost to appropriate conservation measures. Therefore, the coverage category has been upgraded to Covered Species.

GREEN STURGEON

Spatial Overlap and Coincident Habitat Ranks

Because of the lack of spatial data for green sturgeon, no spatial overlap analysis was conducted for this species.

Status and Rank

- Federal: Southern Distinct Population Segment – Endangered; Northern Distinct Population segment - Not Listed
- State: No rank
- Natural Heritage Program: Globally restricted in its range; Imperiled in Washington, vulnerable to extirpation

Population Trends
Current population data is inadequate to assess the population status of green sturgeon (Adams et al. 2002; 50 C.F.R. 223-224, 2003) in Washington.

Coverage Category Status
Although green sturgeon were Green sturgeon were initially recommended as an Evaluation Species, the southern population was listed as Endangered in 2006. As a result of the listing and in consultation with the NOAA Fisheries, the species was upgraded to Covered status.

WHITE STURGEON

Spatial Overlap and Coincident Habitat Ranks
There are 33 activity sub-groups that spatially overlap with white adult sturgeon habitat, with 31 sub-groups overlapping with juvenile habitat (Appendix E), resulting in a "high" species/activity rank for all lifestages. Of the 445 townships where the species occur occur, 291 (65%) of the townships used by adults have overlap with at least one Washington DNR activity and 154 (35%) overlap with juvenile habitat (Appendix F). This results in a coincident habitat rank of "medium" and a "medium" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not Listed
- State: Not Listed
- Natural Heritage Program: Globally secure; Within Washington, breeding populations are uncommon, with non-breeding adults considered secure but of long-term concern.

Population Trends
Lower Columbia River populations appear to have declining recruitment levels, with impounded pollutions relatively abundant in 3 locations on the mainstem Columbia (above Bonneville, the Dalles and Grand Coulee Dams) (Miller et al. 2005) and in 2 locations on the Snake River (above the Lower Granite Dam) (Miller et al. 2005). The remaining 19 populations are considered depressed.

Coverage Category Status
Similarly to Pink salmon, the decision to add green sturgeon as a Covered Species provided benefit to white sturgeon from inclusion with little to no additional effort or cost to appropriate conservation measures. Therefore, the coverage category has been upgraded to Covered Species.

3-3.2 Evaluation Species

BROWN ROCKFISH

Spatial Overlap and Coincident Habitat Ranks
There are 31 activity sub-groups that spatially overlap with brown rockfish habitat during its three lifestages (Appendix E), resulting in a "high" species/activity rank for all

lifestages. Of the 63 townships where brown rockfish occur, 62 (98%) have overlap with at least one Washington DNR activity (Appendix F). This results in a coincident habitat rank of "high" and a "high" potential for activities authorized by Washington DNR activities to affect this species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Unclear.

Coverage Category Status

The species paper determined a "medium" potential for effects to brown rockfish from activities authorized by Washington DNR, resulting in a classification as an Evaluation species. Because the numerical ranking criteria derived from the screen analysis indicate a "high" potential to affect brown rockfish habitat, qualitative metrics were examined further to compensate for the low data resolution used in the screen analysis. The review indicated little direct take as a result of the activity sub-groups and that most effects would be indirect encompassing a relatively small percentage of available habitat. As a result, professional judgment supports the brown rockfish remaining an Evaluation Species.

COPPER ROCKFISH

Spatial Overlap and Coincident Habitat Ranks

Thirty-three 32 activity sub-groups have the potential to spatially overlap with juvenile and larval copper rockfish habitat, with 30 sub-groups overlapping with adult habitat (Appendix E). This results in a "medium" species/activity rank for adults and a "high" rank for the remaining lifestages.

Copper rockfish are found in 186 townships, with benthic juveniles and pelagic larvae interacting with activities closer to shore and adults with those that are further offshore. As a result of these behavioral differences, benthic juveniles and pelagic larvae overlap spatially in 145 (78%) townships, while adults co-occur with Washington DNR activities in only 107 (58%) townships (Appendix F). This results in coincident habitat ranks of "high" and "medium respectively, with the potential for activities authorized by Washington DNR activities to affect this species ranked as "medium" for adults and "high" for juveniles and larvae (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Populations are declining in Puget Sound, with trends on the outer coast of Washington unknown.

Coverage Category Status

While the species paper determined a "medium" potential effect from activities authorized by Washington DNR, resulting in copper rockfish being classified as an Evaluation species, the screen analysis indicates a "high" potential to affect. As a result, qualitative metrics was examined further to compensate for potential interactions missed due to the low resolution of data used in the screen analysis. The review indicated little direct take of individuals or habitat as a result of Washington DNR activities and that most effects would be indirect, encompassing a relatively small percentage of available habitat. Based on professional judgment, copper rockfish are recommended to continue as an Evaluation Species.

PACIFIC COD

Spatial Overlap and Coincident Habitat Ranks

While the species-activity overlap analysis identified 17 activity sub-groups that overlap spatially with Pacific cod habitat during the spawning lifestage, the screen found no overlap with either the pelagic larvae and egg lifestages (Appendix E). However, because species presence is difficult to determine during the larval and egg stages there is a possibility of missed activity/habitat overlap and a "low" species/activity rank was assigned to all lifestages.

Of the 176 townships where adults occur, 109 (62%) have overlap with at least one Washington DNR activity (Appendix F), resulting in a "medium" coincident habitat rank and a "low" potential for activities authorized by Washington DNR to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Pacific cod populations are decreasing throughout the species range in Washington.

Coverage Category Status

The species paper determined a "medium" potential effect from Washington DNR activities on Pacific cod, resulting in the Evaluation classification. However, the numerical ranking criteria derived from the screen analysis indicates a "low" potential to affect and as a result, qualitative metrics were examined to address potential interactions missed due to data resolution. The review determined that there would be little direct take of individuals or habitat as a result of Washington DNR activities, and that most effects would be indirect, encompassing a relatively small percentage of available habitat. As result, Pacific cod are recommended to continue as an Evaluation Species.

PACIFIC HAKE

Spatial Overlap and Coincident Habitat Ranks

While 17 activity sub-groups were identified as having a spatial overlap with Pacific hake habitat during the adult/spawning and the pelagic juvenile lifestages, the screen identified no sub-groups that had the potential to affect the benthic juvenile lifestage (Appendix E). However, because species presence is difficult to determine, there is a possibility of a missed activity/habitat overlap and a "low" activity/species overlap rank was assigned the juvenile lifestage. The activity/species overlap rank for both adults and larvae is also "low".

Of the 176 townships where adults and pelagic juveniles occur, 109 (62%) have overlap with at least one Washington DNR activity (Appendix F), resulting in a "medium" coincident habitat rank and a "low" potential for activities authorized by Washington DNR to affect this species (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Population trends are decreasing throughout its range in Washington.

Coverage Category Status

Pacific hake were initially determined to have a "medium" potential effect from Washington DNR activities, resulting in a classification as an Evaluation species. Because the numerical ranking criteria derived from the screen analysis indicated a "low" potential to affect, qualitative metrics were examined further to compensate for potential interactions missed due to the resolution of the data used in the screen analysis. The review found that there would be little direct effect to individuals or habitat as a result of Washington DNR activities, with most effects indirect and encompassing a relatively small percentage of available habitat. As a result, Pacific hake should remain an Evaluation Species.

PACIFIC HERRING

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 30activity sub-groups that have the potential to overlap spatially with pacific herring habitat during all lifestages (Appendix E), resulting in a "high" species/activity rank for all lifestages. Of the 80 townships where herring occur, 77 (96%) have overlap with at least one Washington DNR activity (Appendix F) resulting in ranks of "high" for coincident habitat and the potential for activities authorized by Washington DNR to affect the species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate

- Natural Heritage Program: Not ranked

Population Trends

Population trends In Washington are stock dependent and vary from stable to declining.

Coverage Category Status

While the species paper determined a “medium” potential effect from Washington DNR activities, recommending Pacific herring be treated as an Evaluation Species, the ranking criteria applied to the screen analysis indicates a “high” potential to affect. As a result, qualitative metrics were examined further to compensate for potential interactions missed due to data resolution. The review indicated that there will be little direct effect to individuals or habitat as a result of Washington DNR activities, and that most effects would be indirect and encompass a relatively small percentage of available habitat. In addition, a status review conducted by NOAA Fisheries concluded that although some Pacific herring populations are declining, others are stable or increasing, and there was no need for protection under the Endangered Species Act. As a result, professional judgment supports the original recommendation that Pacific herring be treated as an Evaluation Species remains.

QUILLBACK ROCKFISH

Spatial Overlap and Coincident Habitat Ranks

Thirty-two activity sub-groups overlap spatially with quillback rockfish habitat during all lifestages (Appendix E), resulting in a “high” species/activity rank. Of the 153 townships where quillback rockfish occur, 127 (83%) have overlap with at least one Washington DNR activity (Appendix F), resulting in ranks of “high” for coincident habitat and the potential for activities authorized by Washington DNR to affect the species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Unclear.

Coverage Category Status

The species paper determined a “medium” potential effect from Washington DNR activities and recommended that quillback rockfish be treated as an Evaluation Species. However, the ranks derived from the screen analysis results indicate a “high” potential to affect. To compensate for potential impacts missed due to data resolution, qualitative metrics were examined, with the review indicating little direct effect to individuals or habitat as a result of Washington DNR activities, and that indirect effects would encompass a relatively small percentage of available habitat. As a result, professional judgment supports that quillback rockfish continue to be treated as an Evaluation Species.

WALLEYE POLLOCK

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 33 activity sub-groups that have the potential to spatially overlap with walleye pollock during all lifestages (Appendix E), resulting in a "high" species/activity rank for all lifestages.

Of the 209 townships where walleye pollock occur, 140 (67%) overlap with at least one Washington DNR activity (Appendix F), resulting in ranks of "high" for coincident habitat and the potential for activities authorized by Washington DNR to affect the species (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Unclear.

Coverage Category Status

The species paper determined a "medium" potential effect from Washington DNR activities and recommended that walleye pollock be treated as an Evaluation Species. However, the numerical ranking criteria derived from the screen analysis indicates a "high" potential to affect and qualitative metrics were examined to compensate for potential impacts missed due to data resolution. The review indicated that there would be little direct effect to individuals or habitat as a result of Washington DNR activities, with most indirect effects encompassing a relatively small percentage of available habitat. As a result, professional judgment supports that walleye pollock continue to be recommended as an Evaluation Species.

3-4 Invertebrates

3-4.1 Evaluation Species

OLYMPIA OYSTER

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 30 activity sub-groups that have the potential to spatially overlap with Olympia oyster habitat (Appendix E), resulting in a "high" species/activity rank. Of the 75 townships where Olympia oyster occur, 54 (72%) have overlap with at least one Washington DNR activity (Appendix F). As a result, there is a "high" coincident habitat rank for both lifestages, with the potential for activities authorized by Washington DNR also ranked "high" (Table 3-2).

Status and Rank

- Federal: Not listed
- State: Candidate
- Natural Heritage Program: Not ranked

Population Trends

Although official estimates of population trends are difficult to determine, populations appear to be stable throughout the state.

Coverage Category Status

The species paper determined a "medium" potential effect from Washington DNR activities and resulted in a species classification of Evaluation. However, the screen analysis indicates a "high" potential to affect and qualitative metrics were examined to compensate for potential impacts missed due to data resolution. As the review indicated that direct effects were unlikely and that indirect would encompass a relatively small percentage of available habitat, no justification was found for changing the species classification rank. Therefore, the coverage category for Olympia oysters remains as Evaluation.

PINTO ABALONE

Spatial Overlap and Coincident Habitat Ranks

At least 25 activity sub-groups were identified that spatially overlap with pinto abalone habitat during all lifestages (Appendix E), resulting in a "medium" species/activity overlap rank for all lifestages. Of the 35 townships where pinto abalone occur as larvae and juveniles, 28 (80%) have overlap with at least one Washington DNR activity, with the egg lifestage having 86 percent of its available habitat effected by at least one Washington DNR activity (Appendix F). As a result, there is a "high" coincident habitat rank for all lifestages, with the potential for activities authorized by Washington DNR ranked "medium" (Table 3-2).

Status and Rank

- Federal: Species of concern
- State: Candidate
- Natural Heritage Program: None

Population Trends

Populations are declining throughout the species range.

Coverage Category Status

Although the screen analysis rankings confirmed the preliminary species paper determination of a "high" potential effect from Washington DNR activities, the species was downgraded to Evaluation due to Washington DNR's inability to address primary threats (overfishing/poaching) and the small area of activity overlap.

3-5 Marine mammals

3-5.1 Covered Species

SOUTHERN RESIDENT ORCA

Spatial Overlap and Coincident Habitat Ranks

Thirty-three activity sub-groups were identified as having spatial overlap with resident killer whale habitat in Washington (Appendix E), resulting in a "high" species/activity rank. Of the 209 townships where killer whales occur, 153 (73%) have overlap with at least one Washington DNR activity (Appendix F). As a result, there is a "high" coincident habitat rank, with the potential for activities authorized by Washington DNR also ranked "high" (Table 3-2).

Status and Rank

- Federal: Endangered
- State: Endangered
- Natural Heritage Program: Apparently and demonstrably secure globally; Southern resident killer whales are ranked as critically imperiled and imperiled (6 to 20 occurrences), very vulnerable to extirpation in Washington.

Population Trends

While trends are difficult to assess for the southern resident population, populations appear to be declining.

Coverage Category Status

Both the Covered Species paper and the screen analysis indicate a "high" potential effect from activities authorized by Washington DNR. As a result of both the potential effect rank and the species federal and state status as endangered, southern resident killer whales should remain as a Covered Species.

3-5.2 Evaluation Species

HUMPBACK WHALE

Spatial Overlap and Coincident Habitat Ranks

The species-activity overlap analysis identified 17 activity sub-groups that have the potential to spatially overlap with humpback whale habitat, resulting in a "low" species/activity rank (Appendix E). Of the 209 townships where humpbacks occur, 115 (55%) have overlap with at least one Washington DNR activity (Appendix F). As a result, there is a "medium" coincident habitat rank, with the potential for activities authorized by Washington DNR ranked "low" (Table 3-2).

Status and Rank

- Federal: Endangered
- State: Endangered

- Natural Heritage Program: Either very rare and local throughout its range or found locally in a restricted range (21 to 100 occurrences). Regularly occurring, usually migratory, non-breeding animals and not of conservation concern Washington.

Population Trends
Humpback whale populations are increasing throughout the species range.

Coverage Category Status
Both the species paper preliminary determination of potential effect and the ranking criteria from the screen analysis indicate a "low" potential effect from Washington DNR activities for humpback whales. To compensate for potential impacts missed due to data resolution, qualitative metrics were examined and found to provide little support for direct effects to individuals or habitat as a result of Washington DNR activities. In addition, indirect effects were found to encompass a relatively small percentage of available habitat. As a result, no justification was found for changing the humpback whale's coverage category and it remains as an Evaluation Species.

NORTHERN SEA OTTER

Spatial Overlap and Coincident Habitat Ranks
Eight activity sub-groups were identified as having spatial overlap with northern sea otter habitat in Washington State (Appendix E), resulting in a "low" species/activity rank. Of the 22 townships where sea otters occur, 5 (23%) have overlap with at least one Washington DNR activity (Appendix F). As a result, there is a "low" coincident habitat rank, with the potential for activities authorized by Washington DNR also ranked "low" (Table 3-2).

Status and Rank
- Federal: Not listed
- State: Endangered
- Natural Heritage Program: Apparently secure globally; although the rank is somewhat uncertain in Washington, the species is classified as rare or uncommon (21 to 100 occurrences).

Population Trends
Populations are increasing throughout its range due to reintroduction efforts and protection under the Marine Mammal Protection Act.

Coverage Category Status
Both the species paper preliminary determination and the screen analysis indicate "low" potential effect on sea otters from Washington DNR activities. As a result, there is no justification altering the species recommendation and northern sea otters remain an Evaluation Species.

3-6 Plants

3-6.1 Evaluation Species

WATER HOWELIA

Spatial Overlap and Coincident Habitat Ranks

No activity sub-groups were found to spatially overlap with water howelia habitat (Appendix E), resulting in a "low" for species/activity overlap, coincident habitat, and potential to effect ranks (Table 3-2). Because this species occurs in small vernal wetlands and oxbow river bends, there is a possibility that some overlap was missed due to the resolution of the data.

Status and Rank

- Federal: Threatened
- State: Threatened
- Natural Heritage Program: Globally, either very rare or local throughout its range; or found locally in a restricted range (21-100 occurrences). In Washington the species is critically imperiled (5 or fewer occurrences).

Population Trends

The few existing populations in Washington appear to be stable.

Coverage Category Status

The water howelia was originally categorized as a Covered Species in part due its rarity in the state of Washington. However, the numerical ranking criteria derived from the screen analysis indicate a "low" potential to affect and there appears to be no spatial overlap between activities authorized by Washington DNR and water howelia habitat. As a result, the water howelia should be reclassified as an Evaluation Species.

Table 3-2 - Screen result ranks.

Species Groups	Species	Lifestage	Overlap Rank	Coincident Habitat Rank	Potential to Effect	
					Numeric Average	Rank
Amphibians & Reptile	Coastal Tailed Frog	All	Low (1)	Low (1)	1	Low
	Columbia Spotted Frog	All	Medium (2)	Low (1)	1.5	Low
	Northern Leopard Frog	Adult / Migration / Spawning / Overwintering	Low (1)	Medium (2)	1.5	Low

Species Groups	Species	Lifestage	Overlap Rank	Coincident Habitat Rank	Potential to Effect Numeric Average	Potential to Effect Rank
	Oregon Spotted Frog	All	Low (1)	0	0	Low[4]
	Western Toad	All	Medium (2)	Medium (2)	2	Medium
	Western Pond Turtle	All	Medium (2)	Medium (2)	2	Medium
Birds	Bald Eagle	All	High (3)	Medium (2)	2.5	Medium
	Black Tern	All	Low (1)	Low (1)	1	Low
	California Brown Pelican	Resident non-breeding / Migration	High (3)	High (3)	3	High
	Common Loon	Migration / Resident non-breeding / Wintering	High (3)	Medium (2)	2.5	Medium
		Nesting	Medium (2)	Low (1)	1.5	Low
	Common Murre	All	High (3)	Low (1)	2	Medium
	Harlequin Duck	Resident non-breeding / Migration / Wintering	High (3)	Medium (2)	2.5	Medium
		Nesting	Low (1)	Medium (2)	1.5	Low
	Marbled Murrelet	All	High (3)	Medium (2)	2.5	Medium
	Tufted Puffin	All	Low (1)	Low (1)	1	Low
	Western Snowy Plover	All	Low (1)	High (3)	2	Medium
Fish	Brown Rockfish	All	High (3)	High (3)	3	High
	Bull Trout	Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium
	Bull Trout	Incubation / Emergence	Medium (2)	Low (1)	1.5	Low
		Freshwater Rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Chinook Salmon	All	High (3)	Medium (2)	2.5	Medium
		Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium

[4] Rank assigned for adults

Species Groups	Species	Lifestage	Overlap Rank	Coincident Habitat Rank	Potential to Effect	
					Numeric Average	Rank
	Chum Salmon	Incubation / Emergence	Low (1)	Low (1)	1	Low
		Freshwater Rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Coastal Cutthrout Trout	Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium
		Incubation / Emergence	Medium (2)	Low (1)	1.5	Low
		Freshwater Rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Coho Salmon	Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium
		Incubation / Emergence	Medium (2)	Low (1)	1.5	Low
		Freshwater rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Copper Rockfish	Adult / Parturition	Medium (2)	Medium (2)	2	Medium
		Benthic Juvenile	High (3)	High (3)	3	High
		Pelagic Larvae	High (3)	High (3)	3	High
	Pacific Cod	All	Low (1)	Medium (2)	1.5	Low[5]
	Pacific Hake	Benthic Juvenile	Low (1)	Medium (2)	1.5	Low[6]
	Pacific Herring	All	High (3)	High (3)	3	High
	Pink Salmon	Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium
		Incubation / Emergence	Low (1)		0.5	Low
		Freshwater Rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Pygmy Whitefish	All	Low (1)	Medium (2)	1.5	Low
	Quillback Rockfish	All	High (3)	High (3)	3	High

[5] Rank assigned for juvenile and larval stages.

[6] Rank assigned for juvenile stage.

Species Groups	Species	Lifestage	Overlap Rank	Coincident Habitat Rank	Potential to Effect	
					Numeric Average	Rank
	Sockeye Salmon	Adult Migration / Spawning / Marine Rearing	High (3)	Medium (2)	2.5	Medium
	Sockeye Salmon	Incubation / Emergence	Medium (2)	Low (1)	1.5	Low
		Freshwater rearing / Outmigration	High (3)	Medium (2)	2.5	Medium
	Steelhead Trout	All	High (3)	Medium (2)	2.5	Medium
	Walleye Pollock	All	High (3)	High (3)	3	High
	White Sturgeon	Adult / Spawning	High (3)	Medium (2)	2.5	Medium
		Juvenile	High (3)	Medium (2)	2.5	Medium
		Egg / Larvae	Medium (2)	Low (1)	1.5	Low
Invertebrates	Olympia Oyster	All	High (3)	High (3)	3	High
	Pinto Abalone	All	Medium (2)	High (3)	2.5	Medium
Marine Mammal	Humpback Whale	All	Low (1)	Medium (2)	1.5	Low
	Killer Whale	All	High (3)	High (3)	3	High
	Northern Sea Otter	All	Low (1)	Low (1)	1	Low
Plants	Water Howellia	All	Low (1)		0.5	Low

4. Potential Effects

This chapter defines a "typical activity" (Sub-section 2-1.1, Activities Database, Descriptive Data) and the area of alteration for each of the 11 activity sub-groups addressed in this analysis. It also provides a discussion of the controlling factors for potential effects through a review of the literature associated with each of the 3 activity groups. Each activity is organized into three sub-sections:

- Typical Activity Description - The spatial and temporal assumptions regarding the activity sub-group and the area of alteration.
- Controlling Factors - A discussion of the effects the activity may have on the environment and potential pathways for those effects.
- Effects Index and Justification - An explanation of the direct and indirect effects of the activities on each species' lifestage. Only those species recommended for "Covered" status by the Screening Analysis (Subsection 2-1.2) are included (Table 4-1).

Table 4-1 - Potentially Covered species recommendations.

Group	Species	Listing Status/Rank	
		Federal	State
Amphibians & Reptiles	Columbia spotted frog	Concern	Candidate
	Northern leopard frog	Concern	Endangered
	Western toad	Concern	Candidate
	Western pond turtle	Concern	Endangered
Birds	Bald Eagle	Threatened	Threatened
	Black tern	Concern	None
	Brown Pelican	Endangered	Endangered
	Common loon	None	Sensitive
	Harlequin duck	None	None
	Marbled murrelet	Threatened	Threatened
	Western snowy plover	Threatened	Endangered
Fish	Bull trout/Dolly Varden	Threatened	Candidate
	Chinook salmon	Endangered or Threatened	Candidate
	Chum salmon	Threatened	Candidate
	Coastal cutthroat	None	None

Group	Species	Listing Status/Rank	
		Federal	State
	Coho salmon	Concern	None
	Pink salmon	None	None
	Sockeye/Kokanee salmon	Endangered	Candidate
	Steelhead	Endangered or Threatened	Candidate
	Green sturgeon	Endangred or Not listed	None
	White sturgeon	None	None
Marine Mammals	Southern resident orca	Endangered	Endangered

4-1 Aquaculture

4-1.1 Typical activity description

SHELLFISH

This activity includes geoduck clam culture because Washington DNR has been obligated by the Washington State legislature to begin leasing lands in 2005 for geoduck clam planting.

Structure

- Various permanent structures are associated with shellfish aquaculture including dikes, permanently moored rafts, stakes and ropes, antipredator nets, etc.
- Aquaculture activities may require overwater structures, shoreline and tideland modification and Nearshore Buildings.

Operation

- Aquaculture activities may use mechanical means to enhance production and reduce populations of perceived pests or competitors (e.g., tilling tidelands, removing submerged aquatic vegetation, eliminating burrowing shrimp, etc.).
- Aquaculture activities may remove or inhibit submerged aquatic vegetation and may introduce exotic species.
- Oyster aquaculture activities may include use of hydraulic escalator dredges to harvest oysters.
- Additional impacts may result from the presence of numerous people on tidelands causing trampling, vessels in nearshore waters, noise, lighting and inadvertent fuel spills.

Temporal Assumptions

- Commercial aquaculture activities occur all year.
- Specific activities including harvesting, culling, planting and maintaining facilities and equipment are scheduled to coincide with low tides or as appropriate for the species and operational needs.
- Aquaculture activities do not result in a permanent change to tidelands and bedlands. Affected areas recover relatively quickly following cessation of culture activities.

Maintenance

- All permanent structures associated with aquaculture activities require maintenance, repair and replacement as needed.
- Planted stocks require periodic monitoring and maintenance.

Assumed Area of Alteration

- The area of alteration includes the area under cultivation and adjacent areas where support activities or other direct effects occur.
- The assumed footprint for mussel, clam and oyster aquaculture activities is approximately 85,248 meters^2 (See Table 4-10 at the end of this chapter).
- In addition to the footprint, areas outside of cultured areas receive direct effects only from associated shoreline structures and disturbance of wildlife by human activities. A relatively small area of alteration is assumed due to the highly localized nature of the activity sub-group, with the total area of alteration equal to 102,300 meters^2.

FINFISH AQUACULTURE

Structure

- Activities require permanently moored structures in the form of net pens with anchors, cables, net enclosures and floats with surface structures.
- Structural materials may include treated wood, plastics, covered polystyrene foam, concrete, treated netting and tires (fenders).
- Additional shoreline modifications and overwater structures may be associated with the aquaculture facility.
- Submerged portions of net pens are constructed of netting that could present an entanglement hazard to waterfowl, finfish and marine mammals.

Operation

- Structures heavily shade the seafloor.
- Net pens employ active predator deterrence measures (e.g., shooting, noise making, lighting).
- Substantial deposition of debris (waste food, feces, dead organisms, lost tools and parts, scraps of netting, fender tire) occurs.

- Water quality degradation occurs from release of waste organic material, antibiotics and growth accelerators. NPDES permits are required for permanent net pen installations.

- A risk of transmittal of disease and parasites to native finfish and invertebrate assemblages may exist.

- A potential for contamination of native gene pools may exist.

- Native finfish may be subject to displacement from habitats or competition by non-native fish escaping from net pens.

- Vessels associated with the aquaculture activity may cause additional impacts (disturbance, harassment, fuel spills, noise) to aquatic biota.

Temporal Assumptions

- Salmonid net pens are in place and operate year round. Associated activities vary in intensity diurnally and perhaps seasonally.

- Feeding, harvesting, restocking and other activities occur on schedules established by the operators.

- Pacific herring containment is used to hold herring for sale as bait to recreational fishers. This activity is dependent on schedules for salmon recreational fishing because the demand for bait only occurs during salmon fishing seasons established by regulatory agencies.

- Herring containment structures are usually moored in marinas for the convenience of bait dealers and recreational fishers.

- Floating net pens may be established by government agency or recreational fishing groups in or near marinas to hold juvenile Pacific salmon prior to release.

Maintenance

- All finfish aquaculture or containment structures require continual maintenance, repair and replacement of components.

Assumed Area of Alteration

- The area of alteration consists of the finfish netpen footprint and an adjacent area of the water column and benthos that may be modified by deposition of waste and debris.

- The assumed footprint for finfish aquaculture activities is approximately 44,652 $meters^2$ (See Table 4-10 at the end of this chapter).

- The area of alteration for finfish aquaculture is based on the extent of direct influence in the form of waste and debris deposition on bedlands under and around the net pen facility and effects on shoreline and shorelands used for support activities. The total assumed area of alteration is 67,000 $meters^2$.

4-1.2 Controlling factors potentially affecting habitat

Table 4-2 summarizes the sources and mechanisms of potential effects from aquaculture activities. The following sections discuss these sources in more detail and provide a literature review.

Table 4-2 - Summary of the controlling factors associated with Aquaculture.

Source of effect	Controlling factor associated with physical habitat structure	Potential biological effect
Tilling, raking and digging to harvest shellfish	▪ Disturbance and long-term modification of sediment substrates and submerged aquatic vegetation in nearshore unconsolidated habitats, displacement of natural biota and replacement with cultured species	▪ Long-term habitat disturbance during active culture
Placement of structures for growing shellfish, stakes, tubes, lines, dikes, mussel rafts	▪ Placement of aquaculture structures preventing access to habitats	▪ Long-term inaccessible habitat and habitat impairment
Harvesting activities, pest control, interaction with aquaculture structures	▪ Human and machinery presence	▪ Temporarily inaccessible habitat, physical trauma, harassment
Mechanical harvesting using hydraulic methods	▪ Increased turbidity; surface/ subsurface substrate and above substrate disturbance (e.g. physical structure or vegetation), disturbance of natural substrate with temporary and localized increases in turbidity	▪ Temporary habitat destruction and inaccessibility, energy resource reduction, water quality impairment
Pest (burrowing shrimp) control using chemical (carbaryl) methods	▪ Contamination of water and substrates with chemical; food web effects	▪ Short-term impairment of water and sediment quality, loss of biomass, incidental mortalities of salmonids, increase in biodiversity and infauna abundance

Source of effect	Controlling factor associated with physical habitat structure	Potential biological effect
Mussel culture using rafts	▪ Deposition of shells and feces and release of sediment when harvesting	▪ Long-term impairment of sediments, temporary impairment of water quality

SHELLFISH

A variety of molluscan bivalve species are cultured or farmed in nearshore unconsolidated habitats of saltwater and estuarine waters in the State of Washington. Washington DNR leases for these activities include several hardshell clam species, such as littleneck clams (*Protothaca staminea*), oysters (*Crassostrea* spp. and *Ostrea* spp.) and mussels (*Mytilus* spp.). The most common methods for farming these species include:

- Oyster culture on and off the seafloor (e.g., stakes and lines).
- Mussels on lines suspended from rafts.
- Hardshell clams harvested from protected wild populations or seeded stocks.
- Geoduck clam culture using planted seed stock with predator deterrence tubes.

To some extent, all of these methods involve direct or indirect modification of saltwater and estuarine nearshore unconsolidated habitats through:

- Emplacement of artificial objects (e.g., stakes, protective tubes or nets, anchors, dikes).
- Modification of the sedimentary environment by digging, tilling or raking to remove target species or to modify the substrate.
- Addition of coarser sediments (e.g., gravel, oyster shell hash).
- Deposition of shells, feces and sediments from mussel rafts.
- Chemical control of burrowing (sand) shrimp in areas of intense oyster cultivation.

Oysters, clams and mussels are direct trophic competitors of other filter feeders thus affecting natural food webs and redirecting energy flows through the food web (Gibbs 2004). This competition can force a shift from pelagic to benthic consumers. Benthic organisms remove food from the water column and provide it to deposit feeders and benthic grazers, including finfish and birds. In addition, bivalve facultative filter feeder diets may shift towards deposit feeding (Leguerrier et al. 2004).

In addition, human activity (e.g., harvest, maintenance, cleaning) in nearshore unconsolidated habitats could displace and disturb migratory and resident birds (Heffernan 1999). Disturbance from maintenance may reduce survival and reproduction rates for avian species by decreasing time spent foraging and loafing and altering nesting behavior that results in increased predation and heat loss for eggs and chicks.

Carbaryl or Sevin™ has been used for more than 30 years to control burrowing shrimp (*Upogebia pugettensis* and *Neotrypaea* (formerly *Callianassa californiensis*) populations in areas of intense oyster cultivation in Willapa Bay and Grays Harbor (Dumbauld et al.

2001, Feldman et al. 2000, Anderson 2002). Final and supplemental Environmental Impact statements were written on this practice in 1984 and 1992, respectively (Anderson 2002). Feldman et al. (2000) reviewed the conflict among crab fishermen, oyster growers and regulatory agencies that has existed over the use of carbaryl.

Stonick (1999) measured concentrations of carbaryl and a toxic breakdown product, 1-naphthol, in sediments in and near application sites. Neither chemical was detected in sediments after 60 days. Thus, the application of carbaryl temporarily impairs sediment and water quality.

Carbaryl applications also impact fauna causing significant mortalities in invertebrates, especially crustaceans, and finfish up to 100 meters away from application sites (Dumbauld et al. 2001, Feldman et al. 2000). Dumbauld et al. (2001) found decreases in abundance and diversity of crustacean infauna (including the burrowing shrimp target species) within hours to weeks following the application of carbaryl. These effects were temporary with abundance recovering to levels comparable or greater than initial levels within three months to one year after a routine application (Feldman et al. 2000, Dumbauld et al. 2001).

The affected crustacean infauna (e.g., copepods, amphipods) is an important prey resource for numerous species including western snowy plover and Pacific salmon. Removal of this energy resource, even temporarily, could affect these consumers. However, when compared to the area of similar habitat available to these species outside the area in which carbaryl is applied and the rapid recovery, the effect would be temporally and spatially relatively minor (Dumbauld et al. 2001, Feldman et al. 2000).

It appears that the removal of burrowing shrimp and the addition of oysters is of more importance in structuring benthic communities than the acute effects of carbaryl in the coastal nearshore unconsolidated habitats where this practice is followed (Dumbauld et al. 2001). Burrowing shrimp are important factors in controlling benthic communities and could be considered a "key stone species" (Dumbauld et al. 2001). In fact, Feldman et al. (2000:166) stated:

> *"Although they have no importance as a food item for human consumption (there is a small commercial and recreational fishery for them as bait), burrowing shrimp play an important role in ecosystem processes and often are dominant component of the benthic community in terms of abundance and invertebrate production. "*

One of their effects on the benthos is the reduction of biodiversity that occurs when high numbers of burrowing shrimp are present (Dumbauld et al. 2001, Feldman et al. 2000, Posey 1986a and b, Hornig et al. 1989). Burrowing shrimp also are an important prey resource for a number of finfish including sculpins, sturgeon, and Pacific salmon (feed on shrimp pelagic larvae), Dungeness crab, and gray whales (Posey 1986a and b, Hornig et al. 1989, Darling et al. 1998, Dunham and Duffus 2001, Weitkamp et al. 1992).

While removal of burrowing shrimp is one of the important factors cited by Simenstad and Fresh (1995) determining the effects of oyster aquaculture, it appears that the presence of oysters may mitigate the use of carbaryl (Dumbauld et al. 2001, Feldman et al. 2000). Oyster culture provides cover, biomass, and hard substrate for a variety of organisms including Dungeness crab whose populations apparently benefit from the presence of oyster shell. According to the studies by Dumbauld et al. and reported by

Feldman et al., the increased abundance and biomass of fauna associated with oyster shell deposits more than compensates for the loss due to the use of carbaryl.

Shellfish aquaculture activities can affect the distribution of submerged aquatic vegetation, especially eelgrass, displacing it in favor of the cultured shellfish (Simenstad and Fresh 1995, Griffin 1997). Griffin cited decreases in benthic surface area and direct physical disturbance as the probable causes of eelgrass depletion at culture sites, with Boese (2002) finding that recreational clam digging reduced eelgrass cover and biomass. Based on these studies, anecdotal observations of commercial clam digging and culture operations, and the reports by Simenstad and Fresh (1995) and Heffernan (1999), it appears that submerged aquatic vegetation and clam aquaculture are not compatible. It is likely that the harvesting of bivalves and intensive cultivation using substrate modification and predator control structures (e.g., tubing and netting) are the major factors directly affecting the vegetation.

Mussel cultivation using ropes suspended from rafts floating over nearshore unconsolidated habitats can have direct effects on water and sediment quality and benthic fauna. Water quality is affected by the filtering action of the mussels, which removes most plankton and suspended sediments (Heffernan 1999, Stenton-Dozey 2001, Cole 2002). Mussels use phytoplankton as food and eject sediment particles and larger zooplankton as pseudofeces. Sediment quality, in turn, can be affected by biodeposits (e.g., shell debris, pseudofeces and feces), that can accumulate in sites that are not well flushed. Sediments receiving the accumulated biodeposits can become finer, enriched and, in some cases, anoxic (Heffernan 1999). Benthic enrichment can change (species composition, decreased diversity, increased abundance of tolerant species) the community structure under the farms dramatically and recovery can take years (Stenton-Dozey 2001, Heffernan 1999). Therefore, not only is the affected nearshore habitat relatively inaccessible due to mussel aquaculture activities, it can be substantially degraded and of little value to finfish, birds, and other species.

Thus, the primary effect of shellfish culture appears from the reviewed literature to be physical habitat alteration with concomitant changes to associated biota and trophic relations (Simenstad and Fresh 1995, Heffernan 1999, Dumbauld et al. 2001, Feldman et al. 2000, Boese 2002, Crawford et al. 2003, Gibbs 2004, Leguerrier et al. 2004). These changes are generally within the scale of natural variation with the exception of large-scale disturbances, which include those associated with bivalve culture such as the use of carbaryl, extensive substrate changes, and continuing intensive cultivation activities. Changes on this scale may cause chronic shifts in benthic communities by removing dominant structural and functional elements including eelgrass and burrowing (sand) shrimp. In addition, food webs may be affected changing the availability of prey items, especially the meiofaunal species preferred by Pacific salmon (Simenstad and Fresh 1995, Feldman et al. 2000, Dumbauld et al. 2001). However, these effects appear to be localized to the vicinity of the aquaculture activities (e.g., lease) and not substantially affect the larger estuarine area in which the activity occurs (Simenstad and Fresh 1995, Dumbauld et al. 2001, Feldman et al. 2000). Effects to threatened and endangered species would also be localized but could be minor to “moderate” depending on the local scale of activity and the listed or Covered Species.

FINFISH AQUACULTURE

Currently, most finfish aquaculture activity on state-owned aquatic lands is restricted to the use of floating net pens in which Atlantic salmon are reared in Puget Sound waters. Similar activities in saltwater include facilities for the delayed release of hatchery-raised Pacific salmon and holding net pens for Pacific herring intended for sale as fishing bait. In addition to leases in saltwater, the RTA systems database listed three finfish aquaculture leases, two in lakes and one on a river.

The extensive studies of the effects of saltwater and estuarine net-pen finfish aquaculture were reviewed recently by Waknitz et al. (2002, 2003), Brooks and Mahnken (2003a and b), Fairgrieve and Rust (2003), Nash (2003) and Nash and Waknitz (2003). According to these reviews, salmon net pens do not have a significant effect on water quality except in shallow, poorly flushed environments (Brooks and Mahnken 2003a). However, biological deposits from the net pens can settle and affect sediment chemistry and macrobenthic communities. Effects of these wastes could include changes in total volatile solids, reduction-oxidation potential depth, and sulfur chemistry (Brooks and Mahnken 2003a). In addition, Brooks and Mahnken (2003b) assessed the risk of zinc and copper accumulating in toxic amounts from feed and antifouling treatments. Toxicity of both of these metals is reduced by the concentration of sulfide in the sediment, which combines with both zinc and copper to reduce their bioavailability to non-toxic levels. Chemical changes in sediments have been observed to distances as far as 205 meters from net pens and biological effects have extended to 225 meters. In all cases, these effects were ephemeral and remediation occurred naturally without active intervention.

Waterfowl and marine pinnipeds (seals and sea lions) may be affected through attraction to the apparent prey resource in the net pen. These predators are subsequently targeted by deterrence actions (noise, lights, shooting) by the facility operators (Cole 2002).

Waknitz et al. (2003) state that little or no risk exists that the escape of Atlantic salmon, a non-native species, will impact the ecosystem of the Pacific Northwest. This conclusion is based on 26 attempted introductions by the state of Washington between 1941 and 1991 of Atlantic salmon to Washington waters. In addition, while numerous escapes of juvenile and adult Atlantic salmon have been documented, researchers have not been able to locate any substantial numbers of the escaped fish or any established populations in Washington State. Because survival in the wild is extremely low for escaped fish, the few natural prey items any escaped fish might consume is negligible when compared to the competitive food requirements of the juvenile Pacific salmon released from hatcheries (Waknitz et al. 2003). Waknitz et al. further state that there is a low risk that Atlantic salmon will increase the incidence of disease among Washington native salmon populations. The specific diseases and their prevalence in cultured Atlantic salmon have not been shown to be any different than those of the stocks of Pacific salmon in hatcheries. These, in turn, are not known to have a high risk for infecting wild salmonids.

4-1.3 Effects index and justification

Summary indices for potential effects related to aquaculture activities are presented in Table 4-3, with the complete Effects Indices presented in Appendix G. The following sections contain Effects Indices justifications for each species group.

Table 4-3. Summary of Magnitude of Effects by species, lifestage, and activity sub-group. *

Species	Lifestage	Shellfish	Finfish
Amphibian complex	Adult	NA	0.25
	Tadpole	NA	0.25
	Egg	NA	0.25
Western pond turtle	Adult	NA	NA
	Overwintering	NA	NA
Bald eagle	Non-nesting	0.25	0.25
	Nesting	0.25	0.25
Black tern	Migration	NA	NA
	Nesting	NA	NA
Brown pelican	Non-nesting	0.25	0.38
Common loon	Non-nesting	0.25	0.25
	Nesting	NA	0.25
Harlequin duck	Non-nesting	0.25	0.25
	Nesting	NA	NA
Marbled murrelet	Non-nesting	0.25	0.25
	Nesting[1]	0.25	0.25
Western snowy plover	Wintering	0.63	NA
	Nesting	0.50	NA
Pacific salmon, trout, and char	Adult	0.25	0.25
	Incubation/ Emergence	NA	0.25
	Freshwater rearing/ Outmigration	0.25	0.25
Green sturgeon	Adult	0.50	0.31
White sturgeon	Adult/Juvenile	0.44	0.31
	Larvae	NA	0.31
	Egg	NA	0.31
Southern resident orca	All	0.00	0.25

* Ranks: "NA" indicates that an intersection between the specific activity and the species group does not occur. 1= "total loss"; 0.75 = "high" effect; 0.5 = "moderate" effect; 0.25 = "low" effect; 0 = "trace" effect.

[1] Because of the coarseness of Washington DNR's leasing data (1 mile^2) the Potential Effects Analysis indicated an overlap with nesting murrelet habitat. While this is unlikely, Effects Index ranks were still assigned.

AMPHIBIANS AND REPTILES

Columbia Spotted Frog, Northern Leopard Frog and Western Toad

Effects Indices
Only Finfish Aquaculture overlaps with habitat for the amphibians listed above.

Potential Direct and Indirect Effects
Major threats to amphibians are from habitat loss and degradation of sediment and water quality (Washington DNR 2007).

- Direct effects from Aquaculture may occur as a result of permanent habitat loss associated with the placement of structures and associated increases in activity and/or alteration in behavior. Because of the relatively small and localized area of alteration, effects to all lifestages are ranked "low".

- Indirect effects from Aquaculture may result from the temporary loss or inaccessibility of habitat, as well as reduced structural habitat metrics and an associated reduction in prey and foraging opportunities. Similarly to direct effects, because of the relatively small and localized area of alteration, effects to all lifestages are ranked "low".

Western Pond Turtle

Effects Indices
There is no spatial overlap with western pond turtle habitat and any Aquaculture sub-group, therefore there are no potential effects associated with this activity group.

BIRDS

Bald Eagle

Effects Indices
Bald eagles are potentially affected by Aquaculture activities at a "low" level in all lifestages.

Potential Direct and Indirect Effects
Major threats to bald eagles are from loss of riparian foraging and nesting habitat, and behavioral disturbance from human activity (Washington DNR 2007).

- Direct effects to individuals from Aquaculture in all lifestages may occur as a result of human disturbance altering activity levels and behavior, with effects ranked "low" for both sub-groups. Habitat level effects may also occur as a result of structural modification or disturbance of nesting and foraging areas, with effects ranked "low".

- Indirect effects from Aquaculture could result from temporary modification and inaccessibility of habitat. While shellfish culture is more intensive and impacts related to intertidal culture are normally year-round, the area of alteration is mostly confined to the activity footprint and easily avoided or accommodated by eagles. Thus, the potential for impact for this sub-group could be "trace" to "low".

Black Tern

Effects Indices

There is no spatial overlap with black tern habitat and any Aquaculture sub-group, therefore there are no potential effects associated with this activity group.

Brown Pelican

Effects Indices

Brown pelicans are potentially affected by Aquaculture activities with effects ranging from "moderate" to "low" dependent on the Aquaculture sub-group.

Potential Direct and Indirect Effects

Major threats to the brown pelican are due to pollution and from habitat loss and disturbance of behavior by human activity (Washington DNR 2007). Finfish Aquaculture may attract brown pelicans leading to harassment and/or harm.

- Direct effects to individuals from Aquaculture may result from disturbances associated with harvest activities and related increases in the birds' activity level, and changes in behavior. Effects are ranked "moderate" for individuals due to Finfish Aquaculture and "low" for Shellfish Aquaculture. Habitat level effects may also occur as a result of structural modification and disturbance of shorelands, tidelands, and bedlands; and are ranked as "low" for Shellfish and Finfish Aquaculture activities.

- Indirect effects from Aquaculture could result from temporary modification and inaccessibility of habitat; reduction in the quality of habitat metrics due to the location of structures; and associated decreases in prey items. While Shellfish and Finfish Aquaculture activities are intensive and effects are normally year-round, the area of alteration is mostly confined to the activity footprint and easily avoided or accommodated by brown pelicans. The potential for indirect effects for all Aquaculture sub-groups is ranked "low", primarily due to impaired water quality effects on prey availability.

Common Loon

Effects Indices

Common loons are potentially affected by Aquaculture activities at a "low" level. Because loons nest in freshwater habitat, there is no spatial overlap between the nesting lifestage and Shellfish Aquaculture.

Potential Direct and Indirect Effects

Major threats to the common loon are from habitat loss and disturbance of behavior by human activity (Washington DNR 2007). Aquaculture could affect loons in nesting (lakes) and wintering, migration, and nonbreeding resident (saltwater and estuarine nearshore) habitats.

- Direct effects to individuals from Aquaculture may result from disturbances associated with harvest activities and related increases in the birds' activity level, and changes in behavior. Habitat level effects may also occur as a result of structural modification and disturbance of shorelands, tidelands and bedlands. Effects to nesting forms are ranked "low" for Finfish Aquaculture. Effects to non-nesting forms ranked "low" for both Shellfish and Finfish Aquaculture.

- Indirect effects from Aquaculture could result from temporary modification and inaccessibility of habitat; reduction in the quality of habitat metrics due to the location of structures; and associated decreases in prey items. While Shellfish and Finfish Aquaculture activities are intensive and effects are normally year-round, the area of alteration is mostly confined to the activity footprint and easily avoided or accommodated by loons. Thus, the potential for direct impact for these sub-group are ranked “low”.

Harlequin Duck

Effects Indices
Because harlequin ducks nest in freshwater habitat, there is no spatial overlap with the nesting lifestage and Shellfish culture. Non-nesting forms have the potential to be affected by at a “low” level of effect.

Potential Direct and Indirect Effects
Major threats to the harlequin duck are from habitat loss and disturbance of behavior by human activity (Washington DNR 2007).

- Direct effects to individuals from Aquaculture could result from disturbances associated with harvest activities and related increases in the birds’ activity level, and changes in behavior. Habitat level effects may also occur as a result of permanent habitat loss associated with structural modification and disturbance of shorelands, tidelands and bedlands. Effects from Shellfish and Finfish culture are ranked “low”.

- Indirect effects from Aquaculture can result from temporary modification and inaccessibility of habitat. Shellfish and Finfish culture are relatively intensive and impacts related to nearshore culture are normally year-round, the area of alteration is mostly confined to the activity footprint. In addition, Shellfish Aquaculture activities generally are placed in low energy unconsolidated habitats, while harlequin ducks prefer higher energy consolidated habitats and could easily avoid or accommodate the effects. Thus, the potential for impact to saltwater populations for these two sub-groups is “low”.

Marbled Murrelet

Effects Indices
Effects to marbled murrelets from Aquaculture activities are ranked as “low”.

Potential Direct and Indirect Effects
Major threats to the marbled murrelet are from nesting habitat loss and disturbance of feeding behavior by human activity (Washington DNR 2007).

- Direct effects to individuals from Aquaculture could result from disturbances associated with harvest activities and related increases in the birds’ activity level, changes in behavior, or actual harm. Habitat level effects may also occur as a result of permanent habitat loss associated with structural modification and disturbance of shorelands, tidelands and bedlands used for foraging during nesting and by wintering and nonbreeding resident populations. Effects to individuals are ranked “low” for all lifestages and sub-groups.

- While indirect effects can result from temporary modification and inaccessibility of habitat, the area of alteration from Shellfish and Finfish culture activities is mostly confined to the activity footprint and would be easily avoided or accommodated by marbled murrelets. Thus, the potential for impact to all lifestages is "low" for these sub-groups.

Western Snowy Plover

Effects Indices
Western snowy plovers are potentially affected by Shellfish Aquaculture in both lifestages, with effects ranging from "high" to "moderate". There is no spatial overlap with plover habitat during either lifestage for Finfish Aquaculture.

Potential Direct and Indirect Effects
Major threats to the western snowy plover is disturbance by human activity during nesting and feeding (Washington DNR 2007). Because these birds use nearshore unconsolidated habitats for feeding and nest near these habitats, Shellfish Aquaculture would pose the greatest threat.

- Direct effects to individuals from Aquaculture could result from disturbances associated with harvest activities and related increases in the birds' activity level, changes in behavior, or actual harm (e.g., nest abandonment). Habitat level effects may also occur as a result of permanent feeding habitat loss and inaccessibility. Effects to individuals are ranked "moderate" for both lifestages. Habitat effects from Shellfish Aquaculture are ranked "high" for the wintering stage and "moderate" for the nesting stage.

- "Moderate" indirect effects could result from temporary modification and inaccessibility of habitat; reduced structural habitat matrices associated with structures (e.g., altered sediment transport); and associated decreases in prey resources. Effects to both lifestages from Shellfish Aquaculture is ranked "moderate".

FISH

Salmon, Trout and Char

Effects Indices
Potential effects to Pacific salmon, trout and char from Shellfish Aquaculture occur in adult and migration lifestages at a "low" level. Because salmonids utilize riverine habitat during the incubation/emergence lifestage, there is no spatial overlap with habitat during this lifestage Shellfish Aquaculture. Potential effects from Finfish Aquaculture occur for all lifestages at a "low" level of effect.

Potential Direct and Indirect Effects
Major threats to all lifestages of salmonids are the disruption and loss of habitat, and the disturbance of migration and foraging behavior (Washington DNR 2007).

- Direct effects to individuals from Aquaculture may occur as a result of in-water activities (e.g., rafts, vessel movement) disturbing juvenile and adult salmonids, thereby disrupting behavior patterns and habitat use, as well as potentially causing harm to fish present in shallower nearshore waters. Habitat level effects may also occur as a result of permanent loss due to modification and disturbance associated with by structures. Effects to individuals are ranked as "low" for Shellfish and Finfish culture.

- Indirect effects to marine and estuarine lifestages and habitats from Shellfish and Finfish Aquaculture can result from temporary modification and inaccessibility of habitat, and accompanying reductions in preferred prey. Additional indirect effects could be caused by finfish net pen placement and supporting structures causing shoreland, tideland, and bedland modifications; as well as water and sediment quality impairment associated with nutrient deposition and use of chemicals to control pests. Effects from Shellfish and Finfish culture are ranked “low” for all lifestages.

Green Sturgeon

Effects Indices

Green sturgeon are potentially affected by Aquaculture activities with effects ranging from “high” to “low” dependent on the activity sub-group.

Potential Direct and Indirect Effects

Major threats to the green sturgeon related to Aquaculture are due to the disruption and loss of habitat, water and sediment quality impairment at chronic levels, and physical harm due to entrapment in associated gear.

- Direct effects to individuals from Aquaculture may occur as a result of in-water activities (e.g., rafts, vessel movement) disturbing the fish, thereby disrupting behavior patterns and habitat use, as well as potentially causing harm to fish present in shallower nearshore waters. The fish may also be harmed due to entanglement in fish pen nets. Habitat level effects may also occur as a result of permanent loss due to modification and disturbance associated with the structures. Effects to individuals are ranked as “low” for Shellfish and Finfish Aquaculture. Habitat level effects ranked as “moderate” for Shellfish Aquaculture and “low” for Finfish Aquaculture.

- Indirect effects could result from temporary modification and inaccessibility of habitat; reduction in the quality of habitat metrics due to the location of structures; and associated decreases in prey items. Additional indirect effects could be caused by finfish net pen placement and supporting structures causing shoreland, tideland, and bedland modifications; as well as sediment quality impairment associated with nutrient deposition and use of chemicals to control pests. Effects from Shellfish Aquaculture on habitat loss are ranked “moderate” due to associated temporary habitat destruction and inaccessibility, while Finfish Aquaculture effect is ranked “low”. Shellfish Aquaculture is ranked “high” for habitat degradation due to water and sediment quality impairment associated with accumulated waste and reduction of structural habitat quality metrics. Finfish Aquaculture is ranked as having a “moderate” effect associated with the impairment of water and soil qualities.

White Sturgeon

Effects Indices

White sturgeon adults and juveniles are potentially affected by Shellfish culture with effects ranging from “moderate” to “low” dependent on the lifestage and activity sub-group. Because the egg and larval lifestages utilize only riverine habitats, the only potential overlap in these life stages is with Finfish Aquaculture.

Potential Direct and Indirect Effects

Major threats to the white sturgeon related to Aquaculture are due to the disruption and loss of habitat, water and sediment quality impairment at acute and chronic levels, and physical harm due entanglement in associated gear.

- Direct effects to individuals from Aquaculture may occur as a result of in-water activities (e.g., rafts, vessel movement) disturbing the fish, disrupting behavior patterns and habitat use, as well as potentially causing harm to fish present in shallower nearshore waters. Sturgeon may also be harmed due to entanglement in fish pen nets. Habitat level effects may also occur as a result of permanent loss due to modification and disturbance associated with the structures. Shellfish Aquaculture was ranked as a "low" effect to individuals and "moderate" effect on the habitat for juvenile/adults. Effects for Finfish Aquaculture are ranked as "low" for all lifestages.

- Indirect effects could result from temporary modification and inaccessibility of habitat and reduction in the quality of habitat metrics due to the location of structures with associated decreases in prey items. Additional indirect effects could be caused by finfish net pen placement and supporting structures causing shoreland, tideland, and bedland modifications. Also sediment quality impairment associated with nutrient and waste deposition and use of chemicals to control pests could be an effect. Effects from Shellfish activities on habitat loss and degradation are ranked "moderate" due to associated temporary habitat destruction and inaccessibility, water and sediment quality impairment associated with accumulated waste, and reduction of structural habitat quality metrics. For all lifestages, Finfish culture is ranked as having a "low" effect on habitat loss and "moderate" effect on habitat degradation in association with the impairment of water and soil qualities.

MARINE MAMMALS

Southern Resident Orca

Effects Indices
Potential effects to killer whales from Aquaculture range from "low" for Finfish Aquaculture to "trace" for Shellfish Aquaculture.

Potential Direct and Indirect Effects
The major threat to killer whales is from disturbance of behavior by humans and pollution (Washington DNR 2007).

- Direct effects to individuals may result from human disturbance associated with Finfish Aquaculture, while direct habitat effects may occur as a result of deeper water (greater than 5 meters) Finfish Aquaculture facilities causing obstructions to killer whales, thereby causing the facility site to be inaccessible for foraging or movement. Direct effects of Finfish Aquaculture are ranked "low", and Shellfish Aquaculture is ranked "trace".

- Indirect effects may result from temporary habitat loss as a result of human disturbance. Indirect effects of Finfish Aquaculture are ranked "low", and Shellfish Aquaculture is ranked "trace".

4-2 Log Booming and Storage

4-2.1 Typical activity description

LOG BOOMING AND STORAGE

Structure

- Specific designated sites are likely to have been used historically used and may contain large accumulations of woody debris.
- Shoreline modifications (ramps, quays, breakwaters, bulkheads) and moorage structures (buoys or piling) may be associated with the site.
- Roadbeds in the form of fill or armoring may be present across shorelands and tidelands.

Operation

- Cut logs may be placed in the water (dumping) from shore or from loaded barges using cranes or other hoists.
- Booming is the formation of a log raft for temporary storage or transport. Rafts may be comprised of loose floating logs (flat raft) or logs bundled with wire or metal bands (bundle boom) and are typically attached to a structure (e.g., pilings) to keep the raft in place.
- Storage may occur in shallow or deep water.
- New structures such as pilings or buoys may require permits from regulatory agencies. Such permits may be conditioned based on baseline environmental assessments and impact evaluations, and may include monitoring requirements.
- Large accumulations of woody debris do not decay or otherwise deteriorate with time if submerged and/or buried.
- Accumulations of debris form low-quality habitats with little use by benthic organisms.
- Disturbance to biota and habitats from both log dumping and handling may be sporadic and substantial.
- Additional impacts may result from noise, contamination from fuel released by vessels and vehicles, and operation of vessels (e.g., propeller).

Temporal Assumptions

- Booming and storage may occur year round with seasonal or other variation in activity caused by market factors or permit conditions.

Maintenance

- Structures associated with log handling and storage may receive maintenance, replacement, or enhancement as needed.

Area of Alteration

- The area of alteration is based on the extent of bark and debris deposition that occurs in areas beneath and adjacent to log storage areas.
- The assumed footprint for log booming and storage areas is 79,994 meters^2 (See Table 4-10 at the end of this chapter).
- Bark deposition may occur on the substrate as far as 60 meters from the edge of the log boom and encompasses approximately 100,000 meters^2 outside the activity footprint. Consequently, the total assumed area of alteration is approximately 180,000 meters^2.

4-2.2 Controlling factors potentially affecting habitat

LOG BOOMING AND STORAGE

Log booming and storage may affect habitat quality by altering substrate composition, degrading water quality, increasing artificial shading, and altering sediment supply and transport processes (Table 4-4). The most widely researched potential effects are those that relate to alteration of the substrate. Substrates beneath log booming and storage areas may be physically disturbed when dumped logs come into contact with the substrate, causing scouring and compaction (Sedell et al. 1991). Pease (1974) examined one dumping site where unconsolidated substrates had been compacted to the extent that the sediment "looked and felt like sandstone". Severe sediment compaction may prevent substrate use by larger suspension feeders such as clams, and shift benthic assemblages such that infaunal detritus feeders become dominant (Sedell et al. 1991). Although not reported in any studies reviewed for this section, direct mortality for benthic organisms in the vicinity of log dumping is also a possibility.

Table 4-4 - Summary of the controlling factors associated with Log Booming and Storage activities and their potential biological effects.

Source of effect	Controlling factor associated with physical habitat structure	Potential biological effect
Waste accumulation on benthos	▪ Altered substrate composition, soil compaction, trash accumulation ▪ Degraded water quality, increased biological and chemical oxygen demand, increased turbidity ▪ Depth and slope alteration	▪ Shifts in biological communities from changes in substrate composition and/or elevation changes ▪ Reduced habitat connectivity ▪ Reduced prey abundance ▪ Behavioral avoidance of degraded water quality

Source of effect	Controlling factor associated with physical habitat structure	Potential biological effect
Boomed logs	▪ Increased artificial shade ▪ Reduced wave energy ▪ Source of bark deposition ▪ Degraded water quality – temperature dissolved oxygen ▪ Altered hydrology – reduced circulation ▪ Altered structural characteristics of habitat ▪ Physical trauma	▪ Shifts in biological communities due to reduced water circulation in sheltered area and degraded water quality ▪ Reduced wave energy alters processes that maintain nearshore beaches ▪ Reduced growth of aquatic plants and macroalgae due to increased shading ▪ Potential increases in pinniped staging areas
Operation	▪ Periodic dredging to maintain boat access to log storage areas ▪ Offloading logs (dumping) compacting sediment or altering depth and slope characteristics ▪ Wave energy from boat traffic increases shoreline erosion ▪ Recurrent episodic and unpredictable human activities	▪ Shifts in biological communities due to changes in elevation ranges from dredging and altered substrate ▪ Physical trauma from dumping or vessels ▪ Reduction of aquatic macroinvertebrate production ▪ Reduced habitat connectivity due to physical barriers (e.g., wood debris) ▪ Behavioral avoidance

Thick accumulations of bark deposits (Pease 1974, Jackson 1986), whole logs, and other miscellaneous trash such as metal bands and cables (Pease 1974, Kirkpatrick et al. 1998) may be common on the substrate beneath both dumping and rafting sites. Bark deposits may extend outward from the site for up to 60 meters (Pease 1974), may be greater than 0.5 meters thick (Jackson 1986), and have been observed to persist at abandoned sites for at least 30 years (Sedell et al. 1991). Accumulated debris, especially larger wood pieces, may persist in freshwater ecosystems for decades (Bilby et al. 1999) to centuries (Naiman et al. 2002). In saltwater systems, the persistence of woody debris may be considerably shorter because infestations of wood-boring organisms known as teredos or shipworms (*Bankia setacea*) compromise the structural integrity of the wood pieces and accelerate decomposition (Pease 1974).

Epibenthic organisms (those occurring near the surface of bottom sediments) including harpacticoid copepods, amphipods (e.g., *Anisogammarus confervicolus*) and isopods (e.g., *Exoshpaeroma oregonensis*) may occur in greater abundance beneath and adjacent to log rafts than in reference sites without rafts. The difference in abundance may be explained by the fact that sunken logs and scattered debris provide structural component that was previously lacking (Sedell et al. 1991). In contrast, organisms living within the substrate in areas covered with bark were less abundant and had lower biomass when compared to reference sites, regardless of depth (Jackson 1986). Suspension feeders were more affected by bark deposits than organisms that feed on deposited material.

Log booming and storage may alter water quality through leaching of pollutants from woody debris, as well as through decreases in dissolved oxygen as a result of decomposition of the debris. Power and Northcote (1991) observed respiratory distress and high mortality rates for caged juvenile sockeye salmon placed in close proximity to boomed logs in the littoral zone of a lake ecosystem. Dissolved oxygen concentrations measured at 0.5 meters below the surface adjacent to the floating logs were as low as 2.0 parts per million while measurements collected lower in the water column below the raft had concentrations as high as 9.0 parts per million. This result suggests that floating logs are a significant source of biological and chemical oxygen demand. Water temperatures in the vicinity of the log booms were strongly stratified, with surface water temperatures substantially warmer than those measured lower in the water column. Temperatures observed at reference sites were unstratified and generally cooler, indicating warming associated with the structure. Pease (1974) also observed acute toxicity for pink salmon from wood leachate in laboratory studies, with toxicity greater in freshwater than saltwater. Water quality impacts may also occur through stormwater runoff originating at onshore log handling facilities.

While the potential effects of log booming and storage on saltwater benthic communities, and to some extent on salmonids, have been studied, information on the other species addressed in this paper is generally lacking. However, many of the species addressed in this analysis are sensitive to human disturbance and it is likely that activities associated with log booming and storage result in temporary or permanent behavioral avoidance. For example, boat presence was shown to reduce both foraging duration and attempts for bald eagles (McGarigal et al. 1991), while harlequin ducks and brown pelicans demonstrate sensitivity to boat traffic (Hendricks 2000, Rodgers and Schwikert 2002) and human foot traffic (Gaines et al. 2003). Brown pelicans are generally less sensitive to human activity, however (Klein et al. 1995).

Log booming and storage increases artificial shading immediately beneath and adjacent to the structure, with the extent of the shade dependant on the orientation of the boom relative to the position of the sun. While little research exist regarding shading from log booming and storage in either fresh- or saltwater, for the purposes of this analysis, potential effects are considered similar to those reviewed in Overwater Structures (Section 4-3). Ancillary structures such as Docks, Wharves, and/or mooring buoys are also addressed in that section.

Additional impacts are related to: alterations in wave energy; nearshore sediment supply and transport processes; substrate composition and bathymetry; bank armoring associated with onshore processing facilities; scour from tug propellers; and impacts from dredging of woody debris.

4-2.3 Effects index and justification

Summary indices for potential effects related to log booming and storage activities are presented in Table 4-5, with the complete Effects Indices presented in Appendix G. The following sections contain Effects Indices justifications for each species group.

Table 4-5 - Summary of Magnitude of Effects by species, lifestage, and activity sub-group.*

Species	Lifestage	Log Booming and Storage
Amphibian complex	Adult	0.13
	Tadpole	0.06
	Egg	0.06
Western pond turtle	Adult	0.13
	Overwintering	0.00
Bald eagle	Non-nesting	0.19
	Nesting	0.75
Black tern	Migration	0.00
	Nesting	0.00
Brown pelican	Non-nesting	0.38
Common loon	Non-nesting	0.38
	Nesting	1.00
Harlequin duck	Non-nesting	0.38
	Nesting	NA
Marbled murrelet	Non-nesting	0.38
	Nesting	0.75
Western snowy plover	Wintering	NA
	Nesting	NA
Pacific salmon, trout, and char	Adult	0.25
	Incubation / Emergence	0.75
	Freshwater rearing / Outmigration	0.44
Green sturgeon	Adult	0.31
White sturgeon	Adult/Juvenile	0.38
	Larvae	0.63
	Egg	0.75
Southern resident orca	All	0.13

AMPHIBIANS AND REPTILES

Columbia Spotted Frog, Northern Leopard Frog and Western Toad

Effects Indices

The amphibians in this complex have all been determined to be potentially affected by Log Booming and Storage. Potential effects range between "trace" and "low."

* Ranks: "NA" indicates that an intersection between the specific activity and the species group does not occur. 1= "total loss"; 0.75 = "high" effect; 0.5 = "moderate" effect; 0.25 = "low" effect; 0 = "trace" effect.

Potential Direct and Indirect Effects
Major threats for the Columbia spotted frog, northern leopard frog, and western toad are habitat conversion and fragmentation (Washington DNR 2007).

- While no direct effects from Log Booming and Storage are identified for tadpoles or eggs, direct effects to adults may occur as a result of logs killing or injuring organisms during the dumping process. Effects to individuals are ranked “trace” for eggs and tadpoles, and “low” for adult lifestages. Effects to habitat are ranked “trace” for all lifestages.

- Indirect effects from habitat degradation are estimated as “low” for all lifestages, with effects potentially occurring as a result of increased wave energy associated with boat traffic and dumping, and degraded water quality. No effects associated with habitat loss are identified.

Western Pond Turtle

Effects Indices
Western pond turtles are determined to be potentially affected by Log Booming and Storage, with effects ranging from “low” to “trace”.

Potential Direct and Indirect Effects
Major threats for the western pond turtle include loss of nesting areas to human activities and predation from native and exotic species (Washington DNR 2007).

- Direct effects from Log Booming and Storage may occur as a result of physical harm or trauma associated with log dumping and vehicle traffic, as well as from permanent loss of habitat. Effects to individuals are ranked “trace” for both lifestages, with effects to habitat ranked “low” for adult migration/spawning/foraging and “trace” for the over-wintering stage.

- Indirect effects to adult migration/spawning/foraging habitat may occur as a result of temporary inaccessibility associated with operations, as well as potential decreases in prey assemblages. Effects are ranked “trace” for both habitat loss and habitat degradation due to potential decreases in energy resources.

BIRDS

Bald Eagle

Effects Indices
The bald eagle is potentially affected by Log Booming and Storage, with effects ranging from “high” to “low” for the nesting lifestage and “low” or “trace” for non-nesting stages.

Potential Direct and Indirect Effects
Major threats for bald eagles related to Log Booming and Storage are related to human disturbance (Washington DNR 2007).

- Direct effects to individuals from Log Booming and Storage may occur as a result of human disturbance and cause associated changes in species activity, alterations in behavior, and physical harassment. Direct habitat effects may also occur as a result of the activity permanently destroying habitat or making it inaccessible. Effects on individuals are ranked “low” for non-nesting forms and “high” for nesting forms, with habitat level effects ranked “high” for nesting forms because of the loss of nesting habitat and “trace” for non-nesting stages.

- Indirect effects from habitat loss are ranked “low” for non-nesting eagles and “moderate” for the nesting lifestage due to temporary inaccessibility when booming and dumping operations are underway. Effects may also occur as a result of habitat degradation due to a potential reduction in the quality of structural habitat metrics (e.g., riparian forest) and preferred prey. Habitat degradation effects for all life-stages is ranked “low”...

Black Tern

Effects Indices
Black terns may be affected by Log Booming and Storage, with effects at “trace”.

Potential Direct and Indirect Effects
Major threats for the black tern include loss or degradation of wetlands used for breeding and migration, nest predation, and human disturbances (e.g., boat activity) (Washington DNR 2007). While black tern densities are highest in seasonal or semi-permanent wetlands (Zimmerman et al. 2002), in northeastern Washington these birds nest in major river valleys (US Fish and Wildlife 1999) and as a result Sediment Removal (e.g., bar scalping, floodplain mines) may occur in close proximity to nest sites increasing the potential for effects.

- While no direct effects from Log Booming and Storage to habitat or nesting individuals are identified, migrating individuals behavior may experience “trace” effects from altered behaviors due to Log Booming and Storage facilities replacing stopover habitat.

- Indirect effects from habitat degradation are estimated as “trace” for both the migration and nesting lifestages, with effects related to structural alteration of shoreline habitats and to energy resource reduction that occurs as a result of the presence of log rafts.

Brown Pelican

Effect Indices
Potential effects for the brown pelican from Log Booming and Storage ranged from “moderate” to “trace”.

Potential Direct and Indirect Effects
Major threats for the brown pelican are related to alteration of shoreline roosting habitat; reduction of forage fish or invertebrate prey; pollution; and human disturbance (Washington DNR 2007, Franson et al. 2003).

- Direct effects to individuals from Log Booming and Storage may occur as a result of human disturbance and associated alterations in species behavior, with direct effects to habitat the result of the activity permanently destroying habitat or making it inaccessible. Effects to non-nesting birds are ranked “low” for individuals and “moderate” for habitat.

- Indirect effects from habitat loss and degradation may occur as a result of foraging habitat being temporarily inaccessible during operations; structural alteration of shoreline habitats; and chronic degradation of water quality and associated decreases in preferred prey. Effects are ranked "trace" for habitat loss and "moderate" for degradation.

Common Loon

Effects Indices

Potential effects for the common loon from Log Booming and Storage are greatest for the nesting lifestage and ranged between "total loss" and "trace", with effects on non-nesting birds ranging from "moderate" to "trace".

Potential Direct and Indirect Effects

Major threats for the common loon are related to alteration of shoreline nesting habitat; reduction of forage fish or invertebrate prey; pollution; and human disturbance (Washington DNR 2007).

- Direct effects to individuals from Log Booming and Storage may occur as a result of human disturbance and associated alterations in species behavior, with direct effects to habitat the result of the activity permanently destroying habitat or making it inaccessible. Effects to non-nesting birds are ranked "low" for individuals and "moderate" for habitat. The greater sensitivity of nesting birds to disturbance resulted in a rank of a "total loss" for both individuals and habitat.

- Indirect effects from habitat loss and degradation may occur as a result of foraging habitat being temporarily inaccessible during operations; structural alteration of shoreline habitats; and chronic degradation of water quality and associated decreases in preferred prey. Effects to all lifestages are ranked "trace" for temporary habitat loss and "low" for degradation.

Harlequin Duck

Effects Indices

Although no spatial overlap exists between harlequin duck nesting habitat and Log Booming and Storage, effects on other life-stages ranged between "trace" and "moderate".

Potential Direct and Indirect Effects

Major threats for harlequin ducks include the loss and degradation of riverine, lacustrine, coastal and inland nearshore habitat; pollution associated with the operation of motorized vehicles; reduced prey abundance associated with invasive species management; and human disturbance (Washington DNR 2007).

- Direct effects from Log Booming and Storage to non-nesting individuals are ranked "low" and may result from operational activities impairing behavior and harming or harassing birds. Habitat level effects are ranked "moderate" due to the logs presence permanently destroying migration or foraging habitat.

- Indirect effects to non-nesting birds from habitat loss and degradation may occur as a result of being temporarily inaccessible during log dumping; structural alteration of shoreline habitats; and chronic degradation of water quality and associated decreases in preferred prey. Effects attributable to habitat loss are ranked "trace" with effects from degradation ranked "low".

Marbled Murrelet

Effects Indices
Marbled murrelets are potentially affected by Log Booming and Storage in all lifestages, with effects ranging from "trace" to a "total loss".

Potential Direct and Indirect Effects
Major threats for marbled murrelets related to Log Booming and Storage include loss of nesting habitat; proximity to human disturbance; and degradation of foraging habitat (Washington DNR 2007).

- Direct effects from Log Booming and Storage may occur from human disturbance, resulting in disruption of foraging behavior and potential increases in nest predation; physical harassment or harm by boats and watercraft; and permanent inaccessibility of habitat. Direct effects to individuals are ranked "low" for non-nesting forms and a "total loss" to nesting forms due to disruption in foraging distance and accompanying increases in nest predation. Habitat level effects are ranked "moderate" for all lifestages.

- Indirect effects associated with habitat loss and degradation may also occur as a result of disturbance making habitat temporarily inaccessible; chronic impairment of water and sediment quality and associated decreases in prey resources; and reduced quality of structural habitat. Indirect effects from habitat loss are estimated as "trace", with effects from degradation ranked "low".

Western Snowy Plover

Effects Indices
Log Booming and Storage does not overlap spatially with the distribution of western snowy plovers

FISH

Pacific Salmon, Trout, and Char

Effects Indices
The salmonids in this group have been determined to be potentially affected by Log Booming and Storage, with effects ranging from "trace" to "total loss" depending on lifestage.

Potential Direct and Indirect Effects
Major threats for Pacific salmon, trout and char related to Log Booming and Storage include habitat degradation and loss, and degradation of water and sediment quality (Washington DNR 2007).

- Direct effects from Log Booming and Storage include impaired behavioral patterns due to disturbance; harm from log dumping; acute water and sediment quality impairment associated with bark accumulations and fuel spills; and permanent inaccessibility of habitat due to bark accumulations. Effects to individuals are ranked "trace" for migrating and marine rearing adults, "moderate" for incubation and emergence lifestages, and “low” for freshwater rearing and outmigration life stages. Habitat-level effects are ranked “moderate” for adult, rearing, and migrating lifestages, and “total loss” for incubation/emergence life stages. Effects to habitat are ranked “moderate” for adult and juvenile lifestages, due to their ability to find suitable habitat, and “total loss” for incubation/emergence lifestages because of bark accumulation and water quality degradation.

- Indirect effects related to temporary habitat loss are due to operational activity. Indirect effects may also occur as a result of habitat degradation via chronic water and sediment quality impairment; decreased quality of habitat structure; and associated reductions in prey. The relative sensitivities of the different lifestages to degradation resulted in effects ranks of “low” for adults, “moderate” for juveniles and a “total loss” for incubation and emergence.

Green Sturgeon

Effect Indices
Potential effects for the green sturgeon from Log Booming and Storage ranged from “moderate” to “trace”.

Potential Direct and Indirect Effects
Major threats for the green sturgeon related to Log Booming and Storage are related to habitat degradation and loss, and degradation of water and sediment quality.

- Direct effects to individuals may occur as a result of physical harm from log dumping and to habitat via destruction and inaccessibility associated with bark accumulations. Effects on individuals are ranked as “trace” and habitat effects are “moderate”.
- Indirect effects from habitat loss and degradation are estimated as “moderate” to “low”. Temporary habitat loss was due to operational activities. Effects may occur as a result of habitat degradation via chronic water and sediment quality impairment; decreased quality of habitat structure; and associated reductions in prey.

White Sturgeon

Effect Indices
Potential effects for the white sturgeon from Log Booming and Storage ranged from “total loss” to “low” depending on lifestage. The only current Washington DNR Aquatic land leases occur downstream of the spawning range of the white sturgeon in the Columbia River.

Potential Direct and Indirect Effects
Major threats for the white sturgeon associated with Log Booming and Storage are related to habitat degradation and loss, and degradation of water and sediment quality.

- Direct effects may occur as a result of physical harm from log dumping; acute water and sediment quality impairment caused by bark accumulations and fuel spills; and habitat loss and inaccessibility due to associated structures and bark accumulation. Effects on individuals are ranked as “low” for juvenile/adults and “moderate” for eggs and larvae due to increased sensitivity to water conditions. Habitat effects are “total loss” for egg/incubation, “high” for larvae, and “moderate” for juvenile/adults because of their ability to swim to avoid disturbances.

- Indirect effects for egg/incubation and larval lifestages from habitat loss and degradation are ranked as "moderate" due to temporary habitat loss from operational activities and degradation of water quality and structural metrics. Effects to juveniles/adults may also occur as a result of habitat degradation via chronic water and sediment quality impairment; and associated reductions in prey and are ranked as "low" for habitat loss and "moderate" for habitat degradation.

MAMMALS

Southern Resident Orca

Effects Indices
Killer whales have been determined to be potentially affected by Log Booming and Storage, with effects ranging from "trace" to "low."

Potential Direct and Indirect Effects
Major threats identified for killer whales as they relate to Log Booming and Storage include sensitivities to noise pollution (e.g., boat traffic); human disturbance; and reductions in prey associated with water quality degradation (Washington DNR 2007).

- No direct effects to individuals are identified. Effects due to the permanent destruction or inaccessibility of habitat used for log storage are ranked "low".
- Indirect effects associated with habitat loss and degradation are estimated as "trace" and are attributed to alteration of structural habitat metrics (e.g., depth, slope, increased artificial shade) and associated reductions in prey.

4-3 Overwater Structures

4-3.1 Typical activity description

Single Element Structures

Single element structures are those with no other associated structures or uses.

SINGLE ELEMENT STRUCTURES ATTACHED TO SHORE

Docks and Wharves

Structure
- Pilings of treated wood, concrete, or composite materials supports the structure.
- Decking material may be treated lumber, concrete, asphalt over wood, metal, or composite materials.
- Structure is typically two meters wide and up to 61 meters long.
- Some dock sections are floating and may ground out during low water.
- Structure is linear and may be "T" or "L" shaped.

- Structure is oriented perpendicular to the shoreline.
- Structure has a fixed connection to shore consisting of smaller floating structures, ramp, or a filled approach.

Operation

- Associated activities include industrial activities, commercial shipping, recreational boating, and vessel fueling.
- Larger piers, wharves, and docks are associated with ports, terminals, marinas, and private commercial/industrial enterprises.

Temporal Assumptions

- Activities associated with the structure occur all year with heavier use of public and recreational facilities in summer months.
- Maintenance activities may occur throughout the year, but are generally concentrated from the beginning of April to the end of October.

Maintenance

- Activities include replacement and repair of structure, support, and decking components.

Assumed Area of Alteration

- The area of alteration includes the footprint of the structure, as well the area potentially altered by changes in hydrodynamics, sediment dynamics, shoreline modification, vessel propeller scour, shading, stormwater, and effects of chemicals leaching from treated timber.
- The assumed footprint for Docks and Wharves is approximately 122 $meters^2$ (see Table 4-10 at the end of this chapter).
- The area of alteration associated with docks and wharves is relatively large due to shading and hydrodynamic alteration. For the purposes of this analysis, it is assumed to encompass 750 $meters^2$.

Boat Ramps/Launches/Hoists

Structure

- Boat ramps are oriented perpendicular to the shoreline and the ramp structure extends beyond ordinary low water.
- Individual ramps are concrete slabs typically 8 meters wide and 31 meters long.
- Areas immediately waterward of the ramp may have been excavated (dredged).
- Boat ramps may have single or multiple floating docks attached to a permanent pier, piling, or dolphin (group of piling) for temporary boat moorage. Each dock is 2 meters wide and 15 meters long. Other characteristics of the dock are consistent with those described under Docks and Wharves.
- Launches and hoists are associated with marinas or ports and are usually attached to piers, modified shoreline (e.g., seawall or bulkhead), or both.

Operation

- Activities associated with ramps include boating, fishing, and swimming.
- Activities associated with hoists may include commercial vessel repair, storage, and sales and recreational activities.

Temporal Assumptions

- Activities associated with the structure occur throughout the year.
- Recreational facilities will experience heavier use in the summer months.
- Maintenance activities may occur from the beginning of April to the end of October
- Activities include dock and ramp repair, sediment removal, and vegetation control.

Assumed Area of Alteration

- The area of alteration for ramps includes the footprint of the structure, along with the surrounding area altered by propeller scour, shoreline modification, and changes in sediment transport.
- The assumed footprint for boat ramps is approximately 248 $meters^2$ (see Table 4-10 at the end of this chapter).
- A relatively small area of alteration results from the physical structure and placement of boat ramps. Due to their low profile that is usually level with or only slightly above existing grade, ramps result in relatively little effect on sediment transport, shading and benthic biota. For the purposes of this analysis, the area of alteration is assumed to encompass 275 $meters^2$.

Nearshore Buildings

Structure

- Structures are built on filled tideland or shoreland with a footprint including structure and fill of 61 meters by 63 meters.
- Structure is 20 meters tall.
- Structure has ancillary dock attached on the waterward side that is typically two meters wide and 61 meters long. Other features of docks are described under Docks and Wharves.
- Vessels cannot be moored to a nearshore building unless a mooring facility is present (e.g., pier or dock).
- Structure has impervious surfaces in the form of sidewalks, parking lots, and roofs.
- Stormwater outfalls may be associated with the structure and associated facilities.
- Fill and bank armoring is in place along the entire shoreline (61 meters).

Operation

- Nearshore buildings may be used for private, industrial, or public access purposes.
- Activities associated with Nearshore Buildings may cause additional effects to biota and habitats.

Temporal Assumptions

- Structure is permanent and present all year.
- Associated activities may vary seasonally or daily.

Maintenance

- Buildings and associated structures will require periodic maintenance, repair, and replacement as needed.
- Maintenance occurs year round.

Assumed Area of Alteration

- The area of alteration includes the footprint of the structure and adjacent aquatic lands that could be affected by the building through shading, shoreline modification and associated vessel activity.
- The assumed footprint for Nearshore Buildings is approximately 3,838 $meters^2$ (See Table 4-10 at the end of this chapter).
- Nearshore buildings have a relatively large area of alteration due to associated modifications of the shoreline and adjacent aquatic land through shading, structures, and vessel activity. For the purposes of this analysis, the area of alteration encompasses approximately 11,500 $meters^2$.

SINGLE ELEMENT STRUCTURES NOT ATTACHED TO SHORE

Mooring Buoys

Structure

- The structure consists of a float one to two meters in diameter and attached to an anchoring system.
- While only one vessel is typically moored to the float, additional vessels may occasionally be rafted to the first vessel.
- The water depth fluctuates up to 3 meters in saltwater environments and seasonally in freshwater.
- Commercial mooring structures are located in water depth greater than 10 meters.
- Recreational mooring buoys are often in depths less than 10 meters and may be inadvertently placed in eelgrass beds.
- Anchor chains are assumed to be 40 meters in length and may drag on the substrate during water level fluctuations.
- Anchoring system is sufficiently stable to keep structure in place.
- Commercial buoys and associated vessels do not usually ground during low water, however recreational buoys and associated vessels may.

Operation

- Activities associated with recreational buoys include boating, fishing, swimming, and fueling with small containers.

- Activities associated with commercial buoys may include vessel repair, fueling and long-term storage.

Temporal Assumptions

- Commercial buoys are present all year.
- Recreational mooring buoys may be removed during winter months.
- Recreational and commercial vessels may be present all year with increased recreational activity between April and October.

Maintenance

- Maintenance activities may include replacement, repair, and cleaning of structure components.
- Maintenance activities for recreational buoys occur between April and October, with commercial buoys maintained throughout the year.

Assumed Area of Alteration

- The area of alteration includes the footprint of the anchoring system and float, the area potentially altered as a result of anchor/chain drag and shading by the buoy and vessel.
- The assumed footprint for mooring buoys is approximately 49 meters^2 (See Table 4-10 at the end of this chapter).
- For the purposes of this analysis, the area of alteration encompasses approximately 100 meters^2. This area includes the area directly impacted by the chain or unbuoyed cable and shading from the attached vessel and the anchor.

Floats and Rafts

Structure

- Structure is a floating dock section approximately 8 meters wide by 8 meters long.
- The deck is constructed of treated wood and floats of steel or concrete.
- The anchoring system is sufficiently stable to keep structure in place, however the chain may drag on the substrate with water level fluctuations.
- Structure does not ground during low water.
- Structure is located within 20 meters of shoreline.

Operation

- Associated activities include boating, fishing, and swimming.

Temporal Assumptions

- Rafts and floats may be present all year or removed during winter months for storage upland.
- Activities associated with the structure are concentrated between April and October.

Maintenance

- Maintenance may include replacement of damaged components and removing accumulated underwater growth of encrusting organisms (e.g., “fouling”).
- Maintenance activities occur between April and October.

Assumed Area of Alteration

- The area of alteration includes the footprint of the structure and the area potentially altered as a result of impacts associated with anchor and chain/cable drag, and shading.
- The assumed footprint for rafts and floats is approximately 64 $meters^2$ (See Table 4-10 at the end of this chapter).
- Due to the similarity in structure and effects (e.g., anchoring system, cable or chain drag, shading), the area of alteration relative to the footprint is assumed to be similar to that for mooring buoys and equals 128 $meters^2$,

Floating Homes

Structure

- Structure is a one story floating home on a barge 8 meters wide and 15 meters long.
- Structure includes an ancillary moorage dock with a moored small- to medium-size recreational boat (up to 8 meters long) or personal watercraft, and a storage/work building.
- Structure does not ground during low water.
- Structure is oriented such that the longer dimension is parallel to the shoreline.
- Structure is located within 10 meters of the shoreline on rivers. Assemblages of Floating Homes may extend further from the shore in lakes or saltwater environments.
- Structure has a fixed ramp that extends from the shoreline to provide access to the home.
- Floating homes are secured to pilings or anchored.

Operation

- Associated activities include those associated with a residence, and recreational activities such as boating, fishing and swimming.
- Hazardous materials stored on site are limited to household products, which are stored in a manner that prevents them from directly entering submerged habitat.
- No insecticide use occurs.
- Trash is disposed of in upland sites.
- No sanding or painting occurs over water.
- All Floating Homes have upland sewage disposal.

Temporal Assumptions

- Activities associated with Floating Homes occur all year.

Maintenance

- Activities include home repair (e.g., painting, roof repair) and fueling of ancillary equipment.
- Maintenance activities may occur throughout the year.

Assumed Area of Alteration

- The area of alteration includes the footprint of the floating home plus the area potentially altered by impacts from moorage systems and shading.
- The assumed footprint for Floating Homes is approximately 810 meters^2 (See Table 4-10 at the end of this chapter).

A relatively small area of alteration is assumed due to the typically low energy and highly impacted environment in which Floating Homes are located. For the purposes of this analysis, the area of alteration encompasses approximately 900 meters^2.

Multiple Element Structures

Multiple element structures are a complex of interrelated structures at a single facility such as a marina.

Marinas

Structure

Marinas may include the following structural components:

- Over and on-water structures in the form of piers, access ramps, and floating docks with and without covers.
- Similar materials to those found in over and in-water and transportation structures (creosote, concrete, metal).
- Breakwaters, riprap, fill, and/or floating structures, and extensive shoreline modification, seawalls and bulkheads.
- Nearshore buildings, roads, and other civil infrastructure.
- Stormwater management systems including direct discharges into adjacent water bodies.
- Fueling facilities.
- Pumpout facilities for the extraction of wastewater from vessel holding tanks.
- Vessel launching facilities including hoists and/or ramps.
- Utilities including pipelines and cables.

Operation

- A breakwater or a combination of a breakwater and a natural shoreline may wholly or partially enclose marinas, forming an enclosed body of water where circulation is reduced.

- Marinas are centers of vessel activity that increase both potential and actual effects from shading, sedimentation, incidental fuel spills, gray and black water discharge, and propeller scour at low tides.

- Marinas may be associated with a park or other facility that provides public access further multiplying the effect of the marina.

- Debris may accumulate on submerged lands from littering or gray water discharge, equipment and/or personal items.

Temporal Assumptions

- Marinas are present throughout the year.

- Associated activities typically increase in summer months and are reduced during the winter season. Activity may cease entirely at marinas with a high percentage of seasonal users with activity limited to year-round residents in winter months.

Maintenance

- Marina facilities require extensive maintenance, repair, and /or replacement activities, especially in association to those components in contact with water.

- Maintenance activities may increase in the spring in preparation for the recreational boating season and again in fall in preparation for winter.

Assumed Area of Alteration

- The area of alteration includes the area of the overwater structure(s) associated with the marina, shading, propeller scour, emissions and exhaust of vehicles and boats, stormwater pollution, disturbance of aquatic species related to boat traffic and shoreline erosion caused by waves produced from the boat. The adjacent area includes that affected by the discharge of water from impermeable surfaces carrying pollutants or from facilities and light or noise pollution. In-water alterations are related to impacts extending beyond the footprint from boat traffic that results in scour from propeller wash, paint releases, waste releases, vessel moorage and loading (e.g. shading, spillage and accidental discharges of toxins or waste), fueling, vessel repair and associated pollutants, and transfer of materials. The operation of boats can create changes in the physical environment beyond the facility through changes in currents, light, water and sediment composition. The net effect is that marinas exert a wider influence on the bottom than that contained within the assumed footprint (Washington DNR 2005c). However, the area of alteration may be restricted due to enclosure by breakwaters that limits the impact of many controlling factors such as stormwater pollutants, scour, noise and wave energy.

- The assumed footprint for a typical marina is 200 meters by 1,000 meters totaling approximately 200,000 $meters^2$ (See Table 4-10 at the end of this chapter).

- Based on the length of 150 meters from each of four sides of the assumed footprint for a typical marina, the assumed dimensions for the area of potential disturbance of aquatic species from boat and personal watercraft operation is 500 meters by 1,300 meters totaling approximately 650,000 meters^2.

Shipyards and Terminals

Structure

Shipyards and Terminals can include the following structural components:

- Over and in-water structures in the form of piers, access ramps, and floating structures with numerous supporting piling.
- Materials similar to those found in over and in-water and transportation structures (creosote, concrete, metal).
- Extensive shoreline modification including filled shorelands and tidelands, seawalls and bulkheads.
- Nearshore buildings, roads, and other civil infrastructure.
- Stormwater management systems with discharges directly into adjacent water bodies.
- Outfalls discharging treated process or wastewater under a NPDES permit.
- Vessel launching facilities including hoists and/or ramps.
- Vessel moorage structures including anchored buoys, docks and wharves, and pilings (single or clustered).
- Utilities including telecommunications, petroleum and natural gas pipelines, and power lines.

Operation

- Shipping terminals are typically locations where larger commercial vessels transfer cargo to and from land-based transport systems and may be outside of a recognized port.
- Shipyards are typically associated with a port.
- Terminals are not typically enclosed in embayments, but are located where rail and highway access coincide with deepwater for moorage, where anchoring is available, and in areas with access to the open ocean and urban centers.
- Shipyards and Terminals typically have dedicated stormwater management systems, spill prevention best management practices, and other environmental protection procedures as required by government regulation.
- Effects from shipping terminals may include indirect effects from potential releases of materials (e.g., petroleum, chemicals, bulk commodities).
- Effects from noise and artificial light may be substantial.
- Debris may accumulate on tidelands and bedlands from lost equipment and breakage.

Temporal Assumptions

- Shipyards and Terminals are permanent throughout the year.

- Associated activities will vary diurnally and in association with operational, market, and cultural factors (e.g., holidays).

Maintenance

- Shipyards and Terminals may require maintenance and repair throughout the year.

Assumed Area of Alteration

- The area of alteration includes the area of the overwater structure(s) associated with the terminal or shipyard, shading, propeller scour, emissions and exhaust of vehicles and boats, stormwater pollution, disturbance of aquatic species related to vessel, vehicle and loading equipment traffic and shoreline erosion caused by waves produced from shipping vessels. Adjacent area includes that affected by the discharge of water from impermeable surfaces carrying pollutants or from facilities and light or noise pollution. In-water alterations are related to impacts extending beyond the footprint from vessel traffic that results in scour from propeller wash, paint releases, waste releases, vessel moorage and loading (e.g. shading, spillage and accidental discharges of toxins or waste), fueling, vessel repair and associated pollutants, and transfer of materials. Terminals are associated with storage and warehousing and the use of heavy equipment and rail or pipelines that move cargo – all of which can contribute toxic discharges, noise and light pollution.

- The assumed footprint for a typical terminal/shipyard is 200 meters by 2,000 meters totaling approximately 400,000 $meters^2$ (See Table 4-10 at the end of this chapter).

- Based on the length of 150 meters from each of four sides of the assumed footprint for a typical marina, the assumed dimensions for the area of potential disturbance of aquatic species from boat and personal watercraft operation is 500 meters by 2,300 meters totaling approximately 1,115,000 $meters^2$.

4-3.2 Controlling factors potentially affecting habitat

Table 4-6 summarizes the sources and mechanisms of potential effects from both single and multiple element overwater structures. The following sections discuss these sources in more detail and provide a literature review.

Table 4-6 - Summary of the controlling factors associated with Overwater Structures and their potential biological effects.

Source of effect	Controlling factor associated with physical structure	Potential biological effect
Dredging	▪ Depth and slope alteration	▪ Altered biological communities as a result of depth increases and greater saltwater intrusion into freshwater ecosystems
	▪ Degraded water quality	▪ Loss of spawning habitat for some species

Source of effect	Controlling factor associated with physical structure	Potential biological effect
	▪ Change in substrate composition	▪ Reduced presence of submerged aquatic vegetation and associated biological communities
	▪ Physical disturbance of substrate	▪ Physical trauma and/or mortality from dredging (e.g., entrainment, crushing)
	▪ Recurrent human activity	▪ Reduced prey abundance
	▪ Loss of natural shade	▪ Behavioral avoidance due to degraded water quality and/or noise
		▪ Reduced fitness and/or increased mortality due to suspension of persistent bioaccumulative toxins
Fishing	▪ Recurrent disturbance	▪ Mortality
	▪ Physical trauma	▪ Reduced fitness
Vehicular, boat, and foot traffic	▪ Altered substrate composition, soil compaction, trash accumulation	▪ Altered biological communities due to changes in substrate, depth and slope
	▪ Degraded water quality, increased biological and chemical oxygen demand, increased turbidity	▪ Reduced habitat connectivity
	▪ Change in substrate composition	▪ Reduced prey abundance
	▪ Depth and slope alteration	▪ Behavioral avoidance of degraded water quality
	▪ Noise	▪ Mortality of eggs, juveniles and adults
	▪ Collision or entrainment	▪ Mortality of eggs, juveniles and adults
Operational activity	▪ Altered depth/slope profile	▪ Behavioral avoidance
	▪ Altered hydrology	▪ Physical disturbance and stress related trauma
	▪ Physical disturbance	▪ Degradation of habitat
	▪ Reflected wave energy	▪ Alteration of substrate composition
	▪ Structural habitat alteration (e.g., depth/slope profile)	▪ Nesting failure
		▪ Increased predation
		▪ Reduced habitat connectivity / increased fragmentation
		▪ Reduced prey abundance
		▪ Reduction of aquatic macroinvertebrate production

Source of effect	Controlling factor associated with physical structure	Potential biological effect
		▪ Physical barriers to migration / movement
	▪ Vessel traffic and accompanying human activity	▪ Noise and other activity can disturb activities such as feeding, nesting, resting
		▪ Propeller wash can create turbidity, change sediment regime, disturb communities and injure species
	▪ Water and sediment quality degradation	▪ Direct mortality
Physical structure	▪ Change in habitat structure (pilings)	▪ Aggregation of predatory finfish species (e.g., bass) in freshwater ecosystems
		▪ Increased predation on juvenile salmonids in freshwater ecosystems
	▪ Displacement of habitat – pilings, boat ramps, and other structures such as bank hardening and breakwaters	▪ Replaces habitats used for foraging, reproducing and migrating with a completely different structure and ecological community.
	▪ Shading - behavioral changes	▪ Modified juvenile salmonid behavior (increased schooling, avoidance) in saltwater, estuarine and freshwater ecosystems
		▪ Increased use of deep water by juvenile salmonids in saltwater ecosystems
	▪ Shading – community changes	▪ Reduction of emergent or submerged aquatic vegetation in saltwater, estuarine and freshwater ecosystems
		▪ Reduction of benthic infauna in wetland ecosystems
		▪ Modification of benthic infauna community structure (reduction of diversity, increase in abundance of tolerant species) in saltwater ecosystems
		▪ Increased population density of mobile benthic predators and scavengers (e.g., crabs, seastars sculpins)

Source of effect	Controlling factor associated with physical structure	Potential biological effect
Placement of nearshore stabilization materials (e.g., breakwalls)	▪ Pollution	▪ Reduced water circulation in sheltered area and water quality degradation results in physiological stress, and acute or chronic toxicity for some organisms
	▪ Altered hydrology	▪ Reduced water circulation in sheltered area and water quality degradation results in physiological stress, and acute or chronic toxicity for some organisms
Placement of shoreline erosion control structures (e.g., rip-rap)	▪ Reduced sediment supply	▪ Changes in community composition and population numbers due to altered habitat
	▪ Reflected wave energy	▪ Increased depth and slope in nearshore ecosystem reduces area within elevation ranges suitable for some organisms
	▪ Change in substrate composition	▪ Loss of large organic debris as cover element
	▪ Depth and slope alteration	▪ Loss of channel complexity
	▪ Structural habitat simplification	▪ Reduced habitat connectivity
	▪ Water quality degradation	▪ Reduced prey abundance
		▪ Behavioral avoidance
Presence of outfall structure on aquatic lands	▪ Artificial hard substrate in habitats	▪ "Artificial reef effect:" Benthic habitat modification through accumulation of species and biomass not typical to habitat, may include predators (e.g., rockfish, sculpins)of Covered Species (e.g., salmonids)
	▪ Physical changes in sedimentary processes (scouring, sediment transport, deposition, sediment composition)	▪ Disturbance and change of existing habitat structure and function from unconsolidated to consolidated
	▪ Physical changes in hydrodynamics	▪ Inaccessible habitat because of presence of structure and effluent plume
Stormwater / Wastewater discharge	▪ Increased nutrient loads	▪ Decreased reproductive success
		▪ Increased productivity and an accompanying decrease in dissolved oxygen
		▪ Increase in algal blooms

Source of effect	Controlling factor associated with physical structure	Potential biological effect
		▪ Localized alteration of benthic communities
	▪ Accumulation of toxins (e.g., metals, pesticides, herbicides, hydrocarbons) and other harmful chemicals (e.g., endocrine disrupters) in sediment	▪ Bioaccumulation of toxins
	▪ Degradation of water and sediment quality	▪ Can have indirect effects on health of species.
		▪ Modification of benthic infauna community structure (reduction of diversity, increase in abundance of tolerant species) in saltwater ecosystems
	▪ Discharge of toxins (e.g., metals, pesticides, herbicides, hydrocarbons) and other harmful chemicals (e.g., endocrine disrupters) into the water column	▪ Altered food web dynamics
	▪ Introduction of human and pet pathogens	▪ Increases in disease or lesions
Treated wood in pilings, other structural components and debris	▪ Impairment of water quality	▪ Little documented effect.
	▪ Impairment of sediment quality	▪ Modification of benthic infauna (decrease in diversity and abundance) in saltwater, estuarine, and freshwater ecosystems.
Waste and chemical contamination	▪ Degraded water quality, increased biological and chemical oxygen demand, increased turbidity	▪ Decreased oxygen levels resulting in impaired respiration
		▪ Introduction of diseases or pathogens

COMMON FACTORS

While their configuration, materials and effects on submerged habitats vary, most overwater structures have features in common with Docks and Wharves. The following is a discussion of the common factors associated with Overwater Structures.

The effects of Overwater Structures in Washington waters have been extensively described in three white papers with Nightingale and Simenstad (2001) addressing saltwater environments, Carrasquero (2001) freshwater ecosystems, and Poston (2001) treated wood issues in both saltwater and freshwater ecosystems. This information is supplemented by recent research by Battelle Marine Sciences Laboratory (Washington DNR 2005c).

Most of the literature on overwater structures in Washington emphasizes their effects on salmonids and their predators and prey base. This emphasis is a result of the importance placed on the salmonids by regulatory and natural resource agencies, as well as the public. Little assessment is available of the effects of overwater structures on other species included in this compliance project. Thus, affects on amphibians, reptiles, birds, and marine mammals must be predicted using available information, professional judgment, and experience.

Overwater structures often induce effects on predation, behavior, and habitat function through alteration of controlling factors (Carrrasquero 2001, Nightingale and Simenstad 2001). These alterations can, in turn, interfere with habitat processes supporting the key ecological functions of spawning, rearing, and refugia. There are three primary direct mechanisms of impact associated with overwater structures, shorezone habitat structure changes, shading and ambient light changes, and disruption of water flow pattern and energy (Carrasquero 2001). Indirect affects include disruption of physical/chemical environmental parameters through water quality degradation, noise, and vessel activity. Structures may induce a response in an organism without altering habitat or predator-prey interactions (Carrasquero 2001).

The effects of overwater structures have two spatial components, the site-specific impacts within the footprint of the activity or structure, and a zone of influence beyond the footprint that together comprise the “area of alteration” (Section 2-2.3). Temporal components are also present because overwater structures are continually present. However, most studies do not separate these effects from the spatial. Thus, this review concentrates on the spatial effects and assumes that temporal ones are integrated with the spatial.

The area of alteration is not only related to the structure, but also to the activities typically associated with that structure. Data compiled from docks, marinas and typical associated activities indicate that the area of alteration is larger than the footprint of the structure (Washington DNR 2005c). The mechanisms of impact include effects such as shading, alteration in sediment dynamics and hydrodynamics and bathymetry (Simenstad et al. 1999, Washington DNR 2005c).

It appears from the reviewed literature that the most important effect of overwater structures in both saltwater and freshwater ecosystems is shading, which also provides an example of dynamics of the area of alteration. For example, shading by overwater structures can eliminate eelgrass and other benthic vegetation from a much larger area than just the surface area of the dock (Nightingale and Simenstad 2001, Simenstad et al. 1999, Washington DNR 2005c). Work done by Battelle (Washington DNR 2005c) found that while a shadowed area varies with season and several other factors (e.g., depth, depth width, vessel presence and dimensions), an approximate shadow-to-deck-area ratio may be 4:1.

In both freshwater and saltwater environments, shading from overwater structures not only affects benthic vegetation, but also the behavior of finfish (Carrasquero 2001, Nightingale and Simenstad 2001, Simenstad et al. 1999). Carrasquero reported that in freshwater ecosystems overwater structures attracted warm water finfish species, especially bass, which are salmonid predators (Bonar et al. 2004, Carrasquero 2001). Because of the higher concentrations of predators associated with overwater structures, increased predation may adversely affect juvenile salmonids.

Effects on juvenile salmonid behavior in saltwater near ferry terminals were reviewed and reported by Simenstad et al. (1999), Nightingale and Simenstad (2000), and Washington DNR (2005c). In addition, Haas et al. (2002) conducted a study on the effect of overwater structures (ferry terminal) on prey resources. The most important effects on juvenile salmonids were from shading, which limited movement and feeding efficiency. In addition, reduced light levels inhibited benthic vegetation and prey production. In contrast to freshwater situations (Carrasquero 2001), Battelle studies in saltwater found no strong evidence of increased predation on juvenile salmon under or near docks.

Toft et al. (2004) and Struck et al. (2004) present additional evidence of effects from overwater structures. Toft et al. documented that overwater structures effectively truncate the shallow portion of the nearshore zone creating deep water immediately adjacent to the shoreline. Higher densities of fish including juvenile salmonids occurred along the more extensively modified shorelines than those with only substrate changes. Toft et al. concluded that juvenile salmonids responded to overwater structures by inhabiting deeper water and schooling more to avoid swimming under overwater structures. In contrast, surfperches (*Embiotocidae*), crabs, and sculpins were observed under decks or adjacent to pilings.

Struck et al. (2004) examined the effect of highway bridges as overwater structures on estuarine wetlands and found similar effects from shading to those documented for freshwater and saltwater nearshore ecosystems. Shaded areas under bridges had significantly diminished macrovegetation, which was positively correlated with reduced benthic invertebrate densities, diversity, dominant taxa, and feeding group structure.

Overwater structures can also affect bathymetry by modifying the longshore transport of sediments. Studies reported by Washington DNR (2005c) show that sediment can accumulate along the shore under and immediately adjacent to a structure. This effect can easily be seen in aerial photographs of Puget Sound shorelines (Figure 4-1).

In addition, vessels using the dock can scour the bottom and deposit sediments adjacent to the scoured area forming a berm. The net effect is that the area of alteration for the structure and associated activity can be approximately 10 times the physical footprint of the overwater structure (Washington DNR 2005c).

Water and sediment quality impairment resulting from chemicals in pilings made of treated wood is one of the indirect effects of overwater structures (Carrasquero 2001). Three major types of treated wood are used in Washington State - creosote, ammoniacal copper zinc arsenate (AZCA) and chromated copper arsenate type C (CCA). Listed and other sensitive species can be exposed to these preservatives through contaminants leaching into the water column and/or sediments, as well as through direct contact with the wood (e.g., eggs deposited directly on treated piling) (Poston 2001, Vines et al. 2000).

Poston (2001) reviewed the findings of a large number of studies on the specific effects of treated wood in both freshwater and saltwater ecosystems. One of the conclusions of this assessment was that the extent of measurable influence for treatment chemicals is generally small and limited to within 10 meters of the structure. For example, Brooks (2000), Weis et al. (1998) and Vines et al. (2000) found that levels of, and effects from, creosote and metals declined with the distance from structures in streams, freshwater and estuarine wetlands, and saltwater nearshore systems, reaching background concentrations in sediments between less than one and up to three meters from structures. These studies also showed that attenuation rates depend on sediment chemical (e.g., oxygen content) and physical (e.g., grain size distribution) factors.

In general, the potential for water quality impacts from trace metals or polycyclic aromatic hydrocarbons (PAH) from treated wood is substantially lower than that for sediments. In addition, the relative spatial and temporal hazard of creosote treated wood is greater than that from CCA Type C or ACZA treated wood in terms of temporal and spatial impact (Poston 2001).

While Poston (2001) stated that available field studies did not specifically address effects on salmonids or other listed species, he utilized the results and conclusion of the studies to project potential effects. In riverine salmon spawning, incubation, and emergence areas, sediment conditions that facilitate accumulation of PAH and trace metals (high concentrations of fine sediments and organic content) are generally not present. In contrast, rearing habitats in freshwater and saltwater ecosystems may include areas that have sediments with high organic content and fines. Despite these conditions, Poston (2001, page 68) concluded "Once juvenile salmon enter larger rivers or engage in an open-water marine lifestage, the potential to be adversely impacted by treated wood contaminants is very low."

Figure 4-1 - Accumulation of sediment resulting from the wave shadow of the Des Moines Marina. *

* Photo courtesy of the Washington State Department of Ecology, Shoreline Aerial web site. http://apps.ecy.wa.gov/shorephotos/index.html

The following are additional factors specific to activity sub-groups.

SINGLE ELEMENT STRUCTURES ATTACHED TO SHORE

Boat Ramps/Launches/Hoists

Thom and Albright (1983) only reported one direct effect associated with overwater structures, which was the loss of habitat and biota within the footprint of the ramp. Their studies showed that there was no significant difference between benthic infauna assemblages both near and removed from a launching ramp. Additional indirect effects may be associated with ramps through increased use of the nearshore environment by vessels and other human activities, dredging to deepen the approach for a ramp, and from associated floating or fixed docks and piers.

Nearshore Buildings

Specific studies describing effects of Nearshore Buildings could not be found. However, it is apparent from their location, construction and known effects of other overwater structures that this activity may have a variety of effects. A nearshore building with an associated dock or pier, ancillary buildings, shoreline modifications, and stormwater or other wastewater discharge could have effects associated with all of these factors. These effects could include shading, interference with sediment dynamics, contamination of the associated water body from stormwater, and increased public use.

SINGLE ELEMENT STRUCTURES NOT ATTACHED TO SHORE

Mooring Buoys, Floats and Rafts

Changes due to impacts from mooring systems associated with vessels and shading are similar and comparable to those of other overwater structures. Many larger mooring systems are usually placed offshore at depths in which eelgrass and other macrovegetation are infrequently found. However, recreational moorings, rafts, and floats may be placed in shallower nearshore waters where benthic vegetation could be affected (Betcher and Williams 1996). While the shading effect can be exacerbated by the fact that the structure is floating thus reducing the height above the vegetation and the amount of light that can diffuse under the buoy raft or float, the structures' ability to move may reduce shading effects by reducing the time that any one area is covered (Nightingale and Simenstad 2001).

In addition to shading, physical effects are possible. The mooring system's anchor will directly impact the area on which it is located And the chain or cable, if not buoyed, can affect the benthos through dragging on and abrading the seafloor, removing vegetation within the scope of the system (Betcher and Williams 1996).

Floating Homes

In addition to factors common to all overwater structures, Floating Homes are typically associated with parking lots and other impervious surfaces that can result in stormwater runoff contaminated with chemicals harmful to aquatic life (Nightingale and Simenstad 2001). In addition, Floating Homes are residences and may be a source of paint and other maintenance debris; petroleum (oils and greases); pesticides; and herbicides that pose special risks to the aquatic life and food webs in the case of spillage.

MULTIPLE ELEMENT STRUCTURES

Marinas, Shipyards and Terminals

are frequently located in productive nearshore or littoral environments in salt and freshwater systems, as well as estuaries. While these facilities may be thought of as single distinct entities, they are in fact a conglomeration of widely varied components. For example, marinas are typically comprised of the following: docks and wharves; nearshore buildings; mooring buoys; breakwaters; stormwater outfalls; fill; shoreline armoring; pumpout facilities; and fueling facilities. As each of these components are sources or mechanisms that alter or control habitat structure, each of the individual components may have its own impact on the biological character of an area. The following review is focused on potential effects associated with the larger size and greater concentration of specific activities characteristic of Marinas, Shipyards and Terminals (i.e. concentration of overwater structures and related activities, concentration of pollutants, large-scale use).

Effects associated with in-water and overwater structures; Nearshore Buildings; vessel moorage; boat launching and hoists; and maintenance activities are provided in Section 4-1 of this document (Overwater Structures). In a comprehensive evaluation of the physical, chemical, and biological impacts of overwater structures, Simenstad et al. (1999) reviewed over 60 direct sources of information related to impacts on juvenile salmon migration from ferry terminals in Puget Sound. Although not a direct study of Marinas, Terminals and Shipyards, their findings have relevance to this review in three subject areas: 1) alteration of migratory behavior; 2) reduction in prey production and availability; and 3) increased predation. Based on the available evidence, the authors concluded that while individual shoreline structures may result in significant impacts to salmon, the exaggerated effect of contiguous and concentrated shoreline modifications are similar to those associated with marinas and terminals. One possible source of impact may be related to changes in ambient light due to both the introduction of artificial light and increased shading associated with large structures. For example, although Docks and Wharves increase artificial shade throughout much of the footprint of the structure, portions of the footprint may be continuously lit by artificial lighting. Researchers hypothesize that changes in ambient light can alter salmonid migratory behavior, but the significance of these changes on survival are not currently understood. Researchers have also hypothesized that a relationship exists between overwater structures and increased predation risk for juvenile salmon around docks. Although limited research has been conducted on this topic, some studies provide evidence that this hypothesis should be rejected. Ward et al. (1994) concluded that waterway developments in the lower Willamette River in Oregon presented few risks to migrating juvenile salmonids related to predation. Williams et al. (2003) found no evidence that areas with overwater structures presented a greater predation risk (avian, mammal, or fish) for salmon than areas without artificial structures.

Large overwater structures like Marinas, Shipyards and Terminals can modify physical and chemical habitat characteristics such as light, temperature, salinity, nutrient levels, and wave action (Simenstad et al. 1999). The production of prey resources important to juvenile salmon is influenced through changes in the rate of photosynthesis, plant distribution, and survival of certain plant species that support these prey resources. Haas et al. (2002) concluded that large overwater structures likely caused changes in prey resources (epibenthic assemblages, diversity and density) through direct disturbance (e.g., propeller wash), reduced benthic vegetation from shading, and physical/biological habitat alterations.

Large facilities are protected with breakwaters with dikes and/or bank armoring used to prevent shoreline erosion. These modifications permanently displace shallow unconsolidated habitats and replace them with deeper, steeper consolidated substrates. Marinas appear to have more significant effects on physical and chemical habitat parameters because they are nearly enclosed with breakwaters to protect the vessels from waves and currents. Although breakwaters may not be as common in Terminals and Shipyards, fill and bank armoring can impact adjacent habitats in similar ways. These structures greatly reduce wave energy, changing sediment composition, and reduce water circulation and exchange, which often leads to degraded water quality.

Cardwell et al. (1980) and Cardwell and Koons (1981) examined biological impacts of marinas in relation to several economically and ecologically important fish and invertebrate species (e.g. Pacific salmon, herring, surf smelt, clams and oysters). They recorded significant increases in temperature and decreases in dissolved oxygen levels in late summer with the changes correlated to increased nutrient concentrations from boat sewage and stormwater runoff and reduced water circulation. As available nutrients increase, biological oxygen demand related to the decomposition of organic material also increases, thereby depleting dissolved oxygen in the water column. Reduced water circulation may increase surface water temperatures, further reducing the availability of dissolved oxygen. With restricted circulation, the warmer and oxygen poor water is not exchanged resulting in potentially lethal and sublethal effects for a number of aquatic organisms (Brett 1952, Brett and Blackburn 1981, Environmental Protection Agency 2005).

Metals and a variety of inorganic, and organic compounds such as are found in the waters surrounding Marinas, Shipyards and Terminals at levels that are toxic to aquatic organisms (Environmental Protection Agency 2005). For example: lead is used as a fuel additive; arsenic is used in marine paint, pesticides, and wood preservatives; zinc anodes are used to deter corrosion in hulls and engines; and both copper and tin are used as biocides in paints. While any of these metals or compounds may be found, copper is the most common (North Carolina Department of Environmental Management 1991). Sediments, especially those with high organic content, often accumulate contaminants and have much higher pollutant concentrations than the overlying water column (EVS Environmental Consultants 2003). Sediments may be re-suspended as a result of propeller turbulence from vessel traffic and can lead to short term increases in contaminant concentrations with metals and other toxins entering the food web through consumption by filter feeders. Contaminants from water and sediment may also bioaccumulate in the fatty tissues of higher level predators, leading to acute or chronic toxicity in aquatic species (EVS Environmental Consultants 2003).

Boat traffic and dredging are both operational and maintenance components for Marinas, Terminals and Shipyards. These activities may alter the depth and slope characteristics of benthic habitat as well as change substrate composition. Docks and terminals can affect the longshore transport of sediments (Downing 1983, Komar 1997). Typically, sediment accumulates along the shore under and immediately adjacent to the dock and forms a portion of the shoreline with a shallower bathymetry (salient zone). In addition, the vessels using the dock or terminal can scour the bottom and deposit sediments adjacent to the scoured area to form a berm. The net effect is that the dock has a wider influence on the bottom than just that contained within the dock footprint and may be 4 to greater than 10 times the area of the structure's decking (Washington DNR 2005c field verification report). Shipyards and Terminals accommodate much larger vessels than marinas and would be expected to have a substantially greater area of effect. The biological effects of propeller wash was summarized by the EPA (2005), with potential effects including increased turbidity and an accompanying decrease in light available for photosynthesis for plants; along with an increase in suspended sediments that could lead due reductions in prey location, clogged gills, and smothering of benthic animals and plants.

4-3.3 Effects index and justification

Table 4-7 provides summary indices for potential effects of overwater structures on species, with the following the justification for the rankings. The complete Effects Indices are presented in Appendix G.

Table 4-7 - Summary of Magnitude of Effects by species, lifestage, and activity sub-group. [*]

		Single Element Structures						Multiple Element Structures	
Species	Lifestage	Docks and Wharfs	Boat ramps, Launches and Hoists	Nearshore Buildings	Mooring Buoys	Floats and Rafts	Floating homes	Marinas	Shipyards and Terminals
Amphibian complex	Adult	0.75	0.75	0.69	0.00	0.00	0.63	0.25	0.25
	Tadpole	0.75	0.75	0.69	0.00	0.00	0.00	0.13	0.13
	Egg	0.75	0.75	0.69	0.00	0.00	0.00	0.06	0.06
Western pond turtle	Adult	0.75	0.75	0.69	0.00	0.00	0.63	0.13	0.13
	Overwintering	0.75	0.75	0.69	0.00	0.00	0.63	0.00	0.00
Bald eagle	Non-nesting	0.25	0.25	0.25	0.00	0.00	0.25	0.38	0.38
	Nesting	0.25	0.25	0.25	0.00	0.00	0.25	0.50	0.50
Black tern	Migration	0.63	0.63	0.63	0.13	NA	NA	0.19	0.19
	Nesting	0.63	0.63	0.63	0.25	NA	NA	0.25	0.19
Brown pelican	Non-nesting	0.50	0.50	0.50	0.25	0.25	0.50	0.38	0.25

[*] Ranks: "NA" indicates that an intersection between the specific activity and the species group does not occur. 1= "total loss"; 0.75 = "high" effect; 0.5 = "moderate" effect; 0.25 = "low" effect; 0 = "trace" effect.

Species	Lifestage	Single Element Structures: Docks and Wharfs	Boat ramps, Launches and Hoists	Nearshore Buildings	Mooring Buoys	Floats and Rafts	Floating homes	Multiple Element Structures: Marinas	Shipyards and Terminals
Common loon	Non-nesting	0.50	0.50	0.50	0.25	0.25	0.50	0.31	0.25
	Nesting	0.75	0.75	0.75	0.25	0.25	0.75	0.31	0.25
Harlequin duck	Non-nesting	0.50	0.50	0.50	0.25	0.25	0.50	0.38	0.31
	Nesting	NA	NA	0.63	NA	NA	NA	0.38	NA
Marbled murrelet	Non-nesting	0.44	0.44	0.44	0.25	0.25	0.38	0.38	0.31
	Nesting	0.44	0.44	0.44	0.25	0.25	0.38	0.44	0.44
Western snowy plover	Wintering	0.75	NA	1.00	NA	NA	NA	NA	0.25
	Nesting	0.75	NA	1.00	NA	NA	NA	NA	0.38
Pacific salmon, trout, and char	Adult	0.75	0.25	0.50	0.13	0.13	0.50	0.38	0.31
	Incubation / Emergence	0.75	0.50	0.50	0.13	0.13	0.50	0.00	0.00
	Freshwater rearing / Outmigration	0.75	0.25	0.50	0.25	0.25	0.50	0.63	0.31
Green sturgeon	Adult	0.25	0.25	0.25	0.06	0.06	0.25	0.38	0.38
White sturgeon	Adult/Juvenile	0.25	0.25	0.31	0.06	0.06	0.13	0.50	0.50
	Larvae	0.50	0.63	0.25	0.25	0.25	0.25	0.50	0.50
	Egg	0.63	0.63	0.50	0.25	0.25	0.25	0.50	0.50
Southern resident orca	All	0.25	0.00	0.00	0.00	0.00	0.25	0.38	0.19

AMPHIBIANS AND REPTILES

Columbia Spotted Frog, Northern Leopard Frog and Western Toad

Effects Indices
The amphibians listed above have the potential to be affected by Overwater Structures. These potential effects occur in all lifestages and range from "high" to "trace" level effects dependent on lifestage and activity sub-group. No species/activity intersection was found for the tadpole or egg stages with Mooring Buoys or Rafts and Floats due to the generalized presence of these structures in deeper water.

Potential Direct and Indirect Effects
Major threats to amphibians related to Overwater Structures are from habitat conversion in low elevation areas, including filling of shallow water areas, armoring, alteration of

emergent shoreline vegetation, impacts to estuarine wetlands, and sediment and water quality impairment (Washington DNR 2007).

- Direct effects to individuals may occur in all lifestages and are associated with human disturbance. They may be a result of increases in activity due to avoidance; impaired foraging or spawning behavior; and physical harm or harassment. Effects on adult, tadpole and egg stages from Docks and Wharves, and Boat Ramps are ranked as “high”, with Nearshore Buildings ranked “moderate”. Effects from Floating Homes to adults are ranked as “low” for adults, with no effect identified for either eggs or tadpoles due to the structures’ location in deeper water. Effects from Marinas, Shipyards and Terminals are ranked “low” for adults and tadpoles with no effect noted for the egg lifestage.

- Direct effects to habitat include the permanent destruction and fragmentation of shallow water habitat as a result of the structure, fill, bank armoring and roads. Effects on habitat for all lifestages are ranked “high” for Docks and Wharves, Boat Ramps and Nearshore Buildings. Habitat level effects from Floating Homes are ranked “high” for adults, with no nexus found for eggs or tadpoles. Effects from Marinas, Shipyards and Terminals are ranked as “low” for adults due both to the relatively small area of suitable habitat within the area of alteration and the deeper water location of this activity group. Egg and tadpole lifestages are assumed to have “trace” effects because little or no habitat in the area of alteration is considered suitable for spawning.

- Indirect effects from habitat loss may result in the use of less than optimal foraging, spawning and rearing locations. Effects may also be associated with habitat degradation through changes to structural metrics such as channel geometry and associated degradation of shallow and low velocity habitats; reduced sources of woody debris or vegetation used for basking and cover; water quality degradation associated with stormwater runoff, incidental fuel spills, and discharges of black or gray water; and reduced prey resources due to chronic chemical or physical habitat degradation. Indirect effects for all lifestages are ranked as “high” for Docks and Wharves, Boat Ramps, and Nearshore Buildings. Due to their location in deeper water, effects from Floating Homes are ranked as “high” for adults and “trace” for tadpoles and eggs. Due to the small area of suitable habitat relative to the total area of alteration, no nexus was found with any lifestage and Marinas, Shipyards and Terminals and habitat loss. However, habitat degradation is ranked “low” for all lifestages.

Western Pond Turtle

Effects Indices

Potential effects to western pond turtles from Overwater Structures occur in all lifestages and range from “high” to “trace” levels dependent on lifestage and overwater structure sub-group. No species/activity intersection was found for either lifestage with Mooring Buoys or Rafts and Floats. Because western pond turtles overwinter in relatively shallow water, no effects are identified for this lifestage and any multiple element structure. However, the adult migration/spawning/foraging lifestage may be affected by Marinas, Shipyards and Terminals, with effects ranked as “low”.

Potential Direct and Indirect Effects
Major threats to pond turtles related to Overwater Structures are from habitat conversion in low elevation areas, degradation of wetland, stream, pond and lake habitats, and sediment and water quality impairment (Washington DNR 2007).

- Direct effects to individuals may occur in the adult migration, spawning and overwintering lifestages as a result of the species' response to the activity (e.g., increased/decreased movement); physical harm or harassment: or from permanent destruction or inaccessibility of habitat due to placing overwater structures in wetlands or on freshwater shorelands. Effects from Docks and Wharves, and Boat Ramps are ranked as "high", with Nearshore Buildings ranked "moderate." Direct effects from Floating Homes are ranked as "low." No direct effects to individuals are identified for Marinas, Shipyards and Terminals.

- Direct effects to habitat may occur as a result of fill and bank armoring permanently destroying wetland, side channel, off channel, and backwater habitat used by migrating, nesting and foraging lifestages. Effects from Nearshore Buildings and Floating Homes are ranked as "high". Effects from Marinas, Shipyards, and Terminals are ranked as "low" due to the relatively small area of suitable habitat relative to the total area of alteration.

- Indirect effects from habitat loss and degradation could result in the use of less than optimal foraging, spawning and rearing locations. Prey resources may also be reduced due to chronic water and sediment quality from direct input of chemicals associated with the operation of a facility (e.g., hydrocarbons, metals, and inorganic compounds); as a result of runoff from roads and other hard surfaces used by vehicles and heavy equipment (e.g. cranes, hoists, fork lifts); or from discharges of black or gray water. Structures also decrease the quality of habitat metrics through increases in shading, changes to structural metrics such as channel geometry degrading shallow and low velocity habitats, and reducing sources of woody debris or vegetation used for basking and cover. Indirect effects to both western pond turtle lifestages are ranked as "high" for habitat loss and degradation for Dock and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes. Effects from Marina, Shipyards and Terminals are ranked as "low" due both to the small area of suitable habitat relative to the total area of alteration for both activities and the species preference for shallower water habitat..

BIRDS

Bald Eagle

Effects Indices
Bald eagles are potentially affected by Overwater Structures in both lifestages, with effects ranging from "high" to "trace" level dependent on lifestage and overwater structure sub-group.

Potential Direct and Indirect Effects
Major threats to bald eagles related to Overwater Structures include habitat loss, human disturbance of foraging and nesting behavior, bioaccumulation of pollutants (e.g., dioxins, PCBs, pesticides and mercury) and reduced prey abundance (Washington DNR 2007).

- Direct effects to individuals for both lifestages from all sub-groups include increased activity and impaired behavior due to disturbance. Effects would be localized and because bald eagles may either habituate to human presence or relocate, the effects indices for Mooring Buoys and Floats and Rafts are ranked as "trace", with all other single element sub-groups ranked as "low". Direct effects from Marinas, Shipyards, and Terminals are ranked "moderate" for non-nesting birds, with effects to nesting birds ranked "high" due to their greater sensitivity to disturbance.

- Direct habitat effects are attributable to the destruction of nearshore habitat; operational disturbance and associated increases in activity and energy expenditures; and disruption of behavior due to avoidance. In addition, both the presence of structures (e.g., docks, bank armoring) and the alteration or elimination of nearshore habitat may also reduce prey abundance. Effects are ranked as "trace" for Mooring Buoys, and Floats and Rafts, with all effects from all other sub-groups ranked as "low".

- Indirect effects from habitat loss and degradation include the temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to water and sediment quality impairment; altered foraging behavior and associated increases in energy used for foraging; and reduced quality of structural habitat metrics (e.g., shoreline complexity, trees). Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings, and Marinas, Shipyards and Terminals may also lead to chronic degradation of water and sediment quality water. Indirect effects for both bald eagle lifestages are ranked as "trace" for Mooring Buoys and Floats and Rafts, with effects from all other single element structures groups ranked as "low". Effects associated with habitat loss are ranked as "moderate" for Marinas, Shipyards and Terminals are ranked as "moderate" for all lifestages, with effects from habitat degradation ranked "low".

Black Tern

Effects Indices

Potential effects to black terns from Overwater Structures occur in both lifestages and range from "high" to "trace" level effects dependent on lifestage and overwater structure sub-group. There is no spatial overlap with black tern habitat during either lifestage with Floats and Rafts or Floating Homes, therefore there are no potential effects associated with these sub-groups.

Potential Direct and Indirect Effects

Major threats to the black tern related to Overwater Structures are disturbance, degradation, and loss of critical nesting and migration habitat (Washington DNR 2007).

- Direct effects to individuals in either black tern lifestage include increased activity; impaired behavior due to disturbance, and physical harm or harassment. Effects are ranked as "moderate" for Docks/Wharves, Boat Ramps/Launches/Hoists, and Nearshore Buildings, with effects from Marinas, Shipyards and Terminals ranked "low". Effects associated with Mooring Buoy are ranked as "trace" for migrating individuals and "low" for all other categories and lifestages.

- Direct habitat effects result from permanent habitat destruction and inaccessibility due to the location of structures in wetlands and nearshore/littoral areas, and dredging and bank stabilization disconnecting habitat or eliminating the physical processes that maintain off channel and wetland habitats or shorelands. Effects for habitat are ranked as “high” for Docks/Wharves, Boat Ramps/Launches/Hoists, and Nearshore Buildings for both lifestages. Direct habitat effects from Marinas are ranked as “low” for nesting forms and “trace” for migratory forms due to the facility’s use of shallower water habitats, with effects for Shipyards and Terminals ranked “trace”.

- Indirect effects associated with habitat loss and degradation include the temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat; and reduced quality of structural habitat metrics (e.g., shoreline complexity) due to shoreline stabilization and breakwaters. Effects from Mooring Buoys are ranked as “trace” for the migration lifestage and “low” for nesting forms, with indirect effects from Docks/Wharves, Boat Ramps/Launches/Hoists and Nearshore Buildings ranked as “moderate” for both lifestages and categories. Indirect effects associated with Marinas, Shipyards and Terminals are ranked “low” for both lifestages and are attributable to stormwater runoff, physical alteration of habitat (e.g., slope depth characteristics of shallow areas, disconnection of existing shallow water habitats), and associated reductions in prey resources.

Brown Pelican

Effects Indices

Brown pelicans are potentially affected by Overwater Structures with effects ranging from “moderate” to “low” levels dependent on the overwater structure sub-group.

Potential Direct and Indirect Effects

Major threats to brown pelicans related to Overwater Structures include habitat degradation due to pollution and the disruption, loss or degradation of foraging and roosting activities (Washington DNR 2007).

- Direct effects to individuals may include increased activity, impaired behavior due to disturbance, and physical harm and harassment. Effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings, Floating Homes and Marinas are ranked as “moderate”. Mooring Buoys, and Rafts and Floats, and Shipyards and Terminals are ranked as “low”.
- Direct habitat effects result from permanent habitat destruction and inaccessibility due to the location of structures in tidelands or on shorelands. Effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes are ranked as “moderate”. Mooring Buoys, and Rafts and Floats, and Shipyards and Terminals are ranked as “low”.

  Indirect effects from habitat loss and degradation include the temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat or altered food webs; chronic water quality impairment in poorly flushed areas; reduced quality of structural habitat metrics associated with structures; and associated reductions in prey availability. Indirect effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes are ranked as “moderate” with effects related to Mooring Buoys, Floats and Rafts, and Shipyards and Terminals are ranked as “low”. Effects associated with Marinas are ranked “moderate” for habitat degradation due to decreased flushing behind breakwaters and effects to water quality (e.g., fuel spills and waste streams) and visibility (turbidity from propellers and increased plankton population from organic inputs) that reduce foraging success. Effects from Marinas associated with habitat lass are ranked “low”.

Common Loon

Effects Indices
Common loons are potentially affected by Overwater Structures, with effects occurring in both lifestages and ranging from “high” to “low” level effects dependent on lifestage and overwater structure sub-group.

Potential Direct and Indirect Effects
Major threats to common loons related to Overwater Structures include the disruption of nesting and foraging activities, the loss of wetlands that serve as critical nesting and migration habitat, and habitat degradation (Washington DNR 2007).

- Direct effects to individuals may occur during both lifestages and include increased activity, impaired behavior due to disturbance, and harassment. Effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes are ranked as “moderate” for non-nesting forms and “high” for nesting forms. Effects to individuals are ranked as “low” for Mooring Buoys, Floats and Rafts, Marinas, Shipyards and Terminals for both lifestages.

- Direct habitat effects may result from permanent habitat destruction and inaccessibility due to the location of structures in wetlands or on shorelands. Effects to habitat from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes are ranked as “moderate” for non-nesting forms and “high” for nesting forms. Mooring Buoys and Rafts and Floats ranked as “low” for both lifestages due to the generally small area of the structure and their location offshore. Direct habitat effects from Marinas, Shipyards and Terminals ranked “low” due to their location in deeper water.

- Indirect effects associated with habitat loss and degradation include the temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat or altered food webs; chronic water quality impairment in poorly flushed areas; reduced quality of structural habitat metrics associated with structures; and associated reductions in prey availability. Indirect effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes are ranked as “moderate” for non-nesting forms and “high” for nesting forms. Effects related to Mooring Buoys and Floats and Rafts are ranked as “low” during all lifestages. Effects associated with Marinas and temporary habitat loss are ranked “low”, with effects from habitat degradation ranked “moderate” for Marinas due to decreased flushing behind breakwaters and effects to water quality (e.g., fuel spills and waste streams) and visibility (turbidity from propellers and increased plankton population from organic inputs) that reduce foraging success. Effects associated with Shipyards and Terminals are ranked “low”.

Harlequin Duck

Effects Indices
Potential effects to harlequin ducks occur in both lifestages and range from “high” to “low” level effects dependent on lifestage and overwater structure sub-group. There is no spatial overlap with nesting habitat and Docks and Wharves, Boat

Ramps/Launches/Hoists, Mooring Buoys, Floats and Rafts, Floating Homes, or Shipyards and Terminals therefore there are no potential effects associated with these .

Potential Direct and Indirect Effects

Major threats to the harlequin duck related to Overwater Structures include degradation of nearshore nesting, molting and wintering habitat, and human disturbance of nesting and foraging habitat (Washington DNR 2007).

- Direct effects to individuals may result from increased activity and impaired behavior due to disturbance. Effects to individuals during the non-nesting lifestage are ranked as “moderate” for Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings and Floating Homes, with Mooring Buoys, Floats and Rafts, Marinas, and Shipyards ands Terminals ranked as “low”. Effects from Marinas to nesting birds are ranked as “low”.

- Direct habitat effects result from permanent habitat destruction and inaccessibility due to the location of shoreline structures. Habitat effects from Nearshore Buildings are ranked as “high” for nesting forms and “moderate” for non-nesting forms, with effects from Marinas ranked “low” for both lifestages. Direct habitat effects to non-nesting forms are ranked as “moderate” for Docks and Wharves, Boat Ramps/Launches/Hoists, and Floating Homes, with Mooring Buoys, Floats and Rafts, Marinas, and Shipyards ands Terminals ranked as “low”.

- Indirect effects to both lifestages associated with habitat loss and degradation result from temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat or altered food webs; acute water and sediment impairment (e.g., fuel spills and waste streams); energy reduction from shading (e.g., loss of primary production and associated prey items); and reduced quality of structural habitat through changes in depth and substrate (e.g., dredging, increased nearshore slopes and sediment regime changes from flow reduction). Indirect effects from Nearshore Buildings and Marinas are ranked as “moderate” for both lifestages. Effects to non-nesting forms are ranked as “moderate” for Docks and Wharves, Boat Ramps/Launches/Hoists, and Floating Homes, with Mooring Buoys and Floats and Rafts ranked as “low”. Indirect effects to non-nesting forms associated with Shipyards and Terminals are ranked are ranked “moderate” for habitat loss and “low” for habitat degradation due to the structures location in deeper water.

Marbled Murrelet

Effects Indices

Marbled murrelets are potentially affected by Overwater Structures in both resident / non-breeding and nesting lifestages, with the effects ranging from “moderate” to “trace” dependent on lifestage and overwater structure sub-group.

Potential Direct and Indirect Effects

Major threats to the marbled murrelet related to Overwater Structures include degradation of nearshore/littoral areas, increasing habitat fragmentation (“edge effect”), and habitat loss and disturbance of behavior associated with human activity (Washington DNR 2007).

- Direct effects to individuals are the result of human disturbance and include increased activity, altered behavior, and harassment. Effects to individuals are ranked as “moderate” for single element structures for both lifestages. Direct effects to individuals from Marinas, Shipyards and Terminals to individuals are ranked as “low” for non-nesting birds ands “moderate” for nesting birds.

- Direct habitat effects result from permanent habitat destruction and/or displacement as a result of structures. Habitat effects are ranked as “trace” for Mooring Buoys and Floats and Rafts due to the structures being located away from foraging and nesting habitat. Habitat effects for all other activity sub-groups are ranked as “low”.

- Indirect effects associated with habitat loss and degradation are the result of temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat or altered food webs; altered foraging behavior and associated increases in energy used for foraging; chronic water and sediment quality impairment (e.g., fuel spills, stormwater discharges); reduced quality of structural habitat from the placement of structures (e.g., shading influences on vegetation, current changes from in- and overwater structures); and associated decreases in potential prey. Effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings, and Marinas are ranked as “moderate”, with effects from Floating Homes ranked “Low”. Effects from Mooring Buoys and Floats and Rafts are ranked as “low” for habitat loss to both life stages, with habitat degradation ranked “low” for non-nesting birds and “trace” for nesting birds. Indirect effects associated with habitat loss and Shipyards and Terminals are ranked “moderate” for both lifestages, with effects from habitat degradation ranked “low” for non-nesting birds and “moderate” for nesting birds.

Western Snowy Plover

Effects Indices

Western snowy plovers have the potential to be affected by Overwater Structures in both the wintering and nesting lifestages, with effects ranging from “total loss” to “high” dependent on lifestage and activity sub-group. Because there is no spatial overlap for western snowy plover habitat and Boat Ramps, Mooring Buoys, Floats and Rafts, Floating Homes, or Marinas authorized by Washington DNR, there are no potential effects associated with these sub-groups.

Potential Direct and Indirect Effects

The major threat to the western snowy plover related to Overwater Structures is human and vehicular/vessel disruption and destruction of nesting and foraging habitat, (Washington DNR 2007).

- Direct effects to individuals may occur as a result of increased activity, altered behavior, and physical harm or harassment. Effects to individuals in both lifestages are ranked as “high” for Docks and Wharves and a “total loss” for Nearshore Buildings. Direct effects from Shipyards and Terminals are ranked as “moderate” for the more sensitive nesting phase, with effects to non-nesting birds ranked “low”.

- Direct habitat effects result from permanent habitat destruction and/or displacement. Habitat effects to both lifestages are ranked as “low” for Shipyards and Terminals, “high” for Docks and Wharves and a “total loss” for Nearshore Buildings.

- Indirect effects associated with habitat loss and degradation are the result of temporary destruction or inaccessibility of habitat due to structures or human presence; reductions in prey resources due to use of less than optimal foraging habitat or altered food webs; changes in the quality of structural habitat associated with the impacts of physical structures (e.g., fill, overwater structures) and dredging on nearshore sediment supplies; chronic water quality impairment (e.g., stormwater, fuel leaks); and associated decreases in the abundance of invertebrate prey. Effects from Docks and Wharves are ranked as “high”, with effects from Nearshore Buildings ranked as a “total loss”. While no effects associated with habitat loss are noted for Shipyards and Terminals, indirect effects from habitat degradation were ranked as “moderate” for both lifestages.

FISH

Pacific Salmon, Trout, and Char

Effects Indices

Potential effects to Pacific salmon, trout and char from Overwater Structures occur in all lifestages and have been ranked as “high” to “trace” depending on lifestage and activity sub-group. Because salmonids generally spawn in smaller rivers, no effects are identified for the incubation/emergence lifestage and Marinas, Shipyards and Terminals..

Potential Direct and Indirect Effects

Major threats to all lifestages of these species related to Overwater Structures include loss of riparian and nearshore/littoral habitat, pollution and increased temperatures from stormwater runoff, altered sediment regimes, decreased light, reduced prey abundance, structural habitat changes, and chronic degradation of water and sediment quality (Washington DNR 2007).

- Direct effects to individuals in all lifestages are the result of human and operational disturbance and include increased activity, altered behavior, and physical harm or harassment (e.g., injury/death from propellers). Effects for all lifestages are ranked as “high” for Docks and Wharves, and “moderate” for Nearshore Buildings and Floating Homes. Effects for Boat Ramps/Launches/Hoists are ranked as “low” for adults and freshwater rearing/outmigrating forms, and “moderate” for incubation/emergence. Mooring Buoys and Floats and Rafts are ranked as having “trace” effects on adults and incubation/emergence, and “low” for freshwater rearing/outmigration. Effects to individuals from Shipyards and Terminals are ranked “low” for both adults and juveniles, with effects from Marinas ranked “low” for adults and “moderate” for juveniles because operational activity is concentrated in nearshore areas utilized by juveniles. Because Marinas, Shipyards and Terminals occur on deeper water no effect was noted for the activities and the incubation/emergence form.

- Direct habitat effects include acute water and sediment quality impairment (e.g., decreased dissolved oxygen, increased temperature, toxins); and displacement from habitat associated with structures (e.g., breakwaters, boat launches and piers). Effects for all lifestages are ranked as “high” for Docks and Wharves, and “moderate” for Floating Homes and Nearshore Buildings. Effects from Boat Ramps/Launches/Hoists are ranked as “low” for adults and freshwater rearing/outmigrating forms, and “moderate” for incubation/emergence, with effects from Mooring Buoys and Floats and Rafts ranked as “trace” for adults, and “low” for incubation/emergence and freshwater rearing/outmigration habitat. Direct habitat effects from Marinas are ranked as “moderate” for adults and juveniles, with no effect noted for incubation/emergence habitat. Because Shipyards and Terminals are located in deeper water, effects to adult and juvenile habitat are ranked "low", with no effects noted for incubation/emergence habitat.

- Indirect effects associated with habitat loss and degradation include temporary habitat destruction and/or inaccessibility; reductions in energy resources and the quality of structural habitat metrics (e.g., shade, altered sediment transport); reduced primary and secondary production thereby impacting prey assemblages; as well as acute water and sediment quality impairment (e.g. fuel spills, stormwater, waste discharges from vessels). Indirect effects on all lifestages are estimated as "high" for Docks and Wharves; "low" to "moderate" for Boat Ramps/Launches/Hoist; "moderate" for Nearshore Buildings and Floating Homes; and "low" to "trace" for Mooring Buoys, and Floats and Ramps. For habitat loss effects from Marinas are ranked "low" for adults, and "high" for incubation/emergence forms, with effects from Shipyards and Terminals ranked as "low" for both adult and juveniles. Effects from habitat degradation are ranked "moderate" for both groups and adults, with effects to juveniles ranked as "high" for Marinas and "moderate" for Shipyards and Terminals. No effects were noted for Marinas, Shipyards and Terminals for the incubation/emergence lifestage and habitat loss due to the structures location in deeper water.

Green Sturgeon

Effects Indices

Green sturgeon are potentially affected by Overwater Structures with effects ranging from "moderate" to "trace" levels dependent on the activity sub-group.

Potential Direct and Indirect Effects

Major threats to green sturgeon related to Overwater Structures include habitat loss and degradation, direct physical harm, and chronic degradation of water and sediment quality from stormwater runoff, altered sediment regimes, decreased light, reduced prey abundance, and structural habitat changes (Washington DNR 2007)

- Direct effects to individuals may include increased activity, altered behavior, and physical harm and harassment (e.g., injury/death from propellers). Effects on individuals from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings, Floating Homes, Marinas, and Shipyards and Terminals are ranked as "low". Effects from Mooring Buoys and Rafts and Floats are ranked as "trace" due to the generally small area of the structures.

- Direct habitat effects include permanent destruction or inaccessibility of habitat due to conversion and the physical location of the structures. Effects on habitat from Mooring Buoys and Rafts and Floats ranked as "trace" due to the generally small area of the structures. Habitat effects from Docks and Wharves, Boat Ramps/Launches/Hoists, Nearshore Buildings, and Floating Homes are ranked as "low", with effects from Marinas and Shipyards and Terminals ranked "moderate" due to the large area of alteration.

- Indirect effects associated with habitat loss and degradation include reductions in prey resources due to use of less than optimal foraging habitat or altered food webs as a result of disturbance and shading; chronic water and sediment quality impairment in poorly flushed areas (e.g., elevated temperatures and/or low dissolved oxygen levels, fuel spills, waste discharges from vessels); reduced quality of structural habitat metrics associated with structures; and associated reductions in prey availability. Marinas, Shipyards and Terminals also alter habitat through changes in depth (e.g., dredging), current changes (e.g., piers, breakwater) or the amount of natural light available under the structures. These changes can reduce primary and secondary productivity thereby impacting prey assemblages. Indirect effects from habitat loss are ranked as "low" for Shipyards and Terminals and "trace" for effects from all other activity sub-groups. Effects associated with habitat degradation are ranked as "moderate" for Nearshore Buildings, Marinas and Shipyards and Terminals, with effects from all other activity sub-groups ranked as "trace".

White Sturgeon

Effects Indices
The effects of Overwater Structures on white sturgeon range from "high" to "trace" levels dependent on the activity sub-group and species lifestage.

Potential Direct and Indirect Effects
Major threats to white sturgeon related to Overwater Structures include loss and degradation of riparian and nearshore habitat, direct physical harm, chronic degradation of water and sediment quality, altered sediment regimes, decreased light, reduced prey abundance, and structural habitat changes (Washington DNR 2007).

- Direct effects to individuals may include increased activity, altered behavior, and physical harm and harassment (e.g., injury/death from propellers) to the juvenile/adult lifestage. Effects on individuals from Docks and Wharves, Boat Ramps/Launches/Hoists, and Nearshore Buildings are ranked as "moderate" for the egg/incubation stage, "high" to "trace" for larvae, and "low" for juvenile/adult lifestage. Due to the generally small area of alteration, effects from Mooring Buoys are ranked "trace" for adults ad larvae, with no effect noted for the egg/incubation lifestage. Effects from Rafts and Floats are ranked "trace" for adults with no effect noted for larvae or the egg/incubation stage or Floating Homes. Effects on all lifestages are ranked "moderate" for Marinas and Shipyards and Terminals.

- Direct habitat effects include permanent destruction and/or displacement and acute water quality impairment due to altered flow conditions and wood treatment. Effects from Docks and Wharves, Boat Ramps/Launches/Hoists, and Nearshore Buildings received rankings of "high" to "moderate" for eggs/incubation, "moderate" for larvae, and "low" for juvenile/adults. Effects rankings for Mooring Buoys, Rafts and Floats, and Floating Homes was "moderate" for egg/incubation and larvae stages, and "low" to "trace" for juvenile/ adult stages due to the use of treated wood and the chance for lethal levels of PAHs. Effects to all lifestages are ranked "moderate" fro Marinas and Shipyards and Terminals, due to the large area of alteration.

- Indirect effects associated wit habitat loss and degradation include temporary destruction or inaccessibility of habitat due to structures, human presence, or water quality; reductions in prey resources from use of less than optimal foraging habitat; altered food webs as a result of disturbance and shading; chronic levels of sediment and water quality impairment; and reduced quality of structural habitat metrics, and associated reductions in prey availability. Effects from Docks and Wharves are ranked as "moderate" or "high" for egg/incubation life stages, and "moderate" for all other life stages. Boat Ramps/Launches/Hoists, and Nearshore Buildings are ranked as "low" for all lifestages, except Nearshore Buildings are ranked "moderate" for habitat degradation effects to juvenile/adult lifestages. Mooring Buoys and Floats and Rafts are ranked as "trace" for habitat loss and "low" for habitat degradation for all life stages. Indirect effects from Floating Homes are "trace" for all lifestages. Indirect effects from Marinas and Shipyards and Terminals associated with habitat loss are ranked "low" for adults and larvae, with no effects noted for eggs/incubation. Effects from habitat degradation are ranked "moderate" for both activity sub-groups and all lifestages.

MARINE MAMMALS

Southern Resident Orca

Effects Indices

Killer whales are potentially affected by Overwater Structures, with effects estimated as ranging from "high" to "trace".

Potential Direct and Indirect Effects

Major threats to the southern resident killer related to Overwater Structures include chemical pollution, noise, harassment by recreational boaters, risk of oil spills and disturbance related to human activity. In addition, killer whales are threatened indirectly by disruption of prey resources due to decreases in salmonid populations and bioaccumulation of contaminants (Washington DNR 2007).

- Direct effects to individual killer whales may occur as a result of disturbance and resulting increases in activity, alterations in behavior, and physical harm and harassment. Disturbance by, and avoidance of, boats and large vessels can create physiological stress that reduces reproductive success, alters behavior, interferes with migration and reduces foraging efficiency. Effects are ranked "low" for Docks and Wharves, Floating Homes, and Shipyards and Terminals; "high" for Marinas; and "trace" for all other activity sub-groups.

- Direct habitat effects result from permanent loss or inaccessibility due to nearshore modifications related to the placement of structures. No effects were noted for Marinas, with effects for Docks and Wharves and Floating Homes ranked as "low" and "trace" for all other sub-groups due both to the species' ability to avoid affected areas and their preference for deeper water habitats.

- Indirect effects associated with habitat loss and degradation are the result of temporary loss or inaccessibility of habitat due to disturbance associated with use of the structure and vessel traffic making habitat temporarily inaccessible; reductions in energy resources through decreased prey (e.g., salmonids) and modification of foraging behavior; a reduction in the quality of structural habitat related to changes in depths and substrates (e.g., dredging, turbidity from propeller scour); acute water quality impairment (e.g., stormwater, metals, polycyclic aromatic hydrocarbons), and associated decreases in the abundance of preferred prey. Indirect effects from Docks and Wharves and Floating Homes are ranked "low", with effects from all other single element sub-groups ranked "trace". Effects from Marinas and Shipyards and Terminals are ranked "low" for habitat degradation, with habitat loss ranked "moderate" for Marinas and "low" for Shipyards and Terminals.

Table 4-10 - Summary of assumed area of alteration by activity.

Section	Activity Group	Activity Sub-group	Number of Leases	Max. Width (meters)	Max. Length (meters)	Assumed Width (meters)	Assumed Length (meters)	Assumed Footprint (meters^2)	Area of Alteration (meters^2)	Relative Size*	Shape Descriptor+
4-1	Aquaculture	Shellfish	134	183	915	1,332	64	85,248	102,300	Very Large	R
		Finfish	19	229	671	122	366	44,652	67,000	Very Large	R
4-2	Log Booming and Storage		61	610	762	622	127	79,994	180,000	Very Large	R
4-3	Overwater Structures – single element	Docks, Wharves	309	10	122	2	61	122	750	Medium	L
		Boat Ramps, Launches, Hoists	56	16	46	8	31	248	275	Medium	R
		Nearshore Buildings	98	244	246	61	63	3,838	11,500	Large	R
		Mooring Buoys	274	10	10	7	7	49	100	Small	C
		Rafts, Floats	8	11	16	8	8	64	128	Small	R

* Relative Size: Small <100 feet^2 ; Medium > 100 feet^2 and < 1000 feet^2 ; Large > 1000 feet^2 and < 10000 feet^2 ; Very Large > 10000 feet^2

+ Shape Descriptor: L = linear; R = rectangular/square; C = circular/elliptical; I = irregular

Section	Activity Group	Activity Sub-group	Number of Leases	Max. Width (meters)	Max. Length (meters)	Assumed Width (meters)	Assumed Length (meters)	Assumed Footprint (meters^2)	Area of Alteration (meters^2)	Relative Size*	Shape Descriptor+
		Floating Homes	68	56	23	45	18	810	900	Medium	R
	Overwater Structures – multiple element	Marinas	394	2,000	400	1,000	200	200,000	650,000	Very Large	R
		Shipyards & Terminals	59	500	4,000	200	2,000	400,000	1,115,000	Very Large	I

5. Potentially Affected Habitat

Although the National Wetlands Inventory dataset (U.S. Fish and Wildlife 2005a) indicates that there are almost 3 million acres of aquatic lands in Washington, the State currently claims ownership of approximately 2.4 million acres of navigable[1] waters (Washington DNR 2005b). The potentially affected habitat calculations presented in this chapter are based on the portion of land owned by the State and managed by Washington DNR where activities are currently authorized. This baseline calculation has been supplemented by additional data quantifying the spatial extent of unauthorized docks[2] and floats on state-owned lands.

5-1 Affected habitat types

What follows is a summary of the affected habitat types organized by species group, with the calculation of affected habitat portrayed as the percentage of the species' habitat occurring on state-owned aquatic lands that may be affected Covered Activities. Because there is considerable overlap in habitat use by species during different lifestages, the values are expressed as the average percentage of affected habitat for each species (total potentially affected habitat for all lifestages divided by the number of species lifestages). However, it is important to remember that for some species there may be little or no overlap in habitat use, and as a result the average values reported may underestimate potentially affected habitat. The data is presented as a relative indication of which types of habitat are most affected for each species. Appendix H illustrates the percentage of habitat occurring on state-owned aquatic lands that is potentially affected for each species/lifestage by ecosystem type (Washington DNR 2005c).

5-1.1 Amphibians and Reptile

COLUMBIA SPOTTED FROG, NORTHERN LEOPARD FROG, WESTERN TOAD, WESTERN POND TURTLE

The percent of state-owned aquatic land used by the species in this group that is potentially affected by Covered Activities ranged between a total of 0.14 for the western toad to 0.05 for the Columbia spotted frog. For the lacustrine ecosystem average values

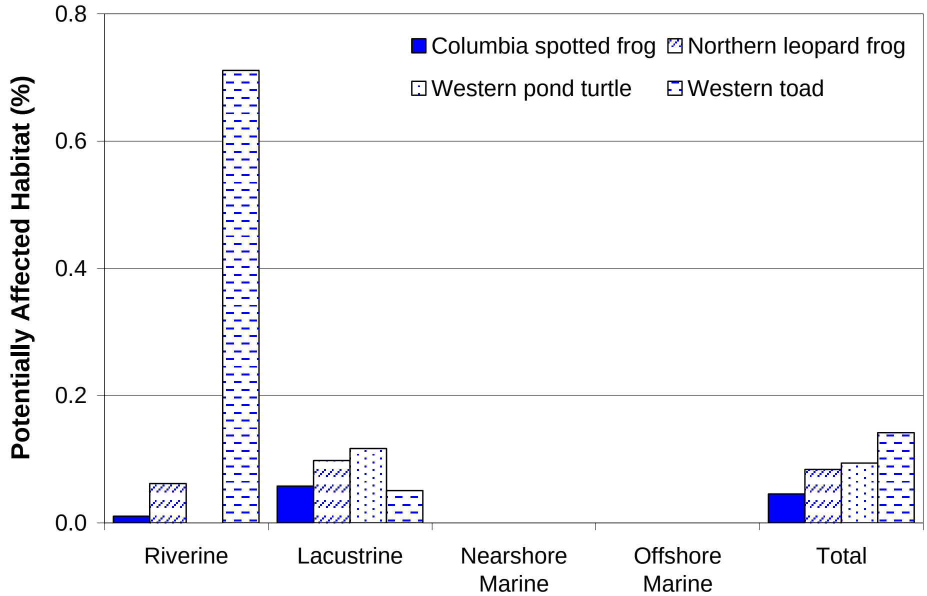
[1] Those bodies of water "…capable or susceptible of having been or being used for the transport of useful commerce" (Washington Administrative Code 332-30-106(40)).

[2] State law grants abutting residential owners the right to install and maintain recreational docks and recreational mooring buoys on state-owned aquatic land without charge (RCW 79.105.430). Because of staffing limitations, Washington DNR has not tracked or explicitly authorized these structures.

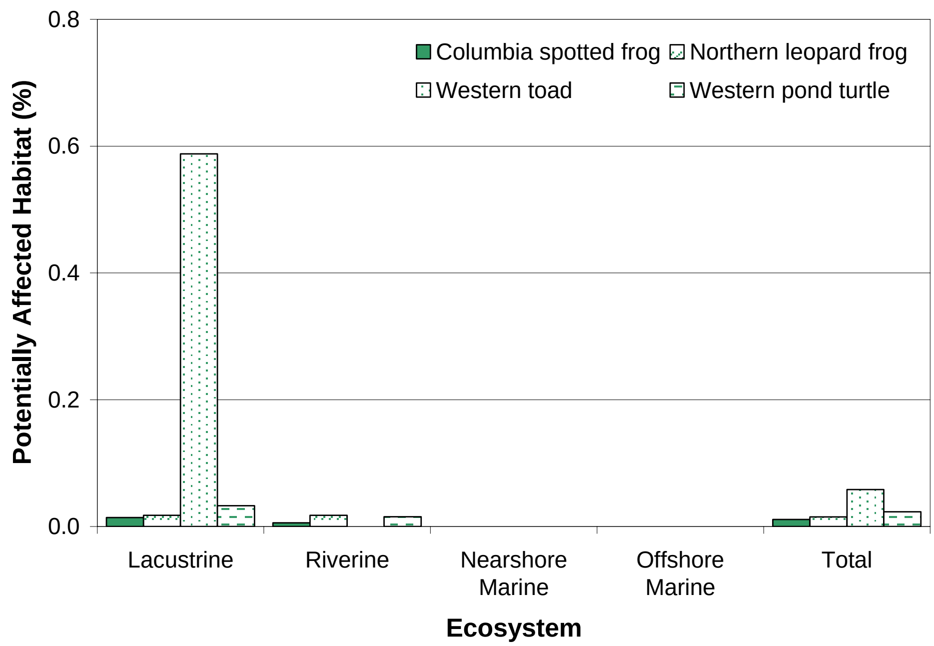
were highest for the western pond turtle (0.12%) and northern leopard fog (0.10%), and lowest for the Columbia spotted frog (0.06%) and western toad (0.05%). Potentially affected riverine habitat was greatest for the western toad (0.71%). Unauthorized docks potentially affect 0.01 percent of lacustrine and riverine Columbia spotted frog habitat, and approximately 0.02 percent of northern leopard frog and western toad habitat. The western pond turtle only overlaps with unauthorized docks in lacustrine systems with approximately 0.6 percent of available habitat potentially affected. Figure 5-1 illustrates potentially affected habitats for all lifestages combined by ecosystem, with Appendix H illustrating individual lifestages.

Figure 5-1 - Percent of Covered Amphibian and Reptile habitat occurring on state-owned land potentially affected by authorized Covered Activities (a) and unauthorized docks (b). The value portrayed is the average[3] for all lifestages combined.

a)



b)



[3] Total potentially affected habitat for all lifestages divided by the number of lifestages per species.

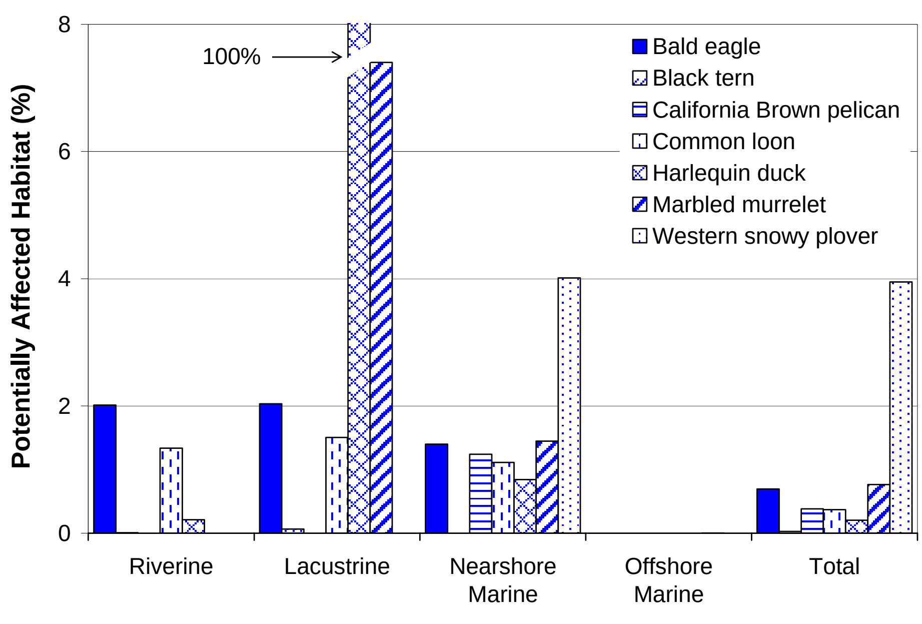
5-1.2 Birds

BALD EAGLE, BLACK TERN, BROWN PELICAN, COMMON LOON, HARLEQUIN DUCK, MARBLED MURRELET, WESTERN SNOWY PLOVER

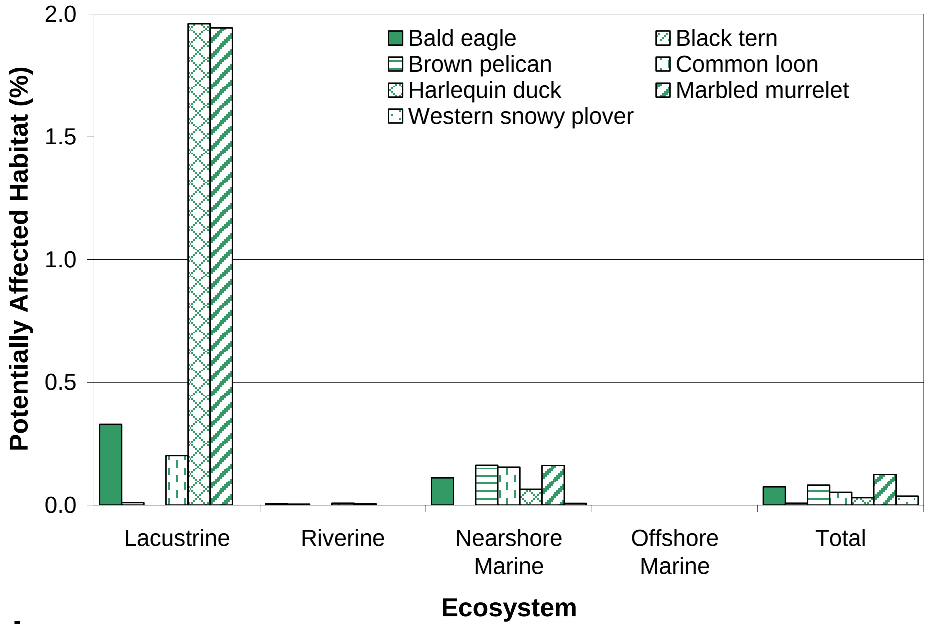
The percent of state-owned aquatic land used by these species that is potentially affected by Covered Activities ranged between a total of 3.95 for the western snowy plover to 0.03 for black tern. Potentially affected habitat was less than 0.01% for all species in the offshore ecosystem, with values ranging between 0.84 percent for the harlequin duck and 4.01 percent for the western snowy plover. In the lacustrine ecosystem 100 percent of harlequin duck nesting habitat is potentially affected, with the values for the other species ranging from 0.06 percent (black tern) to 2.03 percent (bald eagle). The overlap with lacustrine habitats and marbled murrelet foraging habitat is likely an artifact of the coarseness of the leasing data layer used in the potential effects analysis (1 mile^2 or 2.6 kilometer^2). Values for potentially affected habitat in the riverine ecosystem ranged form 0.01 percent for the black tern to 2.01 percent for the bald eagle. The percent of available habitat potentially affected by unauthorized docks ranged from a total of 0.01 for the black tern to 0.12 for marbled murrelets. Figure 5-2 illustrates potentially affected habitats for all lifestages combined by ecosystem, with Appendix H illustrating individual lifestages.

Figure 5-2 - Percent of Covered Bird habitat occurring on state-owned land that is potentially affected by Covered Activities (a) and unauthorized docks (b). The value portrayed is the average for all lifestages combined. Note – scales differ.

a)



b)



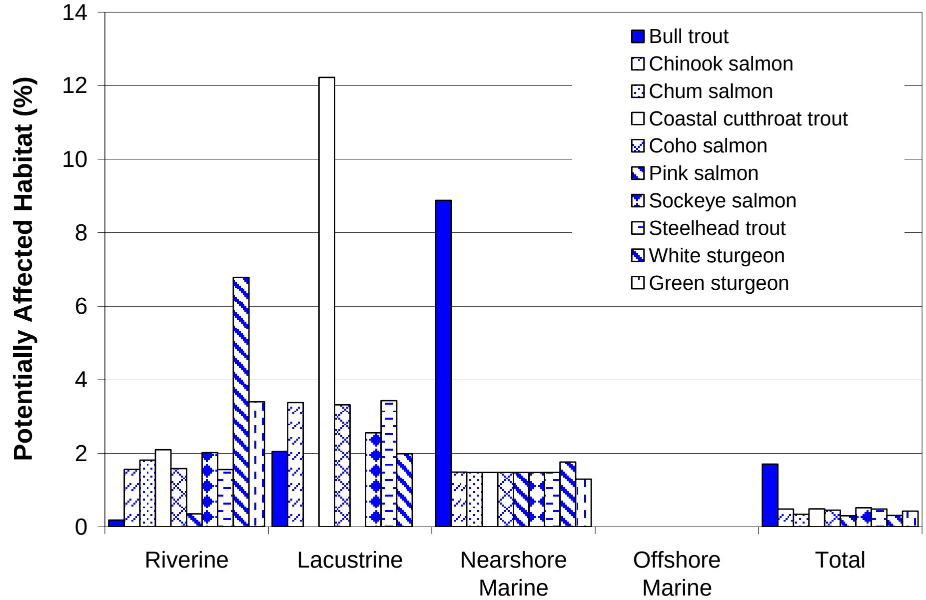
5-1.3 Fish

PACIFIC SALMON, TROUT AND CHAR (BULL TROUT, CHINOOK SALMON, CHUM SALMON, COASTAL CUTTHROAT TROUT, COHO SALMON, PINK SALMON, SOCKEYE/KOKANEE, STEELHEAD); GREEN AND WHITE STURGEON

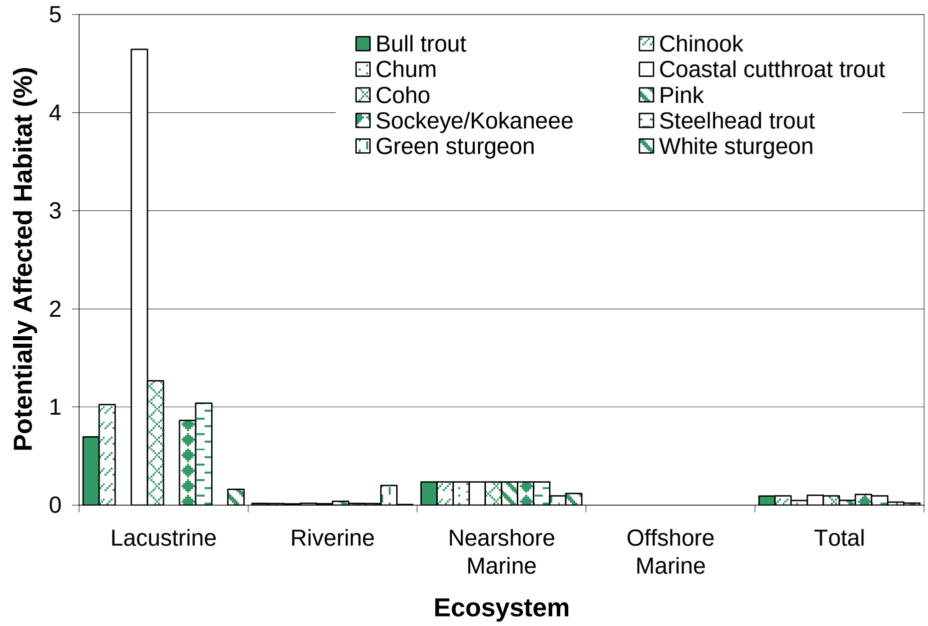
The percent of state-owned aquatic land used by the fish in this group that is potentially affected by Covered Activities ranged between a total of 0.30 for pink salmon to 8.88 for bull trout. Less than 0.01 percent of offshore habitat is potentially affected for all species, with nearshore values the highest for bull trout (8.88%) and lowest for green sturgeon (1.30%). In the lacustrine ecosystem, values were highest for coastal cutthroat (12.22%) and lowest for green and white sturgeon (1.99%), with values for bull trout, Chinook, chum, coho, sockeye and steelhead ranging between 2.05 and 3.43 percent. Average values for potentially affected riverine habitat were highest for green and white sturgeon (3.40 and 6.78% respectively), with the values for salmonids ranging from a low of 0.18 percent for bull trout to 2.10 percent for coastal cutthroat. The percent of available habitat potentially affected by unauthorized docks ranged from a total of 0.11 percent for sockeye to approximately 0.02 percent for green and white sturgeon. For salmonids, values were highest for riverine and nearshore ecosystems with the exception of coastal cutthroat were potentially affected lacustrine habitat was approximately 4.5 percent. Figure 5-3 illustrates potentially affected habitats for all lifestages combined by ecosystem, with Appendix H illustrating individual lifestages.

Figure 5-3 - Percent of Covered Fish habitat occurring on state-owned land that is potentially affected by Covered Activities (a) and unauthorized docks (b). The value portrayed is the average for all lifestages combined. Note – scales differ.

a)



b)

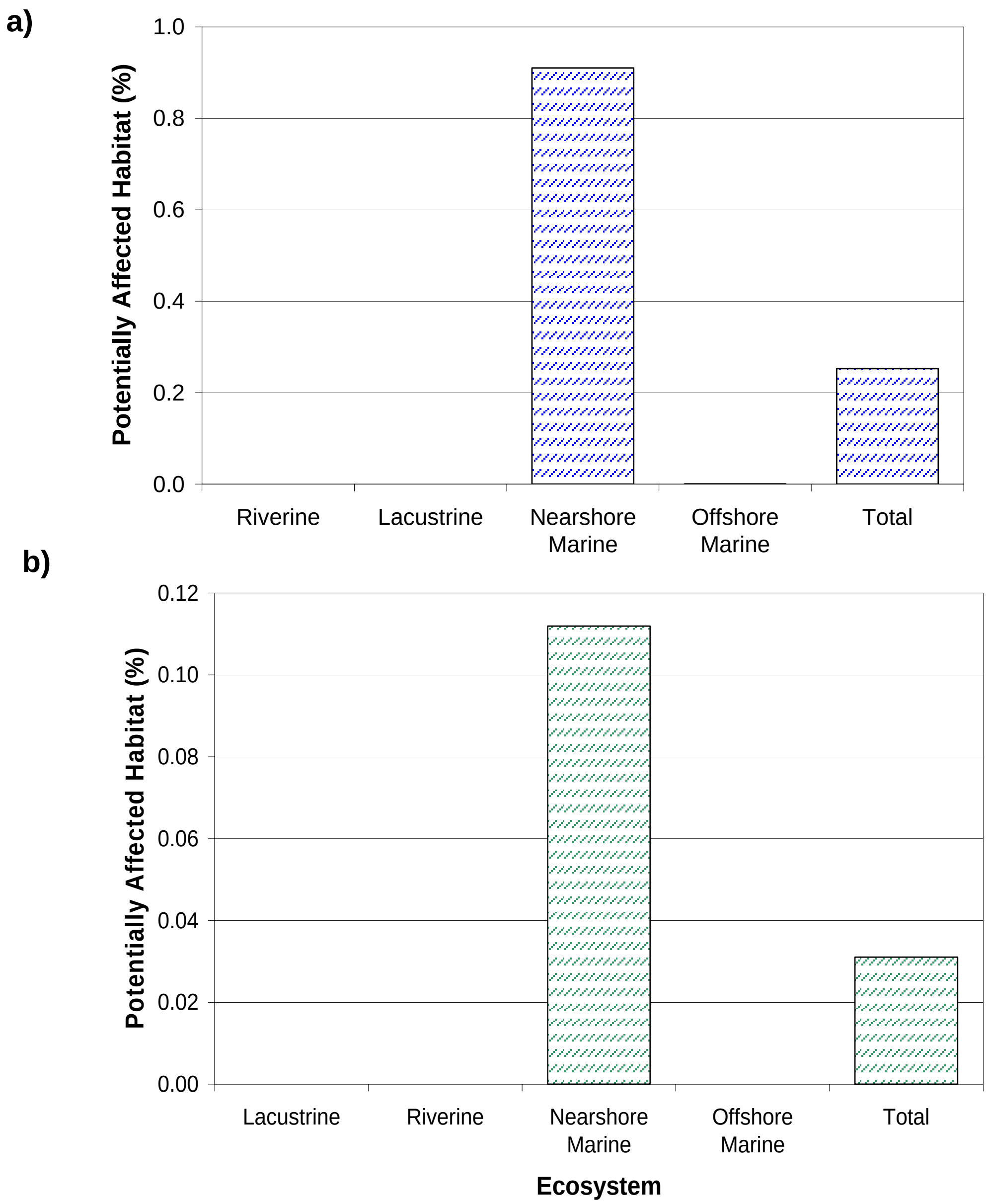


5-1.4 Marine Mammal

SOUTHERN RESIDENT ORCA

The total percentage of state-owned aquatic land used by the southern resident orca that is potentially affected by Covered Activities was 0.25 percent, with values for offshore habitat less than 0.01 percent and nearshore values 0.91 percent. Figure 5-3 illustrates the percentages by ecosystem. Values for unauthorized docks in the nearshore were approximately .011 percent with total habitat values 0.03 percent.

Figure 5-3 - Percent of southern resident orca habitat occurring on state-owned land that is potentially affected by Covered Activities (a) and unauthorized docks (b). Note – scales differ.



5-2 Potentially affected area

In this section, the area of each species' habitat potentially affected by Covered Activities is presented by activity group. The values reported are expressed as the average acreage of potentially affected habitat for each species (total potentially affected habitat for all lifestages divided by the number of species lifestages). Appendix I illustrates potentially affected area for each species lifestage by activity sub-group.

5-2.1 Covered Activities

AQUACULTURE

Figure 5-4 presents the average[4] area potentially affected by authorized Aquaculture for each covered species, with Appendix I illustrating potentially affected area for each species lifestage by activity sub-group. With the exception of the covered amphibians and reptile species group, Shellfish Aquaculture comprised the greatest amount of potentially affected habitat. Please note that due to the variation in the amount of potentially affected habitat for species groups, the scale for individual graphs varies.

Amphibians and Reptile

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

No overlap was found between existing aquaculture authorizations and the species in this group.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

The average area of Covered Bird habitat potentially affected by authorized Aquaculture activities ranged from approximately 3,681 for the western snowy plover to 2,400 acres for the bald eagle, brown pelican, common loon and marbled murrelet. The overwhelming majority of the acreage potentially affected were the result of the Shellfish Aquaculture sub-group (Figure 5-4a). No overlap found with the black tern or harlequin duck. Appendix I illustrates potentially affected area for each species lifestage by activity sub-group.

Fish

Pacific Salmon, Trout and Char (Bull Trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steelhead); Green and White Sturgeon

The average area of fish habitat potentially affected by authorized Aquaculture activities ranged from approximately 3,951 acres for the green sturgeon to 1,426 for the white sturgeon. For the salmonids, potentially affected acreage was highest for pink salmon (2,442) with the average values for the remaining species approximately 1,600 acres (Figure 5-4b). The overwhelming majority of potentially affected acreage were the result of the Shellfish sub-group, with minimal values reported for the egg and incubation lifestages for all species (range 1 to 5 acres). Appendix I illustrates potentially affected area for each species lifestage by activity sub-group.

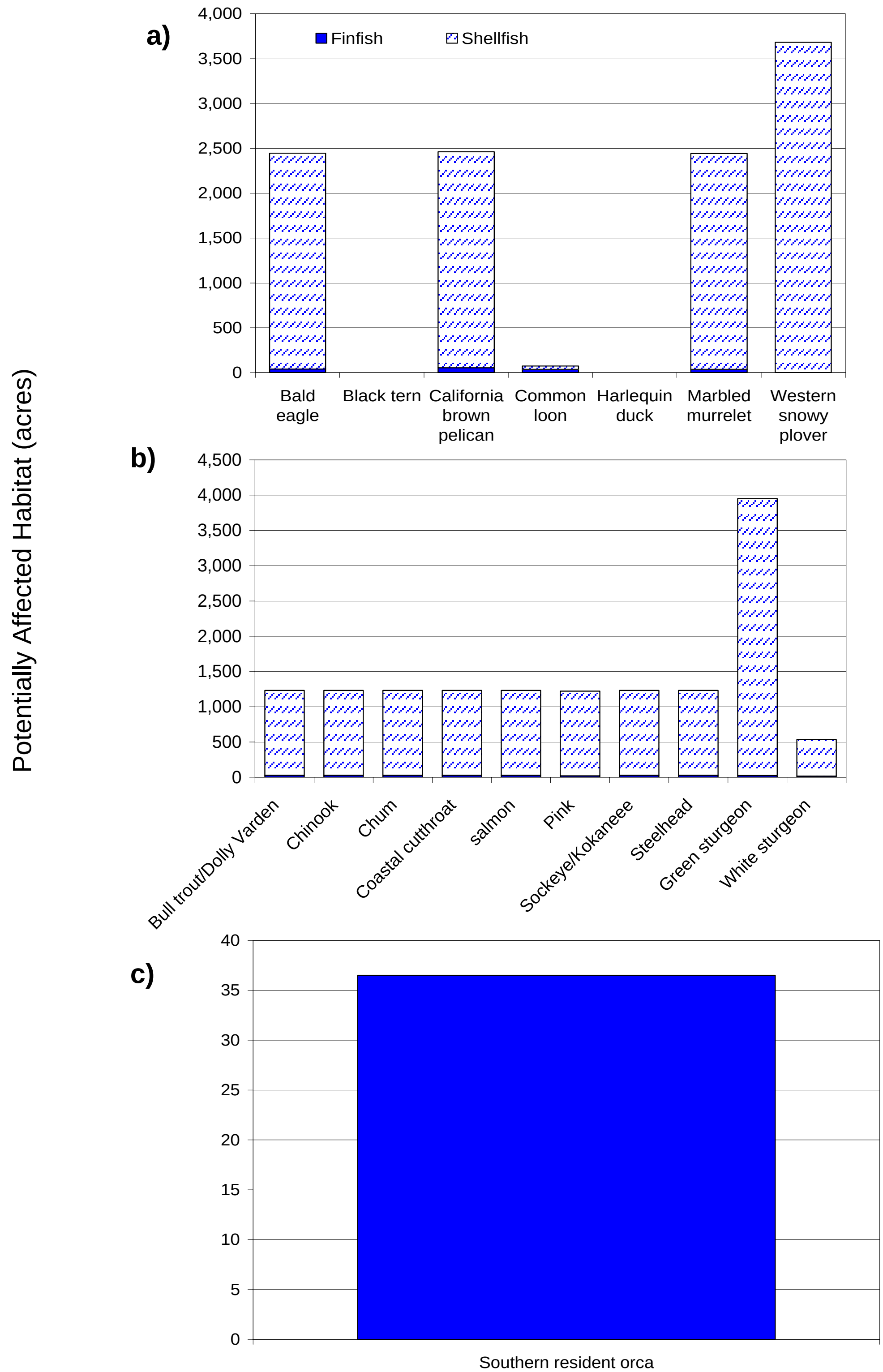
[4] Total potentially affected habitat for all lifestages divided by the number of lifestages per species.

Marine Mammal

Southern Resident Orca

The Finfish Aquaculture sub-group potentially affects approximately 37 acres of habitat for orcas.

Figure 5-4 – Potentially affected area for Covered Birds, Fish and the southern resident orca resulting from authorized Aquaculture. Note – scales differ.



LOG BOOMING AND STORAGE

Figure 5-5 presents the average[5] area potentially affected by authorized Log Booming and Storage for each Covered Species, with Appendix I illustrating potentially affected area for each species lifestage by activity sub-group. Please note that due to the variation in the amount of potentially affected habitat for species groups, the scale for individual graphs varies.

Amphibians and Reptile

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

Existing Log Booming and Storage authorizations do not overlap with either Columbia spotted or northern leopard frog habitat. All lifestages of the western toad are potentially affected, with the average affected habitat value equal to approximately 48 acres. The average value for the western pond turtle equaled approximately 8 (Figure 5-5a). Appendix I illustrates potentially affected area for each species lifestage.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

The average area of bird habitat potentially affected by authorized Log Booming and Storage ranged from over 1,900 acres for marbled murrelets to approximately 758 acres for brown pelicans (Figure 5-5b). No overlap was found with existing authorizations and black terns, harlequin ducks or snowy plovers. Appendix I illustrates potentially affected area for each species lifestage.

Fish

Pacific salmon, trout and char (Bull trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steelhead); Green and White Sturgeon

The average area of salmonid habitat potentially affected by authorized Log Booming and Storage ranged from over 1,300 acres (coho) to approximately 861 acres (chum) (Figure 5-5c). Juvenile habitat comprised the majority of the acreage for all species except bull trout were affected adult habitat predominated (2,446 adult, 1,529 juvenile). Values for the egg and incubation forms were generally low (range 0 to 388) with the exception of sockeye (1,322 acres).

Potentially affected habitat values for adult green sturgeon were approximately 484 acres, with average affected habitat for white sturgeon 543 acres (Figure 5-5c) and distributed fairly evenly across all three lifestages. Appendix I illustrates potentially affected area for each species lifestage.

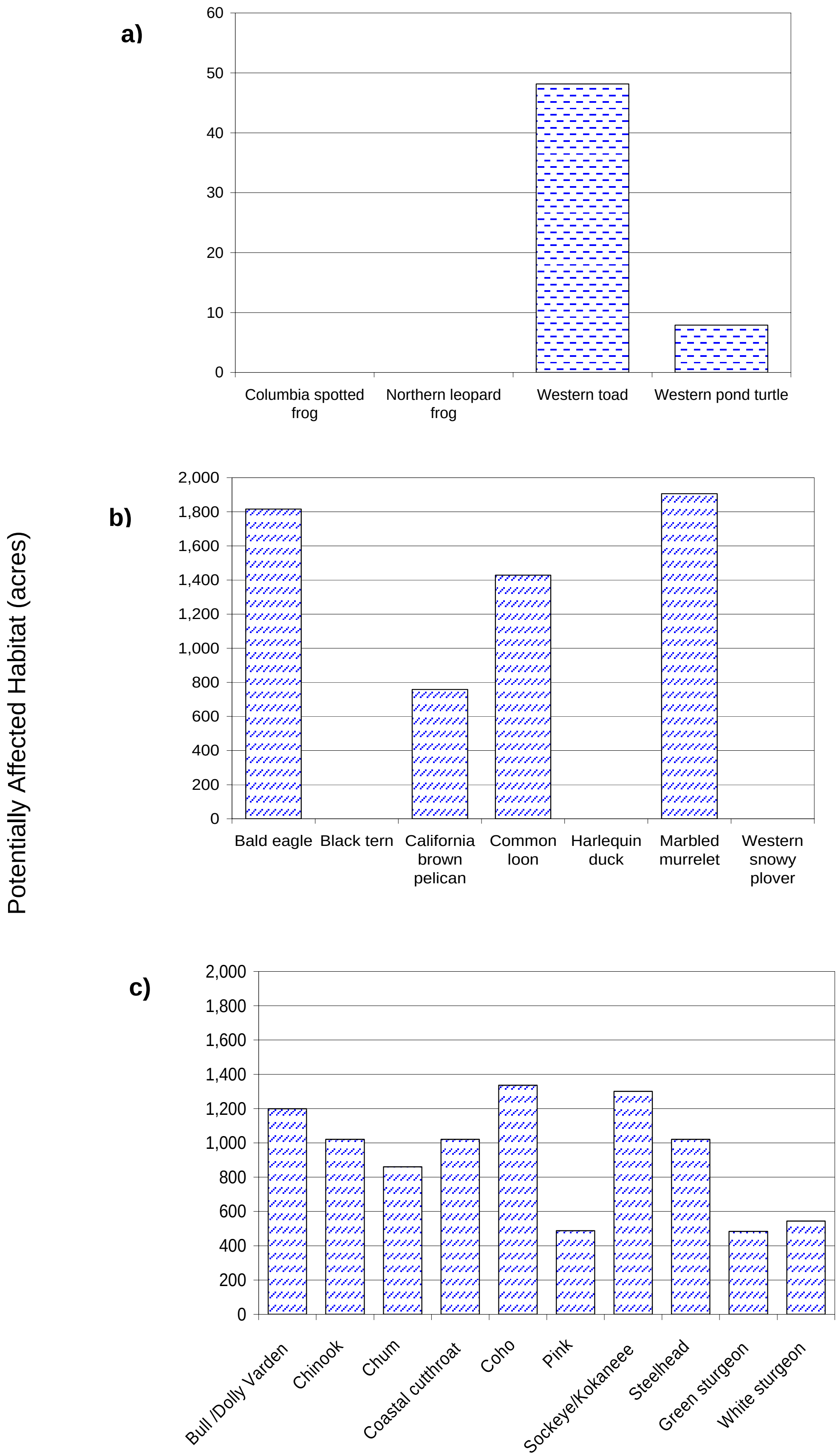
Marine Mammal

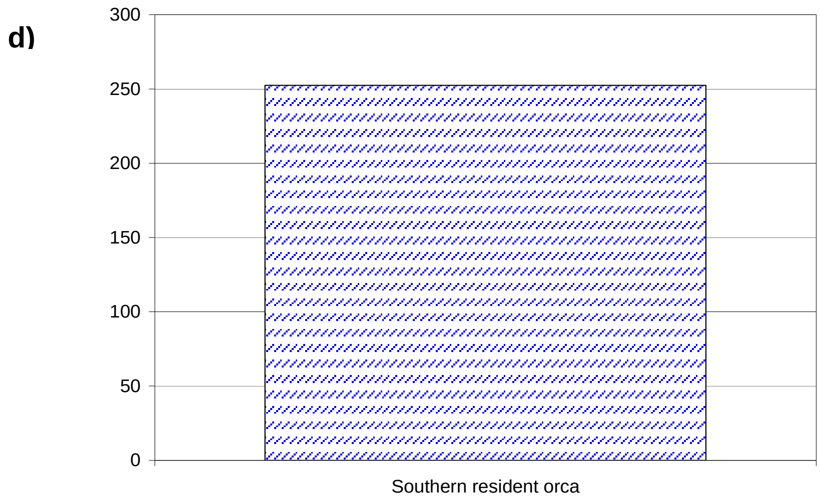
Southern Resident Orca

Roughly 252 acres of orca habitat is potentially affected by Log Booming and Storage (Figure 5-5d).

[5] Total potentially affected habitat for all lifestages divided by the number of lifestages per species.

Figure 5-5 - Potentially affected area for Covered Species resulting from authorized Log Booming and Storage. Note - scales differ





OVERWATER STRUCTURES

Figure 5-6 presents the average total area potentially affected by authorized Overwater Structures for each covered species, with Figure 5-7 illustrating the average acreage for unauthorized docks. Appendix I illustrates potentially affected area for each species lifestage by activity subgroup. For all species, authorized Marinas and unauthorized docks[6] comprised the overwhelming portion of potentially affected area. Please note that due to the variation in the amount of potentially affected habitat for species groups, the scale for individual graphs varies.

Amphibians and Reptile

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

The average area of amphibian and reptile habitat potentially affected by authorized Overwater Structures ranged from approximately 833 acres for the western toad to approximately 108 acres for the northern leopard frog (Figure 5-6a). No overlap was noted with authorized Mooring Buoys or Rafts and Floats and any of these species, with Floating Homes and Shipyards and Terminals overlapping with only the western toad and pond turtle.

Potentially affected area attributable to Unauthorized Docks ranged from an average of 144 acres for western toads to 20 acres for the northern leopard frog (Figure 5-7). Appendix I illustrates potentially affected area for each species lifestage by activity subgroup.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

The average total area of bird habitat potentially affected by existing authorized Overwater Structures ranges from approximately 15,865 acres (bald eagle) to 193 acres (black tern) (Figure 5-6b). Harlequin duck habitat only overlaps with authorized Marinas

[6] Unauthorized docks include all marinas, terminals and docks digitized in the Overwater Structures GIS data layer.

and Nearshore Buildings, with black terns overlapping with Docks and Wharves, Marina and Mooring Buoys. No overlap was found for the western snowy plover and any authorized overwater structure.

Potentially affected area attributable to Unauthorized Docks ranged from an average of 2,386 for the common loon to 13 for the western snowy plover (Figure 5-7). Appendix I illustrates potentially affected area for each species lifestage by activity subgroup.

Fish

Pacific Salmon, Trout and Char (Bull Trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steelhead); Green and White Sturgeon

The average total area of salmonid habitat potentially affected by authorized Overwater Structures ranged from over 10,000 acres (Chinook, sockeye and steelhead) to approximately 4,830 (pink salmon) (Figure 5-6c). For sturgeon, green sturgeon had the smallest amount of average total potentially affected habitat (3,329 acres) and white sturgeon the greatest (5,946 acres) (Figure 5-6c). For all Covered Fish, affected habitat was greatest for adult and juvenile lifestages.

Potentially affected area attributable to Unauthorized Docks ranged from an average of approximately 3,200 for sockeye/kokanee to 303 for adult green sturgeon (Figure 5-7). Appendix I illustrates potentially affected area for each species lifestage by activity subgroup.

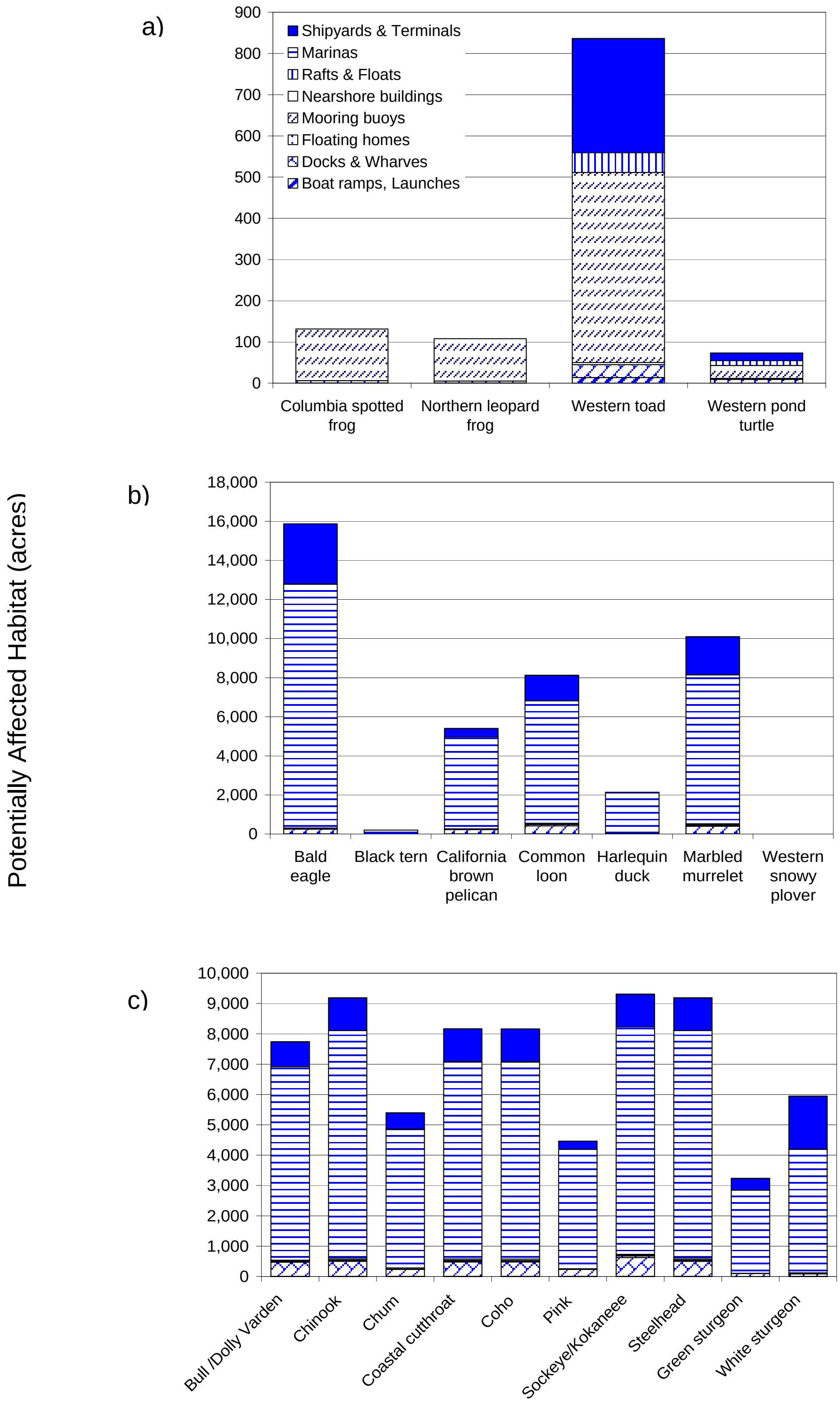
Marine Mammal

Southern Resident Orca

Over 5,000 acres of orca habitat is potentially affected by authorized Overwater Structures (Figure 5-6d), with over 90% of the total being attributable to the Marina sub-group.

Potentially affected area attributable to Unauthorized Docks was approximately 667 acres (Figure 5-7). Appendix I illustrates potentially affected area for each species lifestage by activity subgroup.

Figure 5-6 - Potentially affected area for all Covered Species resulting from authorized Overwater Structures. Note – Scales differ.



d)

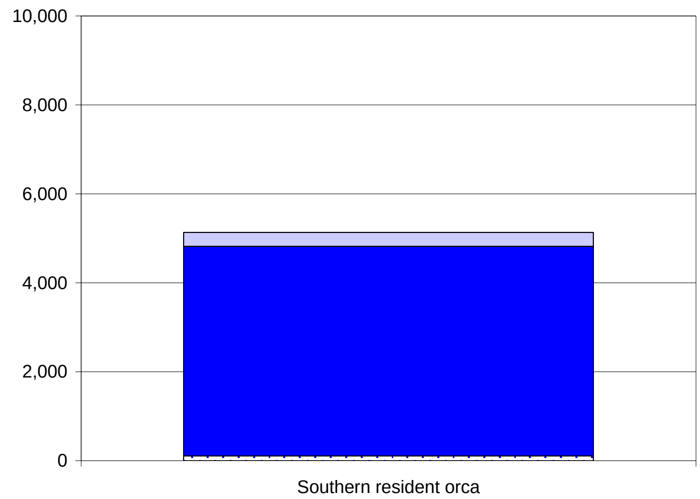
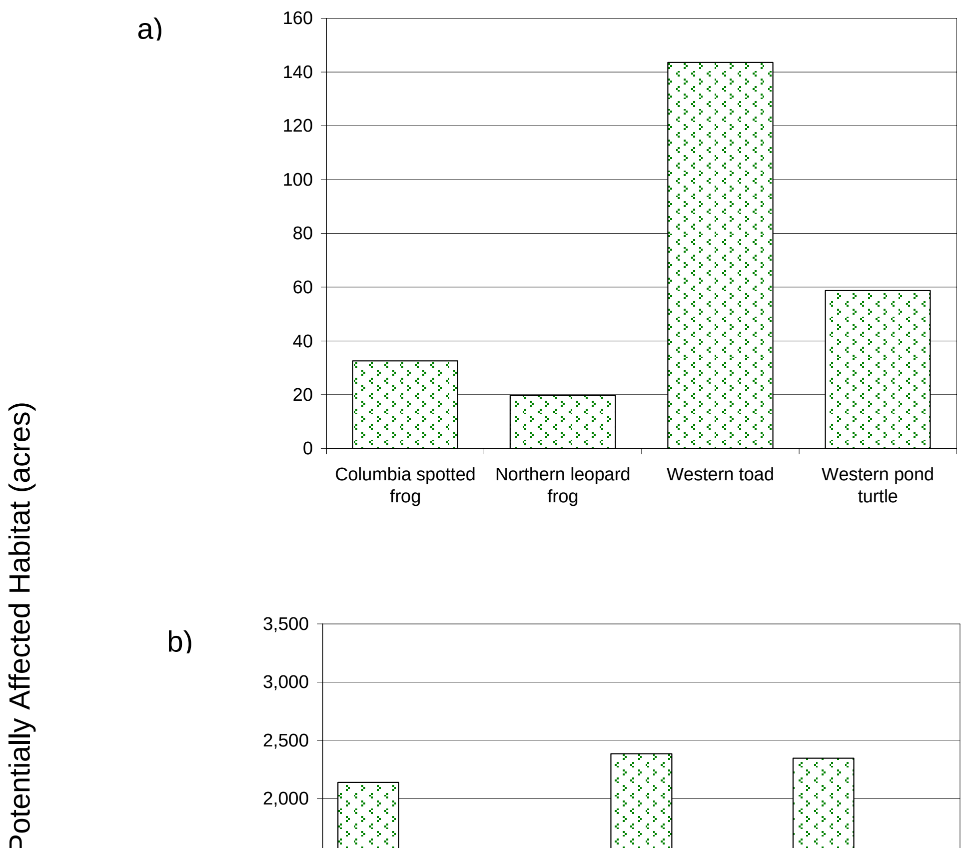
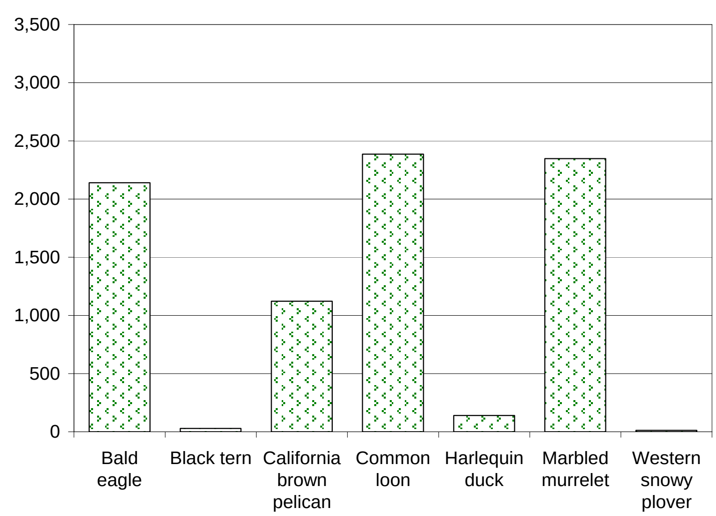


Figure 5-7 – Potentially affected area for all Covered Species from unauthorized docks. Note – Scales differ.

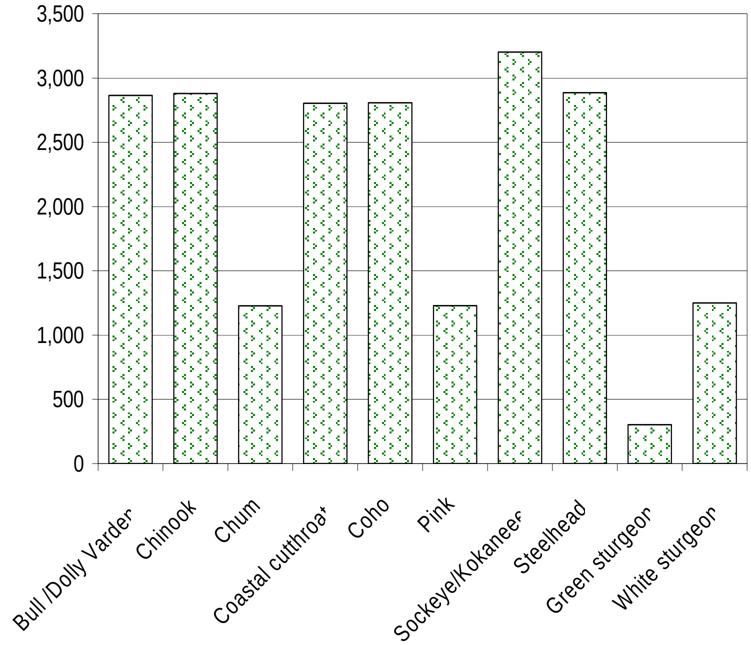
a)



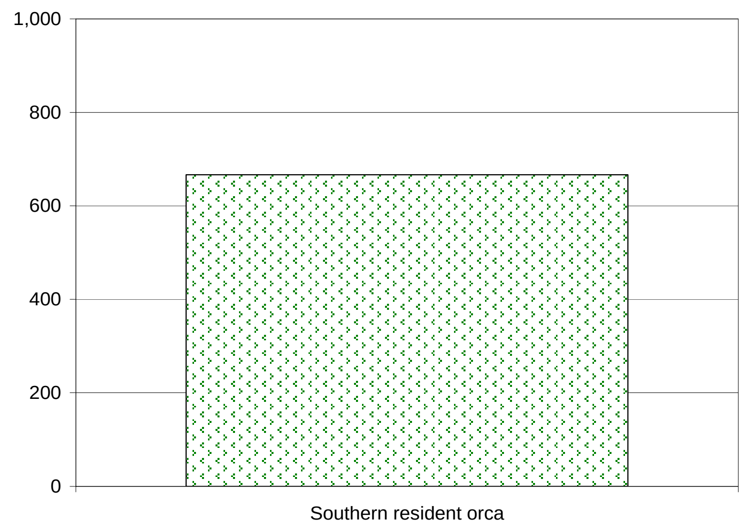
b)



c)


3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bull /Dolly Varden
Chinook
Chum
Coastal cutthroat
Coho
Pink
Sockeye/Kokanee
Steelhead
Green sturgeon
White sturgeon

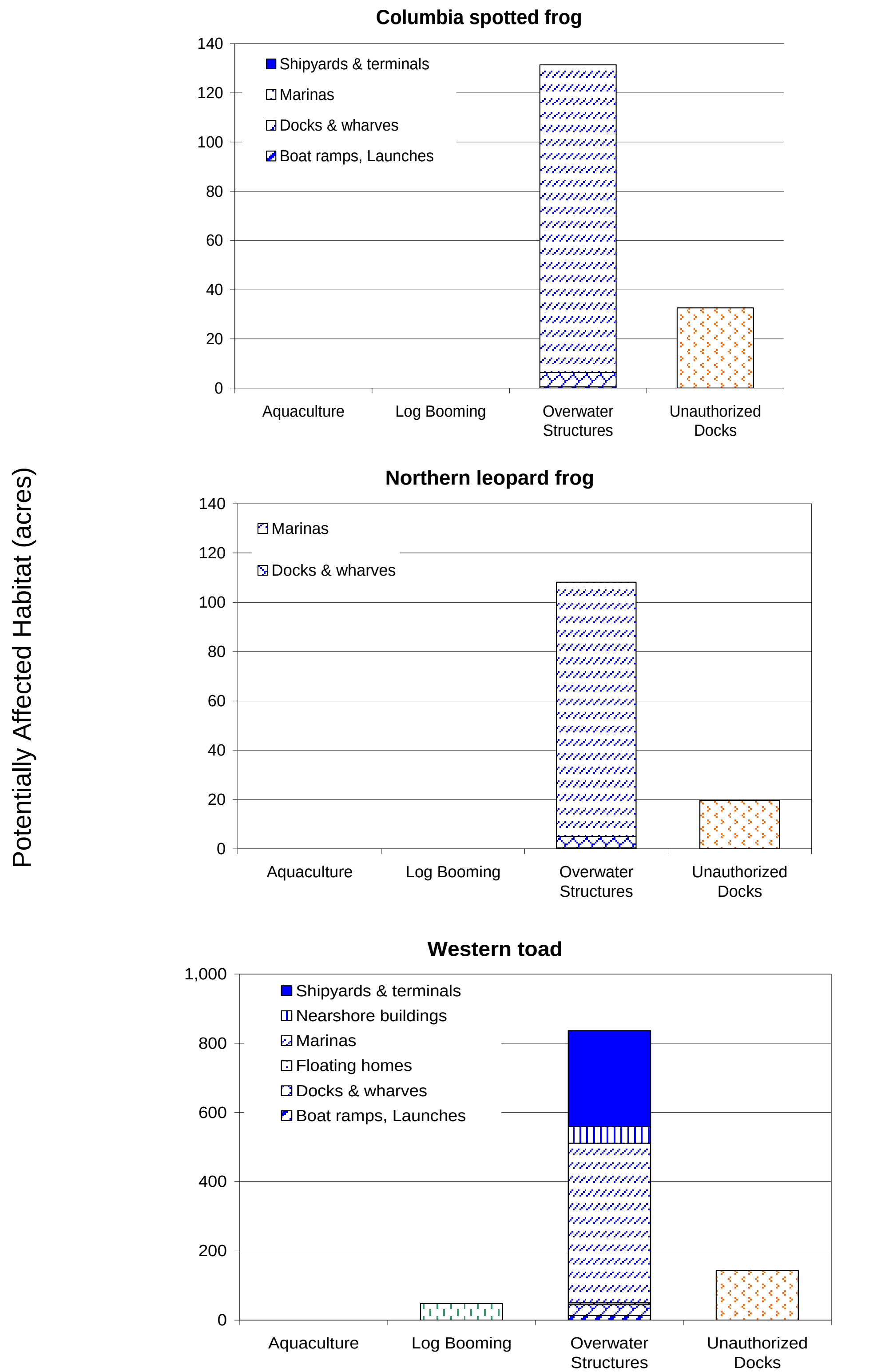
d)

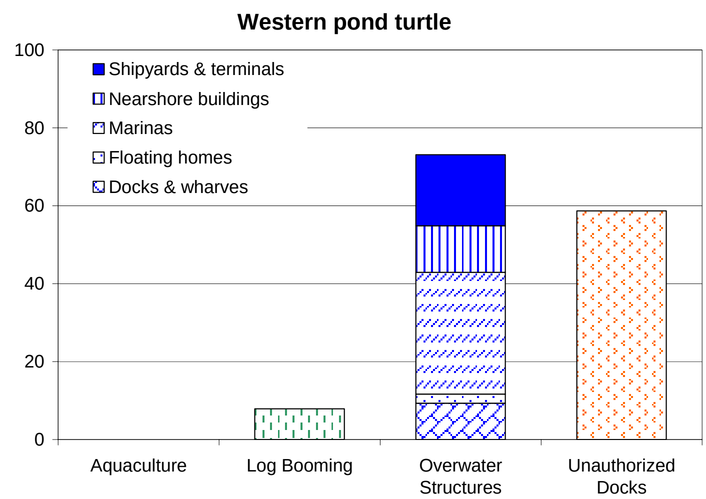

1,000
800
600
400
200
0
Southern resident orca

5-2.2 Covered Species

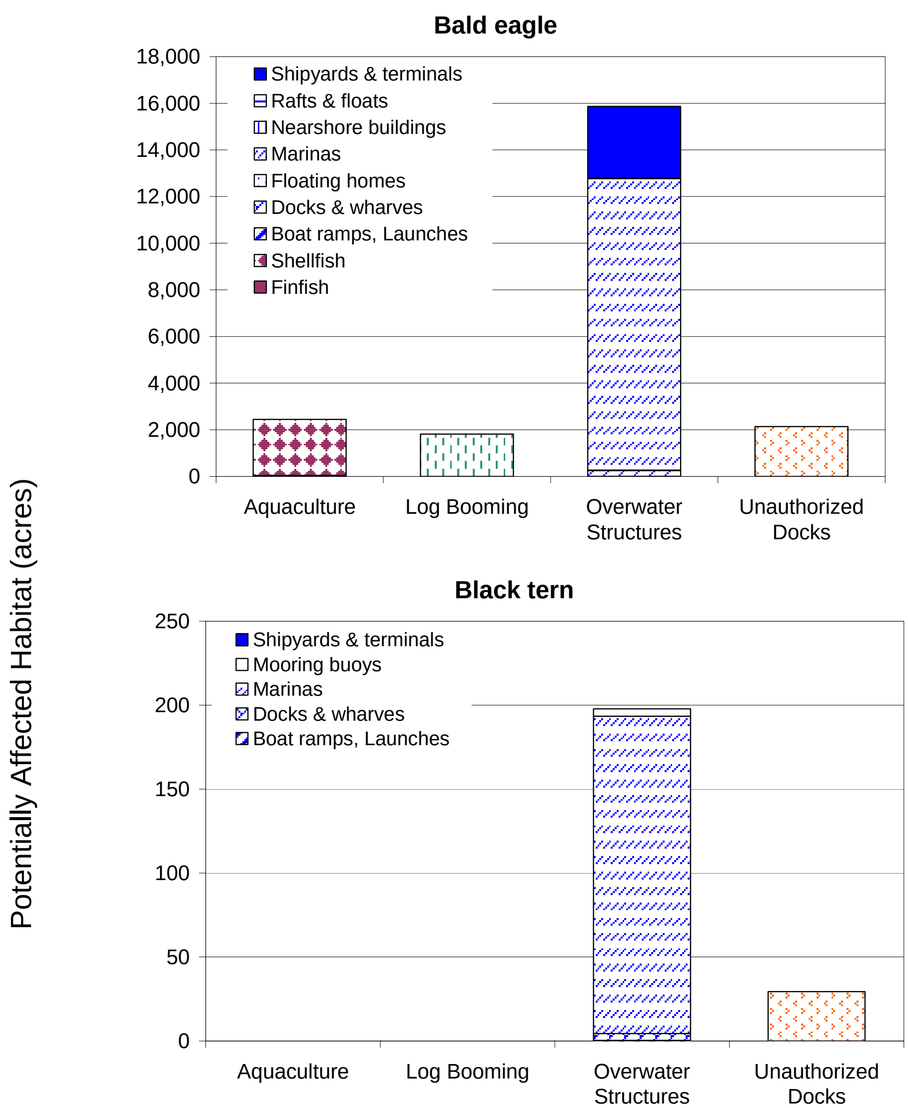
The following graphs are provided to illustrate relative average area of potentially affected habitat for each species as a result of Covered Activities and unauthorized docks. Please note that the scales vary with each species

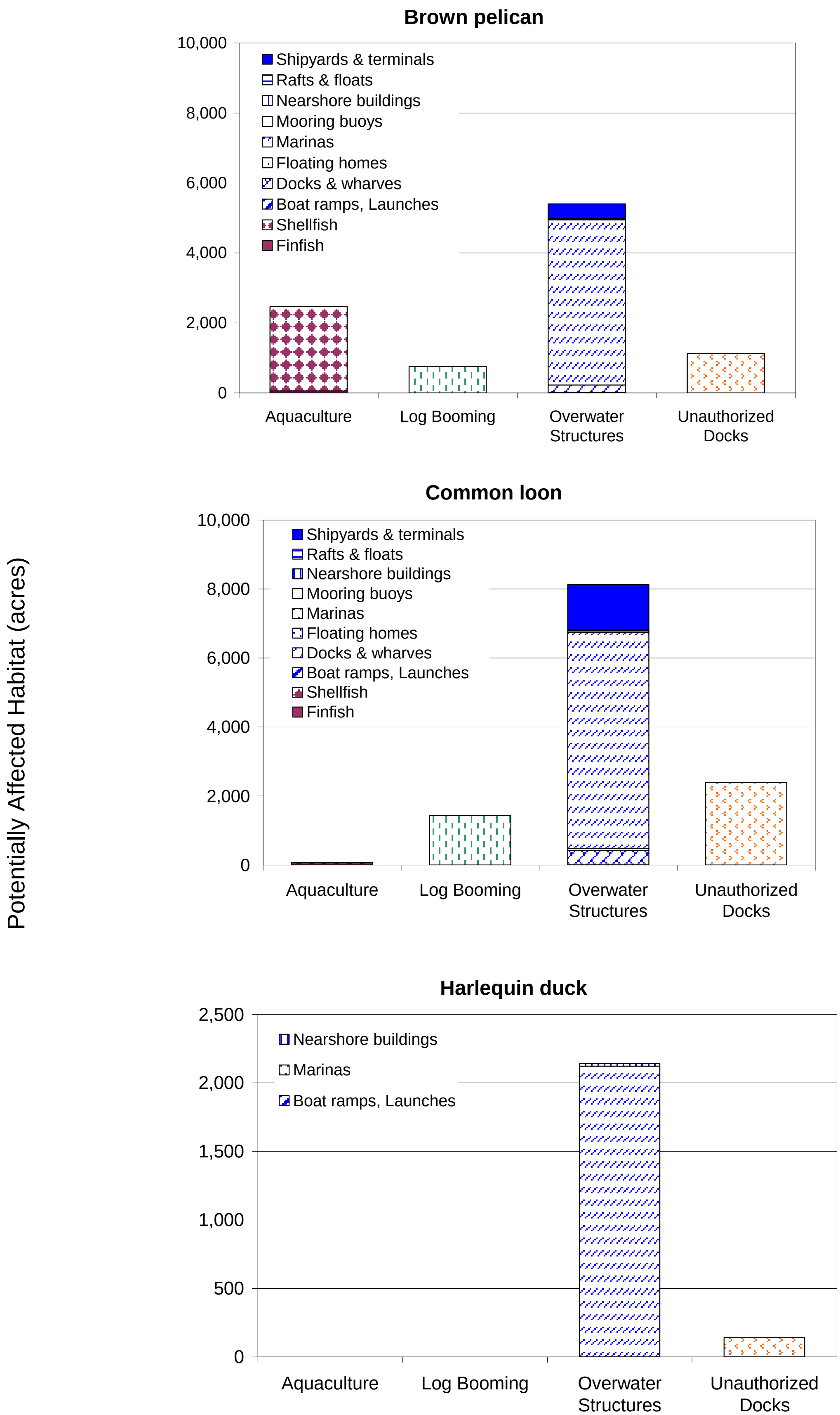
AMPHIBIANS AND REPTILE

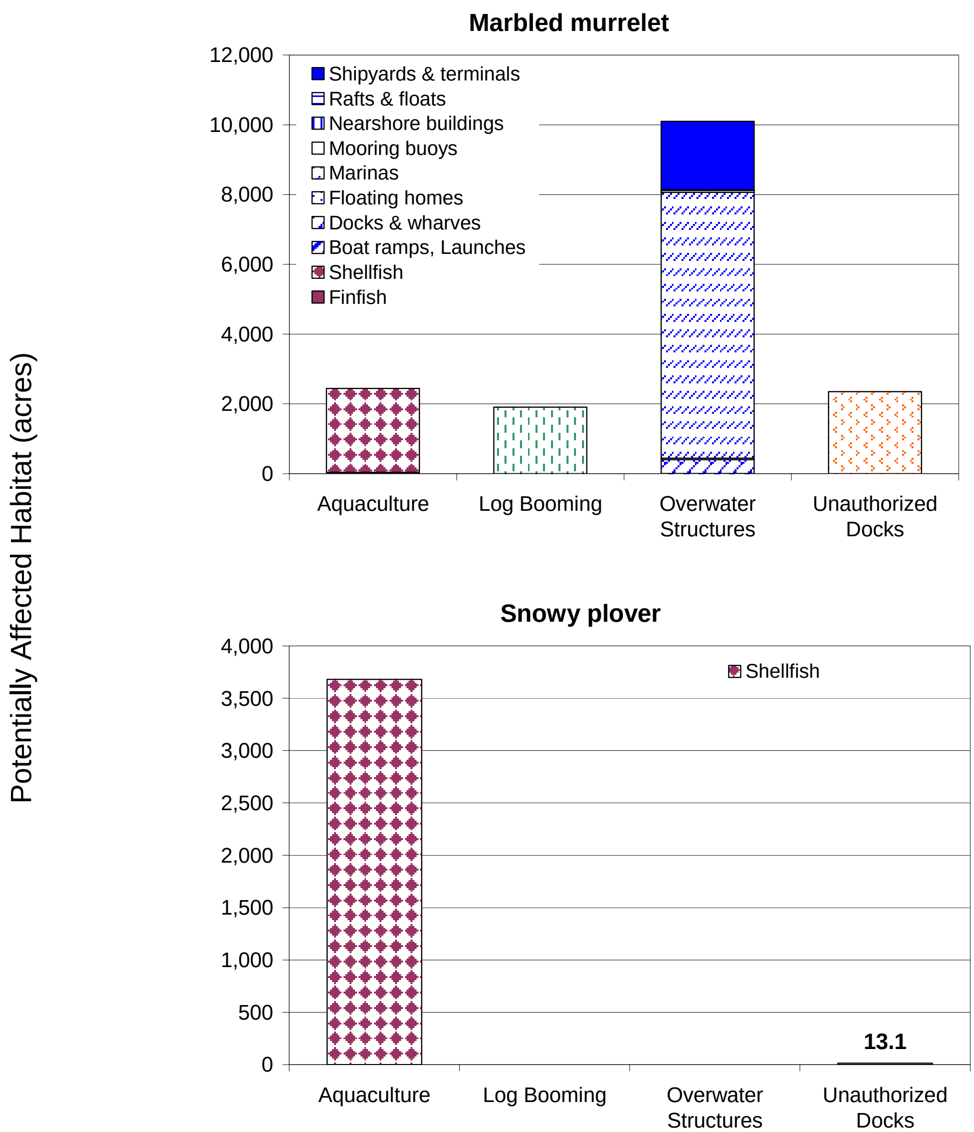



Western pond turtle
100
80
60
40
20
0
Shipyards & terminals
Nearshore buildings
Marinas
Floating homes
Docks & wharves
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks

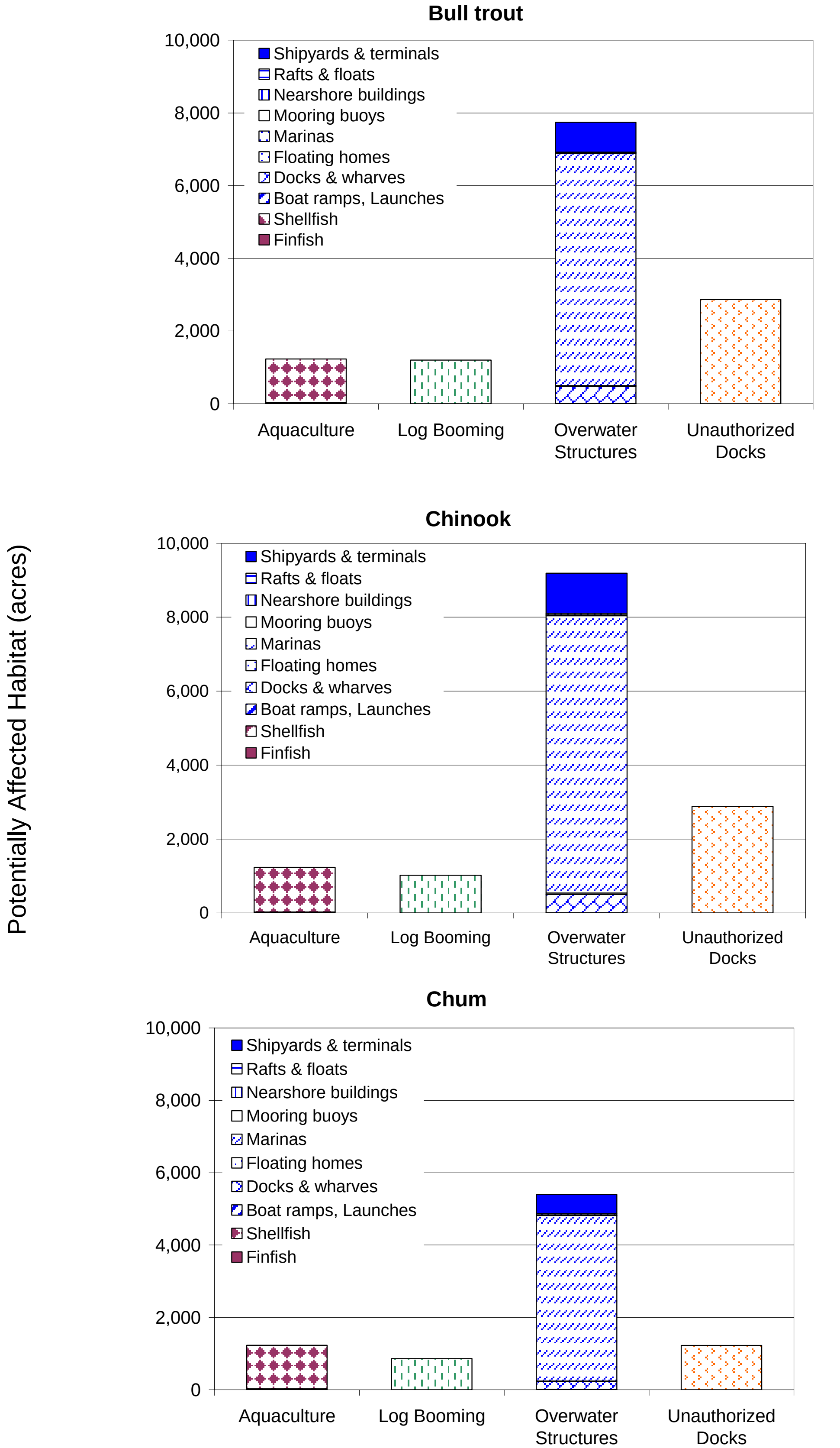
Birds

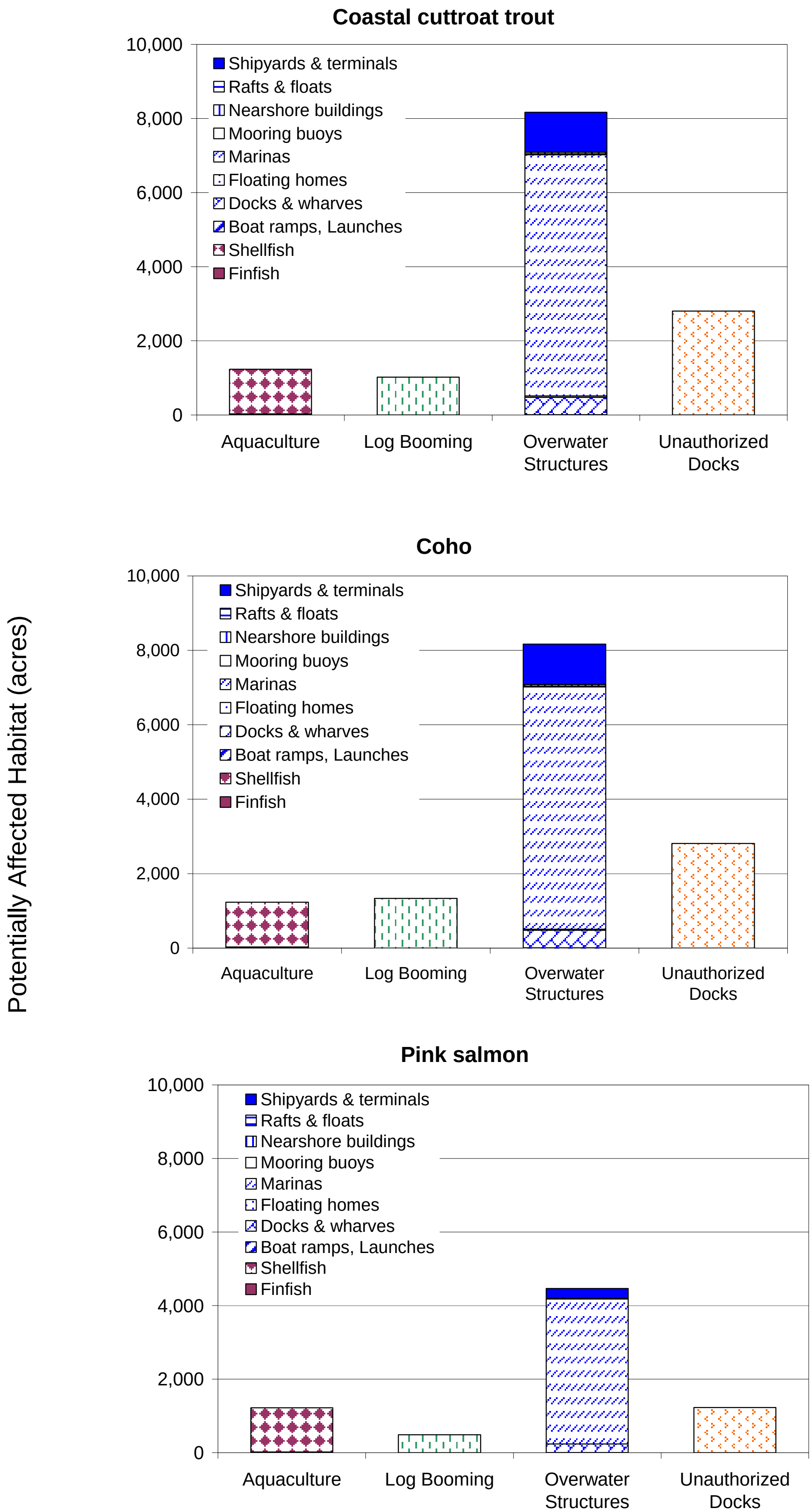

Bald eagle
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Potentially Affected Habitat (acres)
Black tern
250
200
150
100
50
0
Shipyards & terminals
Mooring buoys
Marinas
Docks & wharves
Boat ramps, Launches
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks

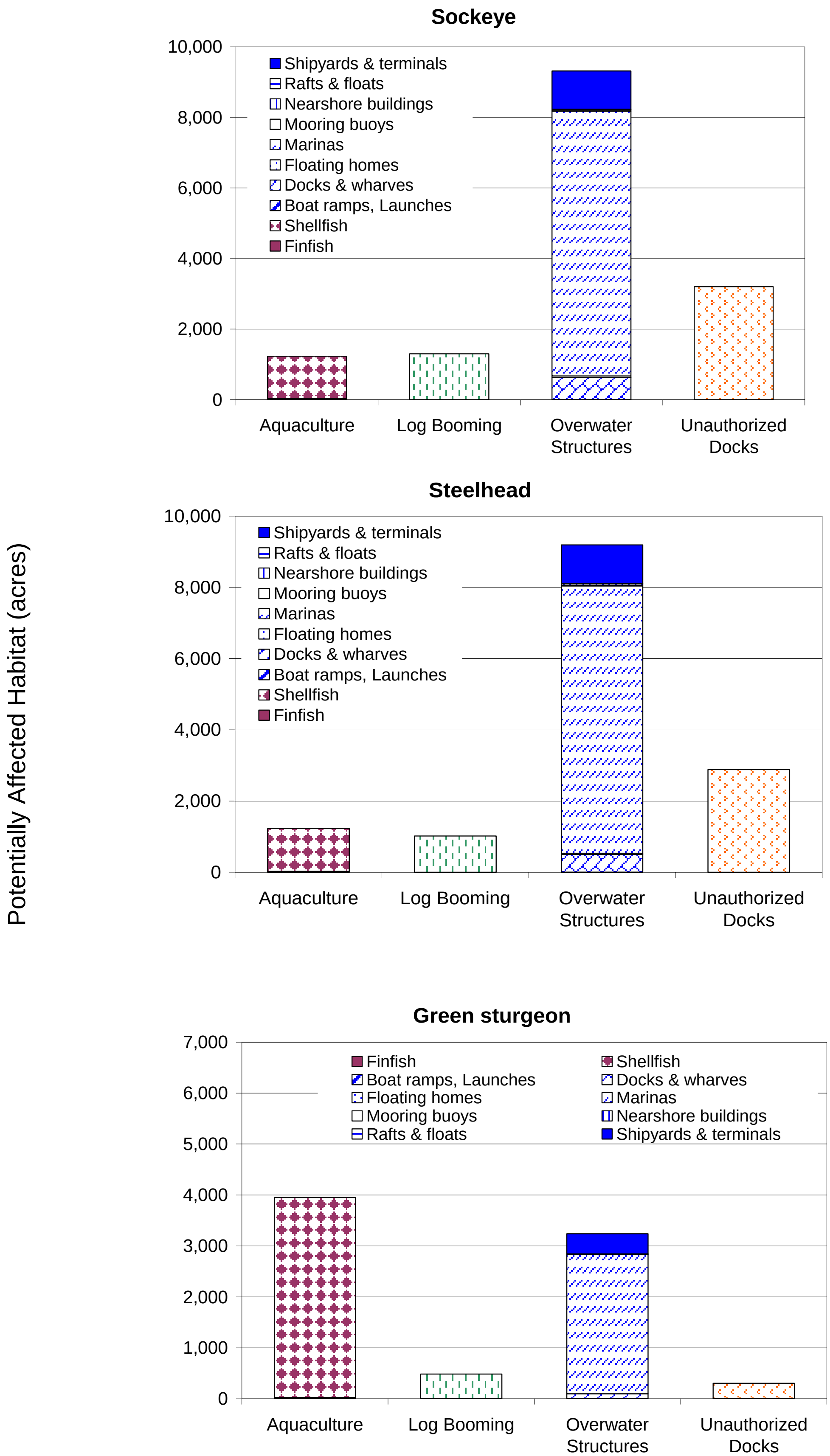

Potentially Affected Habitat (acres)
Brown pelican
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Common loon
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Harlequin duck
2,500
2,000
1,500
1,000
500
0
Nearshore buildings
Marinas
Boat ramps, Launches
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks

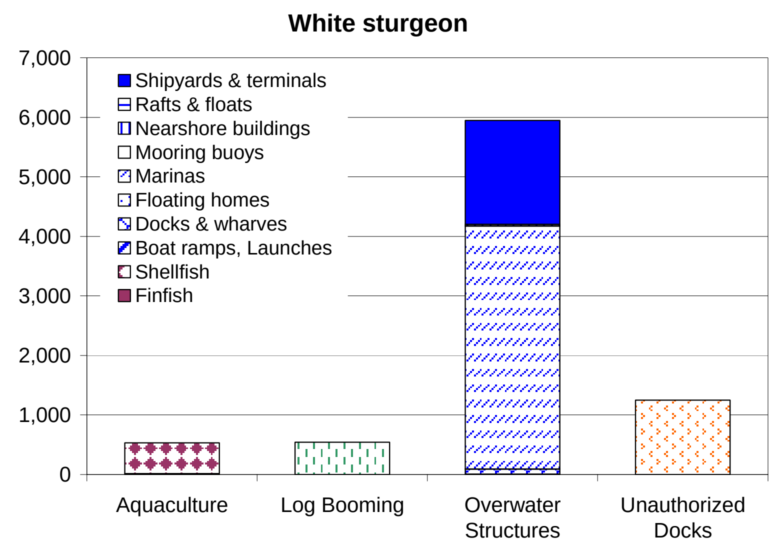

Marbled murrelet
Potentially Affected Habitat (acres)
12,000
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Snowy plover
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Shellfish
13.1
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks

FISH

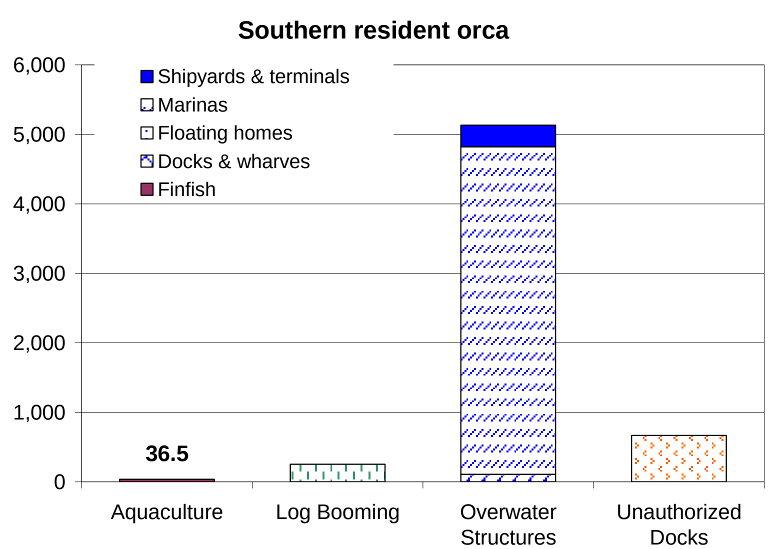

Potentially Affected Habitat (acres)
Bull trout
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Chinook
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Chum
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks


Coastal cuttroat trout
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Coho
Pink salmon
Potentially Affected Habitat (acres)


Potentially Affected Habitat (acres)
Sockeye
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Steelhead
10,000
8,000
6,000
4,000
2,000
0
Shipyards & terminals
Rafts & floats
Nearshore buildings
Mooring buoys
Marinas
Floating homes
Docks & wharves
Boat ramps, Launches
Shellfish
Finfish
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks
Green sturgeon
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Finfish
Shellfish
Boat ramps, Launches
Docks & wharves
Floating homes
Marinas
Mooring buoys
Nearshore buildings
Rafts & floats
Shipyards & terminals
Aquaculture
Log Booming
Overwater Structures
Unauthorized Docks



MARINE MAMMAL



6. Conservation Measures and Outcomes

Washington DNR currently employs a variety of programmatic strategies to help ensure environmental protection of the aquatic lands they lease. Many of these strategies can be considered conservation measures, in that they may help to avoid, minimize, and/or mitigate potential effects on Covered Species and their habitats. These programmatic measures, although not included in the potentially affected habitat calculations, may substantially enhance efforts to conserve and recover endangered, threatened, and imperiled species. Examples of existing programmatic measures include:

- Requiring the receipt of all regulatory permits and conditions prior to execution of an agreement.
- Stipulating in the authorizing document that the lessee/grantee keep current and comply with all conditions and terms of any permits, licenses, certificates, regulations, ordinances, statutes, and other government rules and regulations regarding its use or occupancy.
- Requiring the lessee/grantee to report to Washington DNR all violations issued by regulatory agencies and the remedies prescribed.
- Creating Aquatic Reserves and withdrawing lands from leasing.
- Terminating agreements that fail to conform to regulatory and/or leasehold requirements.
- Conducting periodic inspections of leased sites to ensure the user is meeting their contractual obligations.
- Performing ongoing submerged aquatic vegetation monitoring.
- Managing invasive species.

These existing requirements can be expanded to include:

- Establishing benthic/biological monitoring requirements for covered activities.
- Creating an adaptive management process and monitoring methodology for covered activities.
- Developing a detailed, spatially explicit encumbrance layer that includes descriptive statistics regarding the nature and size of each use authorization.

Washington DNR is also working to broaden and strengthen coordination efforts with the Washington Departments of Ecology, Fish and Wildlife, Health, and Agriculture where obvious mission overlap exists (e.g., invasive species management with Washington Fish and Wildlife and Washington Department of Agriculture; actions to improve sediment and water quality with Washington Departments of Ecology and Health; actions to improve physical habitat quality and sustainable resource management that directly or indirectly benefits covered species with Washington Fish and Wildlife).

The remainder of this chapter presents conservation measures and mitigation options for the three activity groups addressed in this paper, with the selection of applicable measures described in Subsection 2-2.1 (Selection of Conservation Measures). Each activity section presents the following information by species group:

- A summary of major threats, and direct and indirect effects.
- An analysis of the effectiveness of the selected conservation measures.
- The expected outcome or reduction in potentially affected area from implementing the identified conservation measures (Subsection 2-2.2, Characterization of Expected Outcomes).

Because Washington DNR has yet to develop a formal strategy for addressing Unauthorized Docks, no calculation of potential reduction is presented for these structures. The complete list of identified conservation measures, their ranks, and the direct and indirect effects reduced by the measures can be found in Appendix J. Appendix G presents the Adjusted Effects Index worksheets, with Appendix K illustrating the percent reduction in potentially affected area.

6-1 Aquaculture

6-1.1 Conservation Measures

The suite of conservation measures selected for the Aquaculture activity group is provided below. These measures could be incorporated into a best management practices manual that would be specific for each lease.

- Al - Restrict noise and light to harvesting activities, normal operational practices and/or maintenance of safety.
- A2 - Make every reasonable effort to minimize noise and lights during nighttime operations.
- A3 - Use durable, long life materials for site maintenance and construction (e.g., wrapped Styrofoam).
- A4 - Minimize wheeled vehicles from driving on/in intertidal areas (e.g., eelgrass beds, salt marsh).
- A5 - Prevent release of contaminants from equipment into the environment.
- A6 - Prevent the use or discharge of toxic chemicals to control the fouling of net.

- A 7 - Prevent discharge of sanitary waste.
- A8 - Prevent pressure washing or cleaning of machinery in intertidal habitats.
- A9 - Minimize the risk of spills from vessels and equipment through appropriate design, employing appropriate containment devices (such as drip pans), and ensuring prompt cleanup of all spills and leaks.
- A10 - Store all chemicals, fuels and lubricants off site.
- All - Recover and dispose all debris and garbage at an appropriate upland facility.
- A12 - Develop and follow a best management plan for sewage and liquid waste that addresses: toilet facilities; handling and discharge of graywater; transportation and disposal of sewage and liquid waste.
- A13 - Develop and maintain a spill response kit with appropriate equipment, information for notification of authorities and a training plan for employees. Amend the plan whenever operational practices are altered.
- A14 - Follow practices that minimize the buildup of released bio-fouling organisms onto benthic environments.
- A15 - Minimize the discharge of unconsumed feed.
- A16 - Minimize the discharge of accumulated solids and attached marine growth.
- A17 - Minimize harvest/culture where seagrasses or kelp are present; if presence is unavoidable, map aquatic vegetation by species and area and monitor for impacts to determine if mitigation is necessary.
- A18 - Prevent damage/ destruction of covered species or their habitats in the harvest/culture area.
- A19 - Prevent harvest or in-water maintenance and construction during covered species migration windows.
- A20 - Develop and maintain a disease diagnosis and response plan, documenting import and transfer requirements as well as procedures for stock certification; disease containment and eradication; and control chemical use.
- A21 - Prevent commercial harvesting in areas with densities of native hard shell clams less than 2.7/meter^2, or geoduck clam densities less than 0.2/meter^2.
- A22 - Ensure net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey.
- A23 - Ensure predator netting is of appropriate size to avoid entrapment and injury to covered species and their prey ,and that material is tightly secured and regularly inspected.

AMPHIBIANS AND REPTILE

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

Major Threats (Washington DNR 2007)

- Habitat destruction and modification.

Effects Related to Aquaculture

- Water and sediment quality degradation.

Expected Outcomes with Conservation Measures

No spatial overlap was found with existing Aquaculture authorizations and the species in this group.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

Major Threats (Washington DNR 2007)

- Disturbance from maintenance and operation.
- Habitat degradation.
- Water quality impairment.
- Energy resource reduction resulting from decreased prey abundance.

Effects Related to Aquaculture

- Permanent habitat destruction/displacement.
- Energy resource reduction.
- Water and sediment quality degradation.
- Increased activity, impaired behavior, physical harassment.

Table 6-1 - Net Conservation Measure Index scores for Aquaculture and Covered Birds.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index[1] Score	
		Non-breeding	Nesting
Direct - Species level		**0.75**	**0.75**
Increased activity	A1, A2, A19		

[1] Net Conservation Measure Index Ranks: 0 = completely effective at eliminating threats; 0.25 = highly effective; 0.50 = moderately effective; 0.75 = low effectiveness; and 1 = ineffective.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index[1] Score	
		Non-breeding	Nesting
Impair behavior/timing patterns	A1, A2, A19		
Physical harm or harassment	A1, A2, A19		
Direct - Habitat level		**0.75**	**0.75**
Air quality impairment (acute)	A5		
Water quality impairment (acute)	A3, A4 to A13, A15, A16		
Sediment quality impairment (acute)	A4 to A13, A15, A16		
Permanent habitat destruction/displacement	A4, A15 A16, A17, A18, A21, A29		
Permanently inaccessible habitat			
Indirect - Habitat Loss			
Temporary destruction/displacement			
Temporarily inaccessible			
Indirect - Habitat Degradation		**0.75**	**0.75**
Energy resource reduction			
Air quality impairment (chronic)	A4, A5 to A8, A12, A14, A15, A16,		
Water quality impairment (chronic)	A3, A4 to A8, A12, to A14, A15, A16		
Sediment quality impairment (chronic)	A3, A5 to A8, A12, A14, A15, A16		
Reduction of structural habitat quality metrics	A14, A17, A17, A18, A29		

Expected Outcomes with Conservation Measures

Conservation measures reduced the area of potentially affected habitat for brown pelicans by 26 percent for finfish culture and 20 percent for shellfish culture, with affected habitat for bald eagles and marbled murrelets reduced by 20 percent for both lifestages (Appendix K). Affected habitat for non-nesting common loons was reduced by 20 percent, with affects to snowy plover habitat from shellfish culture reduced by 25 percent for the nesting lifestage and 18 percent for the wintering lifestage. No overlap was found for Aquaculture and either the black tern or harlequin duck.

FISH

Pacific Salmon, Trout and Char (Bull Trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steelhead); Green and White Sturgeon

Major Threats (Washington DNR 2007)

- Habitat destruction.
- Disease.

Effects Related to Aquaculture

- Permanent habitat destruction/displacement.
- Physical trauma resulting from disease transmitted by net pens.
- Energy resource reduction resulting from decreased prey abundance.
- Water and sediment quality degradation.
- Increased activity, impaired behavior, and physical harassment.

Table 6-2 - Net Conservation Measure Index scores for Aquaculture and Covered Salmonids.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index Score		
		Adult	Juvenile	Egg
Direct - Species Level		**0.75**	**0.75**	**1**
Increased activity	A1, A2, A19			
Impair behavior/timing patterns	A1, A2, A19			
Physical harm or harassment	A1 to A4, A19, A20, A22, A23			
Direct - Habitat Level		**0.75**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	A3, A4 to A13, A15, A16			
Sediment quality impairment (acute)	A4 to A13, A15, A16			
Permanent habitat destruction/displacement	A4, A15, A16, to A17, A18, A21			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**1**
Temporary destruction/displacement				
Temporarily inaccessible				

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index Score		
		Adult	Juvenile	Egg
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction				
Air quality impairment (chronic)				
Water quality impairment (chronic)	A3, A4 to A8, A12 to A14, A15, A16			
Sediment quality impairment (chronic)	A3, A5 to A8, A12, A14 to A16			
Reduction of structural habitat quality metrics	A14, A17, A21, A18, A23			

Table 6-3 - Net Conservation Measure Index scores for Aquaculture and Covered Sturgeons.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index Score		
		Juvenile / Adult	Larvae	Egg / Incubation
Direct - Species Level		**0.25**	**1**	**1**
Increased activity	A1, A2, A19			
Impair behavior/timing patterns	A1, A2, A19			
Physical harm or harassment	A1 to A4, A19, A20, A22, A23			
Direct - Habitat Level		**0.75**	**1**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	A3, A4 to A13, A15, A16			
Sediment quality impairment (acute)	A4 to A13, A15, A16			
Permanent habitat destruction/displacement	A4, A15, A16, to A17, A18, A21			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**1**	**1**
Temporary destruction/displacement				
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**1**	**1**

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index Score		
		Juvenile / Adult	Larvae	Egg / Incubation
Energy resource reduction				
Air quality impairment (chronic)				
Water quality impairment (chronic)	A3, A4 to A8, A12 to A14, A15, A16			
Sediment quality impairment (chronic)	A3, A5 to A8, A12, A14 to A16			
Reduction of structural habitat quality metrics	A14, A17, A21, A18, A23			

Expected Outcomes with Conservation Measures
Conservation measures reduced potentially affected habitat for salmonids by 12 percent for the adult and freshwater rearing/outmigration lifestage, with no reduction in potentially affected incubation/emergence habitat (Appendix K). Potentially affected adult and juvenile sturgeon habitat was reduced by 35 percent for finfish and 32 percent for shellfish, with no reduction noted any other lifestage.

MARINE MAMMAL

Southern Resident Orca
The conservation measures defined in this paper did not reduce habitat potentially affected by authorized Aquaculture (Appendix K).

6-1.2 Mitigation Options

Aquaculture mitigation measures (AM) 1 to 6 (Appendix J) are related to siting new facilities, which is beyond the scope of this analysis. However, these measures can be utilized to further offset potential effects after the incorporation of the avoidance and minimization measures summarized in the preceding section.

The following provides some general mitigation options that are specific to this activity group and could be further explored in conjunction with the programmatic conservation measures described at the beginning of this chapter. These measures are not all-inclusive and would need to be evaluated on a site-by-site basis in concert with on-going enhancement projects that operators may have already accomplished or are planning.

- Abandon existing Aquaculture facilities that have substantial effects on covered species and use mitigation measures to avoid impacts from relocation to a new facility.
- Provide replacement or enhancement of sensitive habitat that supports the covered species displaced by this activity group, such as shallow nearshore habitats.

6-2 Log booming and storage

6-2.1 Conservation Measures

The complete list of identified conservation measures, their ranks, and the direct and indirect effects reduced by the measures can be found in Appendix J. Appendix G presents the Adjusted Effects Index worksheets,

The suite of conservation measures selected for Log Booming and Storage is provided below. These measures could be incorporated into a best management practices manual that would be specific for each lease.

- LB1 - Site log transfer facilities to avoid bald eagle nests (or other covered species' nests). No project construction or operation should be closer than 330 feet to any bald eagle nest tree unless permitted by U.S. Fish and Wildlife Service.
- LB2 - Site log storage areas and transfer facilities in areas with good currents and tidal exchanges.
- LB3 - Storage of logs should not take place where they will ground at any time.
- LB4 - Storage and handling of logs should be restricted or eliminated from waters where state and federal water quality and sediment standards cannot be met at all times.
- LB5 - Avoid siting log storage areas and facilities in sensitive habitat and areas important for specified species (e.g., salt marshes, kelp or eelgrass beds, seaweed harvest areas or shellfish concentration areas).

AMPHIBIANS AND REPTILE

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

Major Threats (Washington DNR 2007)

- Habitat conversion.
- Habitat fragmentation.

Effects Related to Log Booming and Storage

- Mortality from traffic.
- Physical harm and harassment.
- Habitat degradation.

Table 6-4 - Net Conservation Measure Index scores for Log Booming and Storage and Covered Amphibians and Reptile.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index[2]		
		Egg	Tadpole	Adult
Direct -Species Level		**1**	**1**	**1**
Increased activity	LB 1			
Impair behavior/timing patterns	LB 1			
Physical harm or harassment				
Direct - Habitat Level		**1**	**0.75**	**0.75**
Air quality impairment (acute)				
Water quality impairment (acute)	LB 2, LB 4			
Sediment quality impairment (acute)	LB 2, LB 4			
Permanent habitat destruction/displacement	LB 2, LB 5			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**0.75**
Temporary destruction/displacement	LB 2, LB 3, LB 4, LB 5			
Temporarily inaccessible				
Indirect – Habitat Degradation		**0.5**	**0.5**	**0.5**
Energy resource reduction	LB 4, LB 5			
Air quality impairment (chronic)				
Water quality impairment (chronic)	LB 2, LB 4			
Sediment quality impairment (chronic)	LB 2, LB 4			
Reduction of structural habitat quality metrics	LB 2, LB 3, LB 4, LB 5			

Expected Outcomes with Conservation Measures

Existing Log Booming and Storage authorizations do not overlap with either Columbia spotted or northern leopard frog habitat. Implementation of the conservation measures defined here reduced potentially affected non-wintering western pond turtle habitat by 31 percent, with affected western toad egg and tadpole habitat reduced by 50 percent.

[2] Net Conservation Measure Index Ranks: 0 = completely effective at eliminating threats; 0.25 = highly effective; 0.50 = moderately effective; 0.75 = low effectiveness; and 1 = ineffective.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

Major Threats (Washington DNR 2007)

- Human disturbance.
- Pollution.
- Prey abundance.

Effects Related to Log Booming and Storage

- Habitat destruction.
- Human disturbance.
- Changes in structural habitat.

Table 6-5 - Net Conservation Measure Index scores for Log Booming and Storage and Covered Birds.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index	
		Non-breeding	Nesting
Direct - Species Level		**0.75**	**0.5**
Increased activity	LB1		
Impair behavior/timing Patterns	LB1		
Physical harm or harassment	LB1		
Direct - Habitat Level		**0.75**	**0.5**
Air quality impairment (acute)			
Water quality impairment (acute)	LB2, LB4		
Sediment quality impairment (acute)	LB2, LB4		
Permanent habitat destruction/displacement	LB2, LB5		
Permanently inaccessible habitat			
Indirect - Habitat Loss		**1**	**1**
Temporary destruction/d is placement	LB2, LB3, LB4, LB5		
Temporarily inaccessible			
Indirect - Habitat Degradation		**0.75**	**0.75**
Energy resource reduction	LB4, LB5		
Air quality impairment (chronic)			
Water quality impairment (chronic)	LB2, LB4		
Sediment quality impairment (chonic)	LB2, LB4		

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index	
		Non-breeding	Nesting
Reduction of structural habitat quality metrics	LB2, LB3, LB4, LB5		

Expected Outcomes with Conservation Measures

Conservation measures reduced the amount of potentially affected habitat for bald eagles by 16 percent for non-nesting birds and 25 percent for nesting birds, with affected migratory brown pelican habitat reduced by 26 percent (Appendix K). For common loons the reductions ranged from 26 (non-nesting) to 50 percent (nesting), with reductions for marbled murrelet habitat ranging from 49 (non-nesting) to 26 percent (nesting). No spatial overlap was found with existing authorizations and black terns, harlequin ducks or snowy plovers.

FISH

Pacific Salmon, Trout and Char (Bull Trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steel head); Green and White Sturgeon

Major Threats (Washington DNR 2007)

- Habitat degradation.
- Human disturbance.

Effects Related to Log Booming and Storage

- Water and sediment quality degradation.
- Human disturbance.
- Habitat degradation.

Table 6-6 - Net Conservation Measure Index scores for Log Booming and Storage and Covered Salmonids.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Adult	Juvenile	Egg
Direct - Species Level		**1**	**1**	**1**
Increased activity	LB1			
Impair behavior/timing patterns	LB1			
Physical harm or harassment				
Direct - Habitat level		**0.75**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	LB2, LB4			
Sediment quality	LB2, LB4			

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Adult	Juvenile	Egg
impairment (acute)				
Permanent habitat destruction/displacement	LB2, LB5			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**1**
Temporary destruction/displacement	LB2, LB3, LB4, LB5			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction	LB4, LB5			
Air quality impairment (chronic)				
Water quality impairment (chronic)	LB2,LB4			
Sediment quality impairment (chronic)	LB2, LB4			
Reduction of structural habitat quality metrics	LB5			

Table 6-7 - Net Conservation Measure Index scores for Log Booming and Storage and Covered Sturgeon.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	Larvae	Egg / Incubation
Direct - Species Level		**1**	**1**	**1**
Increased activity	LB1			
Impair behavior/timing patterns	LB1			
Physical harm or harassment				
Direct - Habitat level		**0.75**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	LB2, LB4			
Sediment quality impairment (acute)	LB2, LB4			
Permanent habitat destruction/displacement	LB2, LB5			

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	**Larvae**	**Egg / Incubation**
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**1**
Temporary destruction/displacement	LB2, LB3, LB4, LB5			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction	LB4, LB5			
Air quality impairment (chronic)				
Water quality impairment (chronic)	LB2,LB4			
Sediment quality impairment (chronic)	LB2, LB4			
Reduction of structural habitat quality metrics	LB5			

Expected Outcomes with Conservation Measures

For salmonids, conservation measures reduced the amount of potentially affected habitat by 24 percent for adult habitat and 23 percent for juvenile lifestages (Appendix K). Affected adult sturgeon habitat decreased by 26 percent for green sturgeon and 18 percent for white sturgeon, with affected white sturgeon egg/incubation habitat decreasing by 16 percent. Conservation measures did not change the potentially affected habitat for the salmonid incubation or white sturgeon larval lifestages.

MARINE MAMMAL

Southern Resident Orca

Major Threats (Washington DNR 2007)

There are no major threats to the southern resident orca associated with Log Booming and Storage.

Effects Related to Log Booming and Storage

- Habitat destruction.

Table 6-8 - Net Conservation Measure Index scores for Log Booming and Storage and the southern resident orca.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index
Direct - Species Level		**1**
Increased activity	LB1	

Impair behavior/timing patterns	LB1	
Physical harm or harassment		
Direct - Habitat Level		**1**
Air quality impairment (acute)		
Water quality impairment (acute)	LB2, LB4	
Sediment quality impairment (acute)	LB2, LB4	
Permanent habitat destruction/displacement	LB2	
Permanently inaccessible habitat		
Indirect - Habitat Loss		**1**
Temporary destruction/displacement	LB2, LB3, LB4	
Temporarily inaccessible		
Indirect - Habitat Degradation		**1**
Energy resource reduction	LB4.LB5	
Air quality impairment (chronic)		
Water quality impairment (chronic)	LB2,LB4	
Sediment quality impairment (chronic)	LB2,LB4	
Reduction of structural habitat quality metrics	LB2, LB3, LB4, LB5	

Expected Outcomes with Conservation Measures
Killer whales received no benefit from the conservation measures identified for this activity sub-group (Appendix K).

6-2.2 Mitigation Options

The following text provides some general mitigation options that are specific to this activity group and could be further explored in conjunction with the Programmatic Conservation Measures described in the beginning of this chapter. These measures are not all-inclusive and would need to be evaluated on a site-by-site basis in concert with on-going enhancement projects that operators may have already accomplished or are planning.

- Abandon and restore existing facilities that have substantial effects on covered species and use mitigation measures to avoid impacts from a new facility.
- Provide mitigation for sediment regime changes such as beach nourishment.
- Restrict the use of structures to those that are absolutely required.
- Replace structures, gradually, with more environmentally friendly structures.

- Provide replacement or enhancement of sensitive habitat that supports the covered species displaced by this activity group, such as shallow nearshore and wetland habitats.

6-3 Overwater structures

6-3.1 Conservation Measures

The complete list of identified conservation measures, their ranks, and the direct and indirect effects reduced by the measures can be found in Appendix J. Appendix G presents the Adjusted Effects Index worksheets,

The following conservation measures could be incorporated into a best management practices manual that would be specific for each lease.

- OS1 - Deploy anchorage systems in a manner that prevents dragging.
- OS2 - No large woody debris may be removed during construction of operation.
- OS3 - Avoid casting artificial light into the ambient night-time aquatic environment and orient night lighting such that illumination of the surrounding waters is avoided.
- OS4 - Floats shall not rest on the tidal substrate and must use stoppers or supports that keep the bottom of the floatation device at least 1 (one) foot above the level of the substrate.
- OS5 - Require subsurface float to prevent the line from dragging on the bottom during low water;
- OS6 - Cover Styrofoam floatation material so Styrofoam can’t escape throughout the useable life of the float.
- OS7 - Perform maintenance activities using environmental windows that protect spawning periods and periods of presence of covered species.
- OS8 - Incorporate measures that increase the ambient light transmission under piers and docks during daylight hours. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint; grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials that absorb light such as wood) on the underside of the dock to reflect ambient light; using the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate; and aligning piers, docks and floats in north-south orientation to allow arc of sun to cross perpendicular to structure and reduce duration of light limitation.
- OS9 - Remove existing skirting and do not authorize for maintenance activities.

- OS10 - Prevent work over or in close proximity to submerged vegetation.
- OS11 - Situate buoys so that vessels do not ground out at low water.
- OS12 - Ensure that the length of mooring lines between the anchor and the subsurface float exceed the water depth as measured at extreme high tide plus 20 percent.
- OS13 - Use materials such as steel, concrete, recycled plastic, anchors and elastic rods or alternative dock mooring systems when replacing structure parts during maintenance.
- OS14 - Place shallow draft vessels nearshore to avoid the need for dredging.
- OS15 - Maintain dredged basins with more than one water depth so that depth decreases with distance from the entrance to avoid internal deeper pockets that can act as unflushed holding basins.
- OS16 - Do not allow new, additional filling of lands.
- OS17 - Locate floats in deep water to avoid light limitation and grounding impacts and maintain at least one foot of water between the substrate and the bottom of the float.
- OS18 - Orient night lighting such that illumination of the surrounding waters is avoided.
- OS19 - Incorporate best management practices to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
- OS20 - Use upland boat storage whenever possible to minimize need for overwater structures.
- OS21 - Include low-wake vessel technology, appropriate routes, and best management practices for wave attenuation structures as part of the design and permit process. Vessels should be operated at sufficiently low speeds to reduce wake energy, and no-wake zones should be designated near sensitive habitats.
- OS22 - Encourage only seasonal use of docks and off-season haul-outs.
- OS23 - Use environmental windows for any maintenance activities (and operations to the extent possible) that include protection for spawning periods and periods of presence of juvenile salmonids, forage fish, groundfish, and Dungeness crab .
- OS24 - Minimize changes to natural sediment processes and avoid effects to wave energy that determine characteristics of adjacent habitats.
- OS25 - Assess water drainage and runoff patterns and alter them to reduce direct inputs.

- OS26 - Avoid use of treated wood timbers or pilings to the extent practicable. Use of alternative materials such as untreated wood, concrete, or steel is recommended.
- OS27 - Ammoniacal Copper Quaternary (ACQ) treated wood may not be used in marine environments Require replacement on existing structures within 10 years.

AMPHIBIANS AND REPTILE

Columbia Spotted Frog, Northern Leopard Frog, Western Toad, Western Pond Turtle

Major Threats (Washington DNR 2007)

- Habitat conversion, modification, and/or fragmentation.
- Predation by introduced species.
- Disease.
- Human removal (Western pond turtle).

Effects Related to Overwater Structures

- Permanent destruction and fragmentation of wetland, side channel and backwater habitats.
- Changes in habitat structure (e.g., channel morphology).
- Increase in predation.
- Water and sediment quality degradation.
- Physical harm or harassment.

Table 6-9 – Net Conservation Measure Index Scores for single element[3] Overwater Structures and Covered Amphibians and Reptile.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index[4]		
		Egg	Tadpole	Adult
Direct - Species Level		**1**	**0.75**	**1**
Increased activity	OS3, OS7			
Impair behavior/timing patterns	OS3, OS7, OS8			
Physical harm or harassment				
Direct - Habitat level		**1**	**1**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	OS7			

[3] Single element structures are those with no other associated structures or uses.

[4] Net Conservation Measure Index Ranks: 0 = completely effective at eliminating threats; 0.25 = highly effective; 0.50 = moderately effective; 0.75 = low effectiveness; and 1 = ineffective.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index[4]		
		Egg	Tadpole	Adult
Sediment quality impairment (acute)				
Permanent habitat destruction/displacement	OS4			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**0.75**
Temporary destruction/displacement	OS1, OS4, OS5, OS7, OS11, OS12			
Temporarily inaccessible				
Indirect - Habitat Degradation		**1**	**0.75**	**0.75**
Energy resource reduction	OS4, OS8, OS10			
Air quality impairment (chronic)				
Water quality impairment (chronic)	OS7			
Reduction of structural habitat quality metrics	OS2, OS4, OS5, OS8, OS10, OS11, OS12			

Table 6-10 - Net Conservation Measure Index scores for multiple element[5] Overwater Structures and Covered Amphibians and Reptile.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Egg	Tadpole	Adult
Direct - Species Level		**0.75**	**0.75**	**0.75**
Increased activity	OS22, OS17, OS18, OS21, OS22,			
Impair behavior/timing patterns	OS23			
Physical harm or harassment	OS23			
Direct - Habitat level		**0.75**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26			
Sediment quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26			
Permanent habitat destruction/displacement	OS4			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**1**	**1**	**1**
Temporary destruction/displacement	OS4, OS20			
Temporarily inaccessible				

[5] Multiple element structures are a complex of interrelated structures at a single facility.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Egg	Tadpole	Adult
Indirect - Habitat Degradation		**0.75**	**0.75**	**0.75**
Energy resource reduction	OS17, OS24, OS8			
Air quality impairment (chronic)				
Water quality impairment (chronic)	OS13, OS14, OS15, OS27, OS21, OS22, OS25, OS26			
Sediment quality impairment (chronic)	OS13, OS14, OS15, OS27, OS25, OS26			
Reduction of structural habitat quality metrics	OS20, OS24, OS8			

Expected Outcomes with Conservation Measures

Reductions on potentially affected habitat as a result of the application of conservation measures ranged between 12 and 31 percent for the species in this group, with the amphibian tadpole lifestage seeing the greatest decrease in affected habitat (Appendix K). No spatial overlap was found with any activity and northern leopard frog eggs or tadpoles, or mooring buoys and any species.

BIRDS

Bald Eagle, Black Tern, Brown Pelican, Common Loon, Harlequin Duck, Marbled Murrelet, Western Snowy Plover

Major Threats (Washington DNR 2007)

- Habitat degradation.
- Human disturbance.
- Bioaccumulation of pollutants.
- Reduced prey abundance.

Effects Related to Overwater Structures

- Habitat destruction, conversion and degradation.
- Impaired behavior.
- Changes in habitat structural matrices.
- Water and sediment quality degradation.
- Human disturbance.
- Reduced prey abundance and reductions in energy resources.

Table 6-11 - Net Conservation Measure Index scores for single element Overwater Structures and for Covered Birds.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index	
		Non-breeding	Nesting
Direct - Species level		**1**	**1**
Increased activity	OS3, OS7		
Impair behavior/timing patterns	OS3, OS7, OS8		
Physical harm or harassment			
Direct - Habitat level		**1**	**1**
Air quality impairment (acute)			
Water quality impairment (acute)	OS7		
Sediment quality impairment (acute)			
Permanent habitat destruction/displacement	OS4		
Permanently inaccessible habitat			
Indirect - Habitat loss		**0.75**	**0.75**
Temporary destruction/displacement	OS1, OS4, OS5, OS7, OS11, OS12		
Temporarily inaccessible			
Indirect - Habitat Degradation		**0.75**	**0.75**
Energy resource reduction	OS4, OS8, OS10		
Air quality impairment (chronic)			
Water quality impairment (chronic)	OS7		
Sediment quality impairment (chronic)			
Reduction of structural habitat quality metrics	OS2, OS4, OS5, OS8, OS10, OS11, OS12		

Table 6-12 - Net Conservation Measure Index scores for multiple element Overwater Structures and Covered Birds.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index	
		Non-breeding	Nesting
Direct - Species level		**0.75**	**0.75**
Increased activity	OS22		
Impair behavior/timing patterns	OS17, OS18, OS21, OS22, OS23		
Physical harm or harassment	OS22, OS23		
Direct - Habitat Level		**0.75**	**0.75**

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index	
		Non-breeding	Nesting
Air quality impairment (acute)			
Water quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26		
Sediment quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26		
Permanent habitat destruction/displacement	OS4		
Permanently inaccessible habitat			
Indirect - Habitat loss		**1**	**1**
Temporary destruction/displacement	OS4, OS20		
Temporarily inaccessible			
Indirect - Habitat Degradation		**0.75**	**0.75**
Energy resource reduction	OS17, OS24, OS8		
Air quality impairment (chronic)			
Water quality impairment (chronic)	OS13, OS14, OS15, OS27, OS21, OS22, OS25, OS26		
Sediment quality impairment (chronic)	OS13, OS14, OS15, OS27, OS25, OS26		
Reduction of structural habitat quality metrics	OS20, OS24, OS8		

Expected Outcomes with Conservation Measures

For single element structures, conservation measures reduced the amount of potentially affected habitat by 12 percent for the bald eagle, brown pelican, common loon, and harlequin duck, 16 percent for black terns and 18 percent for marbled murrelets (Appendix K). For multiple element structures, reductions in potentially affected habitat ranged from 12 to 24 percent. No spatial overlap exists with authorized Overwater Structures and the western snowy plover.

FISH

Pacific Salmon, Trout and Char (Bull trout, Chinook Salmon, Chum Salmon, Coastal Cutthroat Trout, Coho Salmon, Pink Salmon, Sockeye/Kokanee, Steel head); Green and White Sturgeon

Major Threats (Washington DNR 2007)

- Sediment and water quality impairment.
- Habitat quality impairment (e.g., shading).
- Loss of habitat.
- Increases in temperature.
- Release of toxic materials.

- Altered structural habitat.

Effects Related to Overwater Structures

- Habitat conversion and degradation.
- Sediment and water quality degradation.
- Physical trauma, harm and harassment.
- Reduced structural habitat quality.
- Energy resource reduction.

Table 6-13 - Net Conservation Measure Index scores for single element Overwater Structures and Covered Salmonids.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Adult	Juvenile	Egg
Direct - Species level		**1**	**0.75**	**1**
Increased activity	OS3, OS7			
Impair behavior/timing patterns	OS3, OS7, OS8			
Physical harm or harassment				
Direct - Habitat level		**1**	**1**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	OS7			
Sediment quality impairment (acute)				
Permanent habitat destruction/displacement	OS4			
Permanently inaccessible habitat				
Indirect - Habitat loss		**0.75**	**0.75**	**0.75**
Temporary destruction/displacement	OS1, OS4, OS5, OS7, OS11, OS12			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.5**	**1**
Energy resource reduction	OS4, OS8, OS10			
Air quality impairment (chronic)				
Water quality impairment (chronic)	OS7			
Sediment quality impairment (chronic)				
Reduction of structural habitat quality metrics	OS2, OS4, OS5, OS8, OS10, OS11, OS12			

Table 6-14 - Net Conservation Measure Index scores for multiple element Overwater Structures and Covered Salmonids.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Adult	Juvenile	Egg
Direct - Species Level		**0.75**	**0.75**	**1**
Increased activity	OS22			
Impair behavior/timing patterns	OS17, OS18, OS21, OS13 0, OS23			
Physical harm or harassment	OS22, OS23			
Direct - Habitat Level		**1**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26			
Sediment quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26			
Permanent habitat destruction/displacement	OS4			
Permanently inaccessible habitat				
Indirect - Habitat Loss		1	1	1
Temporary destruction/displacement	OS4, OS20			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction	OS17, OS24, OS8			
Air quality impairment (chronic)				
Water quality impairment (chronic)	OS13, OS14, OS15, OS27, OS21, OS22, OS25, OS26			
Sediment quality impairment (chronic)	OS13, OS14, OS15, OS27, OS25, OS26			
Reduction of structural habitat quality metrics	OS20, OS24, OS8			

Table 6-15 - Net Conservation Measure Index scores for single element Overwater Structures and Covered Sturgeon.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	Larvae	Egg / Incubation
Direct - Species Level		**1**	**1**	**1**
Increased activity	LB1			
Impair behavior/timing	LB1			

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	Larvae	Egg / Incubation
patterns				
Physical harm or harassment				
Direct - Habitat level		**0.75**	**0.75**	**1**
Air quality impairment (acute)				
Water quality impairment (acute)	LB2, LB4			
Sediment quality impairment (acute)	LB2, LB4			
Permanent habitat destruction/displacement	LB2, LB5			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**1**
Temporary destruction/displacement	LB2, LB3, LB4, LB5			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction	LB4, LB5			
Air quality impairment (chronic)				
Water quality impairment (chronic)	LB2,LB4			
Sediment quality impairment (chronic)	LB2, LB4			
Reduction of structural habitat quality metrics	LB5			

Table 6-16 - Net Conservation Measure Index scores for multiple element Overwater Structures and Covered Sturgeon.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	Larvae	Egg / Incubation
Direct - Species Level		**1**	**1**	**1**
Increased activity	LB1			
Impair behavior/timing patterns	LB1			
Physical harm or harassment				
Direct - Habitat level		**0.75**	**0.75**	**1**

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index		
		Juvenile / Adult	Larvae	Egg / Incubation
Air quality impairment (acute)				
Water quality impairment (acute)	LB2, LB4			
Sediment quality impairment (acute)	LB2, LB4			
Permanent habitat destruction/displacement	LB2, LB5			
Permanently inaccessible habitat				
Indirect - Habitat Loss		**0.75**	**0.75**	**1**
Temporary destruction/displacement	LB2, LB3, LB4, LB5			
Temporarily inaccessible				
Indirect - Habitat Degradation		**0.75**	**0.75**	**1**
Energy resource reduction	LB4, LB5			
Air quality impairment (chronic)				
Water quality impairment (chronic)	LB2,LB4			
Sediment quality impairment (chronic)	LB2, LB4			
Reduction of structural habitat quality metrics	LB5			

Expected Outcomes with Conservation Measures

Conservation measures reduced the amount of potentially affected habitat for the salmonid freshwater rearing lifestage by 17 to 25 percent for all species, with reduction sin affected adult habitat ranging from 31 to 12 percent (Appendix K). The conservation measures defined here offered no reduction in potentially affected habitat for the egg/incubation lifestage and any salmonid. Reductions in potentially affected adult/juvenile sturgeon habitat ranged from a maximum of 67 percent for Mooring buoys, Rafts and Floats, to approximately 24 percent for Marinas, Nearshore buildings and Shipyards and Terminals, and 12 percent for Floating homes. Larval and egg/incubation lifestages experienced similar reductions in potentially affected habitat as those for adults.

MARINE MAMMAL

Southern Resident Orca

Major Threats (Washington DNR 2007)

- Toxic releases.
- Human disturbance.

Effects Related to Overwater Structures

- Human disturbance.
- Energy resource reduction.
- Water quality impairment.
- Altered behavior, physical harm.

Table 6-17 - Net Conservation Measure Index scores for single element Overwater Structures and the southern resident orca.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index
Direct - Species Level		**1**
Increased activity	OS3, OS7	
Impair behavior/timing patterns	OS3, OS7, OS8	
Physical harm or harassment.		
Direct - Habitat Level		**1**
Air quality impairment (acute)		
Water quality impairment (acute)	OS7	
Sediment quality impairment (acute)		
Permanent habitat Destruction/displacement	OS4	
Permanently inaccessible habitat		
Indirect. Habitat Loss		**1**
Temporary destruction/displacement	OS1, OS4, OS5, OS7, OS11, OS12	
Temporarily inaccessible		
Indirect. Habitat Degradation		**1**
Energy resource reduction	OS4, OS8, OS10	
Air quality impairment (chronic)		
Water quality impairment (chronic)	OS7	
Sediment quality impairment (chronic)		
Reduction of structural habitat quality metrics	OS2, OS4, OS5, OS8, OS10, OS11, OS12	

Table 6-18 - Net Conservation Measure Index scores for multiple element Overwater Structures and the southern resident orca.

Potential Effect Mechanisms	Conservation Measures	Net Conservation Measure Index
Direct - Species Level		**0.75**
Increased activity	OS22	
Impair behavior/timing patterns	OS17, OS18, OS21, OS22, OS23	
Physical harm or harassment	OS22, OS23	
Direct - Habitat Level		**1**
Air quality impairment (acute)		
Water quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26	
Sediment quality impairment (acute)	OS13, OS14, OS15, OS27, OS25, OS26	
Permanent habitat destruction/displacement	OS4	
Permanently inaccessible habitat		
Indirect – Habitat Loss		**1**
Temporary destruction/displacement	OS4, OS20	
Temporary inaccessible		
Indirect – Habitat Degradation		**1**
Energy resource reduction	OS17, OS24, OS8	
Air quality impairment (chronic)		
Water quality impairment (chronic)	OS13, OS14, OS15, OS27, OS21, OS22, OS25, OS26	
Sediment quality impairment (chronic)	OS13, OS14, OS15, OS27, OS25, OS26	
Reduction of structural habitat quality metrics	OS20, OS24, OS8	

Expected Outcomes with Conservation Measures
Application of conservation measures did not change the small amount of killer whale habitat potentially affected by Overwater Structures.

6-3.2 Mitigation Options

Overwater Structure mitigation measures (OSM) (Appendix J) are generally related to construction of new facilities, which is beyond the scope of this analysis. However, many of these construction-related measures can be used for mitigation that could further offset potential effects after the incorporation of avoidance and minimization measures summarized in the preceding tables. In addition, these measures should be used when replacing existing facilities, or portions of facilities (e.g., docks) that are known to have substantial effects on the Covered Species.

7. References

Ackerman, D. and S.B. Weisberg. 2003. Relationship Between Rainfall and Beach Bacterial Concentrations on Santa Monica Bay Beaches. Journal of Water and Health 1(2):85-89.

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindley, and M L. Moser. 2002. Status Review for North American Green Sturgeon, *Acipenser medirostris*. National Marine Fisheries Service. Santa Cruz, California.Allan J.D. and Flecker A.S. 1993. Biodiversity Conservation in Running Waters. BioScience, 43, 32–43.

Ambrose, R.F. 1994. Mitigating the Effects of a Coastal Plant on a Kelp Forest Community: Rationale and Requirements for an Artificial Reef. Bulletin of Marine Science 55:694-708

Anchor Environmental, Inc. 2000. Intalco Sediment Investigation. Ferndale, WA.

Anderson, G. 2002. Fact sheet for NPDES permit no WA0040975. Willapa Bay/Grays Harbor Oyster Growers Association. Washington Department of Ecology. Accessed October 25, 2005. http://www.ecy.wa.gov/programs/wq/pesticides/final_pesticide_permits/oyster/oyster_index.html.

Andrew, J.M., and J.A. Mosher. 1982. Bald Eagle Nest Site Selection and Sesting Habitat in Maryland. Journal of Wildlife Management. 46:382-390.

Anthony, R.G., F.B. Isaacs, and R.W. Frenzel (eds.). 1983. Proceedings of a Workshop on Habitat Management for Nesting and Roosting Bald Eagles in the Western United States. Cooperative Wildlife Research Unit, Oregon State University. Corvallis, Oregon.

Anthony, R.G., Isaacs, F.B. 1989. Characteristics of Bald eagle Nest Sites in Oregon. Journal of Wildlife Management. 53: 148–159.

Aresco, M. J. 2005. The Effect of Sex-specific Terrestrial Movements and Roads on the Sex Ratio of Freshwater Turtles. Biological Conservation 123:37–44.

Arkoosh, M.R., E. Casillas, E. Clemons, A.N. Kagley, R. Olson, P. Reno, and J.E. Stein. Effects of Pollution on Fish Diseases: Potential Impacts on Salmonid Populations. Journal of Aquatic Animal Health. 10(2):182-190.

Ashley and Robinson. 1996. Road Mortality of Amphibians, Reptiles and other Wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist. 110(3): 403-412.

Ashley, J. 1994. 1992–93 Harlequin duck monitoring and inventory in Glacier National Park, Montana. Glacier National Park, MT: Division of Resource Management..

Ashton, D.T., A.J. Lind, and K.E. Schlick. 1997. Western Pond Turtle (*Clemmys marmorata*). Natural History. Redwood Sciences Laboratory. Arcata, CA.

Asplund, T.R. 2000. The Effects of Motorized Watercraft on Aquatic Ecosystems. Wisconsin Department of Natural Resources Bureau of Integrated Science Services. PUBL-SS-948-00. Madison, WI.

Banerjee, A., Sarkar, R.K. and Mukherji, S. 1983. Reduction in Soluble Protein and Chlorophyll Contents in a Few Plants as Indicators of Automobile Exhaust Pollution. International Journal of Environmental Studies, 20: 239-243.

Barret J. C., G. D. Grossman, J. Rosenfeld. 1992. Turbidity Induced Changes in Reactive Distance of Rainbow Trout. Transactions of the American Fisheries Society. 121:437–443.

Bayley, P.B. 1995. Understanding Large River-Floodplain Ecosystems. BioScience, 45(3): 153-128.

Beechie, T.J., and M. Liermann, E.M. Beamer, and R. Henderson. 2005. A Classification of Habitat Types in a Large River and Their Use by Juvenile Salmonids. Transactions of the American Fisheries Society 134:717-729.

Bennett, A.F. 1991. Roads, Roadsides, and Wildlife Conservation: A Review. In: Nature Conservation, Volume 2, The Role of Corridors. D. A. Saunders and R. J. Hobbs, editors. Surrey Beatty & Sons, Victoria, Australia.

Berg L., T. G. Northcote. 1985. Changes in Territorial, Gill-flaring, and Feeding behavior in Juvenile Coho Salmon (*Oncorhynchus kisutch*) Following Short Term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Sciences. 42:1410–1417.

Beschta, R.L. 1997. Riparian Shade and Stream Temperature: An Alternative Perspective. Rangelands 19(2).

Betcher, C. and B. Williams. 1996. Impact of Mooring Buoy Installations on Eelgrass and Macroalgae. Unpublished report. Washington State Department of Fish and Wildlife. Olympia, WA.

Bettoli, P. W., and R. S. Osborne. 1998. Hooking Mortality and Behavior of Striped Bass Following Catch and Release Angling. North American Journal of Fisheries Management 18:609-615.

Bevanger, K. 1994. Bird Interactions with Utility Structures: Collisions and Electrocution, Causes and Measures. Ibis. 136(4):412-425.

Bhowmik, N. G., T. W. Soong, W. F. Reichelt, and N. M. L. Seddick. 1992 . Waves Generated by Recreational Traffic on the Upper Mississippi River System. Illinois State Water Survey Research Report 117.

Biedenharn, D.S., C.M. Elliot, and C.C. Watson. 1997. The WES Stream Investigation and Streambank Stabilization Handbook. U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, MS.

Bilby, R. E., K. Sullivan, and S. H. Duncan. 1989. The Generation and Fate of Road-Surface Sediment in Forested Watersheds in Southwestern Washington. Forest Science, 35(2), 453–468.

Bilby, R.E., J.T. Heffner, B.R. Fransen, and J.W. Ward. 1999. Effects of Immersion in Water on Deterioration of Wood from Five species of Trees Used for Habitat Enhancement Projects. North American Journal of Fisheries Management 19:687-695.

Bisson, P.A. and 10 coauthors. 2000. The Columbia River Estuary and the Columbia River Basin Fish and Wildlife Program. Independent Scientific Advisory Board. Northwest Power Planning Council. National Marine Fisheries Service. ISAB 2000-5.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. In: Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19:83-138. Bethesda, MD.

Blane, J.M., and R. Jaakson. 1994. The Impact of Ecotourism Boats on the St Lawrence Beluga Whales. Environmental Conservation 21:267-269.

Boese, B.L. 2002. Effects of Recreational Clam Harvesting on Eelgrass (*Zostera marina*) and Associated Infaunal Invertebrates: In-situ Manipulative Experiments. Aquatic Botany 73:63-74.

Boggs, C.T., M.L. Keefer, C.A. Peery, T.C. Bjornn, and L.C. Stuehrenberg. 2004. Fallback, Reascension, and Adjusted Fishway Escapement Estimates for Adult Chinook Salmon and Steelhead at Columbia and Snake River Dams. Transactions of the American Fisheries Society 133:932-949.

Bokuniewicz, H.J. and R.B. Gordon. 1980. Deposition of Dredged Sediment at Open Water Sites. Estuarine and Coastal Marine Science Vol 10, No 3, p 289-303, March 1980.

Bolton, S. and J. Shellberg. 2001. Ecological Issues in Floodplains and Riparian Corridors. Submitted to Washington Departments of Fish and Wildlife, Ecology, and Transportation. Olympia, WA.

Bonar, S. A., B. D. Bolding, M. Divens, and W. Meyer. 2004. Effects of Introduced Fishes on Wild Juvenile Coho Salmon Using Three Shallow Western Washington Lakes. Washington State Department of Fish and Wildlife, Warmwater Fish Program. Accessed October 17, 2005. http://wdfw.wa.gov/fish/warmwater/library/fpt04-03.pdf.

Booth, D.B. and C.R. Jackson. 1997. Urbanization of Aquatic Systems – Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation. Journal of the American Water Resources Association. 33(5).

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Information and Technology Report. USGS/BRD/ITR—1998-0004. US Geological Survey. Fort Collins, CO.

Bratton, S. 1990. Boat Disturbance of Ciconiiformes in Georgia Estuaries. Colonial Waterbirds 13(2): 124-128.

Brett J. R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus Oncorhynchus. Fisheries Research Board of Canada 9(6).

Brett J. R. and J. M. Blackburn. 1981. Oxygen Requirements for Growth of Yong oho (*Oncorhynchus kisutch*) and Sockeye (*O. nerka*) Salmon at 15^0C. Canadian Journal of Fisheries and Aquatic Sciences 38:399-404

Brett, J.R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus Onchorhynchus. Journal of the Fisheries Research Board of Canada, 9.

Brett, J.R. and J.M. Blackburn. 1981. Oxygen requirements for Growth of Young Coho (*Oncorhynchus kisutch*) and Sockeye (*O. nerka*) Salmon at 15 C. Canadian Journal of Fisheries and Aquatic Sciences, 38:399-404.

British Columbia Ministry of Agriculture and Lands. 2005 - Fisheries and Aquaculture. Accessed September 13, 2005. http://www.agf.gov.bc.ca/fisheries/

Brooks, K. M. 2000. An Assessment of the Environmental Effects Associated with Bridges Constructed of Wood Preserved with Creosote, Pentachlorophenol or Chromated Copper Arsenate. FPL-RP-587. U.S. Department of Agriculture, Forest Service. Washington, DC.

Brooks, K.M. 2004. Polycyclic Aromatic Hydrocarbon Migration from Creosote-treated Railway Ties into Ballast and Adjacent Wetlands. Research Paper FPL-RP-617. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Madison, WI

Brooks, K.M. and C.V.W. Mahnken. 2003a. Interactions of Atlantic salmon in the Pacific Northwest. II. Organic Wastes. Fisheries Research 62:255-293.

Brooks, K.M. and C.V.W. Mahnken. 2003b. Interactions of Atlantic salmon in the Pacific Northwest. III. Accumulation of zinc and copper. Fisheries Research 62:295-305.

Brown, A.V., M.M. Lyttle, and K.B. Brown. 1998. Impacts of Gravel Mining on Gravel Bed Streams. Transactions of the American Fisheries Society 127:979-994.

Brown, L.R. 2003. Will Tidal Wetland Restoration Enhance Populations of Native Fishes? San Francisco Estuary and Wetland Science 1(1):1-42.

Buckley, R.M. 1982. Marine Habitat Enhancement and Urban Recreational Fishing in Washington. Marine Fisheries Review 44(6-7):28-37.

Buckley, R.M. 1994. Artificial Reef and Fish Aggregating Device Habitats in Washington. Bulletin of Marine Science 55(2-3):1330.

Buckley, R.M. 2005. Fisheries Biologist. Washington Department of Fish and Wildlife, Olympia. October 14, 2005.

Buckley, R.M. and G.J. Hueckel. 1985. Biological Processes and Ecological Development on an Artificial Reef in Puget Sound, Washington. Bulletin of Marine Science 37(1):50-69.

Buehler, D.A., T.J. Mersmann, J.D. Fraser, and J.K.D. Seegar. 1991. Effects of Human Activity on Bald Eagle Distribution on the Northern Chesapeake Bay. Journal of Wildlife Management 55:282-290.

Burger, A.E. 1995. Inland Habitat Associations of Marbled Murrelets in British Columbia. In: Ecology and Conservation of Marbled Murrelet. Ed: C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. Chapter 16. USDA Forest Service Gen. Tech. Rep. PSW-152. 1995.

Burger, J. 1981. The Effect of Human Activity on Birds at a Coastal Bay. Biological Conservation 21: 231–241

Burger, J. 1982 The Role of Reproductive Success in Colony Site Selection and Abandonment in Black Skimmers. Auk 99:109-l 15.

Burger, J. 1998. Effects of Motorboats and Personal Watercraft on Flight Behavior Over a Colony of Common Terns. The Condor, 100 (3): 528-534.

Cada, G. F. 1990. A Review of Studies Relating to the Effects of Propeller-type Turbine Passage on Fish Early Life Stages. North American Journal of Fisheries Management 10:418–426.

California Coastal Commission. 2004. Seawater Desalination and the California Coastal Act. March 2004. Accessed October 20, 2005. http://www.coastal.ca.gov/energy/14a-3-2004-desalination.pdf.

Callaway, J.C., and M.N. Josselyn. 1992. The introduction and spread of smooth cordgrass (*Spartina alterniflora*) in south San Francisco Bay. Estuaries 15: 218-226.

Cardwell D. C. and R. R. Koons. 1981. Biological Consideration for the Siting and Design of Marinas and Affiliated Structures in Puget Sound. Washington Department of Fisheries, Technical Report 60.

Cardwell D. C., M. I. Carr, and E. W. Sanborn. 1980. Water Quality and Flushing of Five Puget Sound Marinas. Washington Department of Fisheries, Technical Report 56.

Carrasquero, J. 2001. Over-Water Structures: Freshwater Issues. White Paper submitted to Washington State Departments of Fish and Wildlife, Ecology, and Transportation. Accessed October 24, 2005.http://wdfw.wa.gov/hab/ahg/overwatr.htm.

Cassirer, E. F., and C. R. Groves. 1994. Ecology of Harlequin Ducks in Northern Idaho. Unpublished Report, Idaho Department of Fish and Game, Boise, ID.

Cassirer, E. F., G. Schirato, F. Sharpe, C. R. Groves, and R. N. Anderson. 1993. Cavity Nesting by Harlequin Ducks in the Pacific Northwest. Wilson Bulletin 105:691-694.

Castro, J. and B. Cluer. 2003. Instream Aggregate Mining Issues in Oregon. U.S. Fish and Wildlife Service. Oregon Fish and Wildlife Office. Portland, OR.

Cederholm, C. J., D. H. Johnson, R. E. Bilby, L.G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B.G. Marcot, J. F. Palmisano, R. W. Plotnikoff, W. G. Pearcy, C. A. Simenstad, and P. C. Trotter. 2000. Pacific Salmon and Wildlife - Ecological Contexts, Relationships, and Implications for Management. In: Wildlife-Habitat Relationships in Oregon and Washington. Ed: D. H. Johnson and T. A. O'Neil. Northwest Habitat Institute. Corvallis, OR.

Chapman, D.W. and E. Knudsen. 1980. Channelization and Livestock Impacts on Salmonid Habitat and Biomass in Western Washington. Transactions of the American Fisheries Society. 109:357-363.

Cheney, D., R. Oestman, G. Volkhardt, and J. Getz. 1994. Creation of Rocky Intertidal and Shallow Subtidal Habitats to Mitigate for the Construction of a Large Marina in Puget Sound, Washington. Bulletin of Marine Science 55(2-3):772-782.

Clark, KE, L.J. Niles, and W. Stansley, 1998. Environmental Contaminants Associated with Reproductive Failure in Bald Eagle (Haliaeetus leucocephalus) Eggs in New Jersey. Bulletin of Environmental Contamination and Toxicology Vol. 61, no. 2, pp. 247-254.

Clark, R.N., and Gibbons, D.R.. 1991. Recreation. In: Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19:459-481.

Clarkson, P. 1992. A Preliminary Investigation Into the Status and Distribution of Harlequin Ducks in Jasper National Park. Alberta, Canada: Natural Resource Conservation, Jasper National Park, Alberta, Canada..

Code of the Federal Resister. Title 50, Parts 223 and 224, Volume 68, Number 19. 2003. Endangered and Threatened Wildlife and Plants; Twelve Month Finding on a Petition to List North American Green Sturgeon as a Threatened or Endangered Species.

Code of the Federal Register. Title 65, Chapter 164, pp. 51264-51270 Installing and Maintaining Commercial Submarine Cables in National Marine Sanctuaries.

Colborn, T., F.S. Saal, and A.M. Soto. 1993. Developmental Effects of Endocrine-Disrupting Chemicals in Wildlife and Humans. Environmental Health Perspectives 101 (5):378-384.

Cole, R. 2002. Impacts of marine farming on wild fish populations. Final Research Report for Ministry of Fisheries Research Project ENV2000/08 Objective One. National Institute of Water and Atmospheric Research. Accessed October 24, 2005. http://www.mfe.govt.nz/issues/resource/aquaculture/environmental-info/impacts-wild-fish.pdf.

Collins, K.J., A.C. Jensen, and S. Albert. 1995. A review of Waste Tyre Utilization in the Marine Environment. Chemistry and Ecology 10(3-4):205-216.

Collins, K.J., A.C. Jensen, J.J. Mallinson, V. Roenelle, and V.P. Smith. 2002. Environmental Impact Assessment of a Scrap Tyre Artificial Reef. ICES Journal of Marine Sciences 59 Supplement:S243-S249.

Cosmopolitan Engineering Group and M.A. Kyte. 2005. Lakehaven Utility District Wastewater Treatment Plant Outfall Replacement, Redondo, Washington. Redondo, WA.

Crawford, C.M., C.K.A. Macleod, and I.M. Mitchell. 2003. Effects of Shellfish Farming on the Benthic Environment. Aquaculture 224:117-140.

Crump, D. 2001. The effects of UV-B Radiation and Endocrine-disrupting Chemicals (EDCs) on the Biology of Amphibians. Environmental Reviews 9:61-80.

Cubbage, F.W. 1995. Regulations of private forest practices: what rights, which policies? Journal of Forestry. 93(6) 14-20.

Damstra, T., S. Barlow, A. Bergman, R. Kavlock, and G. v. Der Kraak (editors). 2002. Global Assessment of the State-of-the-science of Endocrine Disruptors. International Programme on Chemical Safety, World Health Organization, the International Labour Organization, and the United Nations Environment Programme. WHO/PCS/EDC/02.2. Accessed November 2005. http://www.who.int/ipcs/publications/new_issues/endocrine_disruptors/en/index.html.

Danovaro, R., C. Gambi, A. Mazzola, and S. Mirto. 2002. Influence of Artificial Reefs on the Surrounding Infauna: Analysis of Meiofauna. ICES Journal of Marine Sciences 59 Supplement:S356-S362.

Darling, J.D., K.E. Keogh, and T.E. Steeves. 1998. Gray Whale (*Eschrichtius robustus*) Habitat Utilization and Prey Species off Vancouver Island, B.C. Marine Mammal Science: Vol. 14 (4):692–720.

Davis, N., VanBlaricom, G., & Dayton, P. K. 1982. Man-made Structures on Marine Sediments: Effects on Adjacent Benthic Communities. Marine Biology 70:295–303.

DeMaynadier, P.G. and M.L. Hunter. 2000. Road Effects on Amphibian Movements in a Forested Landscape. Natural Areas Journal 20:56-65.

Department of the Navy. 1999. Environmental Assessment of the Disposition of ex-Oriskany (CVA 34). U.S. Naval Systems Command. Accessed October 17, 2005. http://peoships.crane.navy.mil/reefing/ORISKANY%20EA%20FONSI.pdf.

Diefenderfer, H.L., C.G.C. Roegner, R.M. Thom, E.M. Dawley, A.H. Whiting, G.E. Johnson, K.L. Sobocinski, M.G. Anderson, and B.D. Ebberts. 2005. Evaluating Cumulative Ecosystem Response to Restoration Projects in the Columbia River Estuary, First Annual Report 2004. Draft submitted to Portland District, U.S. Army Corps of Engineers. Pacific Northwest National Laboratory. PNNL-15102.

Diener, D. Riley, B. Robertson, G. Maurer, D. Gerlinger, T. and I. Haydock. 1997. An Ocean Outfall As an Artificial Reef: Impacts to the Benthic Environment and a Balanced Indigenous Population California and The World Ocean ' 97: taking a look at California s ocean resources: agenda for the future: conference proceedings / edited by Orville T. Magoon et al. March 24- 1997, Town & Country Hotel, San Diego, California

Donaldson, G.M., J.L. Shutt, and P. Hunter. 1999. Organochlorine Contamination in Bald Eagle Eggs and Nestlings from the Canadian Great Lakes. Archives of Environmental Contamination and Toxicology 36: 70-80.

Douzinas, R. 2001. Literature Review on Substances of Potential Concern in Reclaimed Water. The Washington Water Resource. The quarterly report of the Center for Urban Water Resources Management. 12(2):11-14.

Downing, J. 1983. The coast of Puget Sound. Puget Sound Books, Washington Sea Grant, Seattle, WA.

Dumbauld, B.R., K.M. Brooks, M.H. Posey M.H. 2001. Response of an Estuarine Benthic Community to Application of the Pesticide Carbaryl and Cultivation of Pacific oysters (*Crassostrea gigas*) in Willapa Bay, Washington. Marine Pollution Bulletin 42:826–844.

Dunham, J.S. and D.A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia, Canada. Marine Ecology Progress Series 223:299-310.

Eggen, M. 1997. That Sinking Feeling. Do "Artificial Reefs" in BC Waters Increase Biodiversity or Waste? Alternatives 23(1):7.

Eisenhardt, E. 2001. Effect of the San Juan Islands Marine Preserves on Demographic Patterns of Nearshore Rocky Reef Fish. Master of Science thesis. University of Washington. Seattle, WA.

Eiswerth, M. E., S. G. Donaldson, and W. S. Johnson. 2000. Potential Environmental Impacts and Economic Damages of Eurasian watermilfoil (*Myriophyllum spicatum*) in Western Nevada and Northeastern California. Weed Technology 14:511-518.

Elliot, J.E. and R.J. Norstrom. 1998. Chlorinated Hydrocarbon Contaminants and Productivity of Bald Eagle Populations on the Pacific Coast of Canada. Environmental Toxicology and Chemistry 17(6): 1142-1153.

Elliot, J.E., R.J. Norstrom, A. Lorenzen, L. E. Hart, H. Philibert, S.W. Kennedy, J.J. Stegeman, G.D. Bellward, and K.M. Cheng. 1996. Biological Effects of Polychlorinated Dibenzo-*p*-dioxins, Dibenzofurans, and Biphenyls in Bald Eagle (*Haliaeetus leucocephalus*) Chicks. Environmental Toxicology and Chemistry 15(5): 782-793.

Environmental Protection Agency. 2000. Authorization to Discharge Under the National Pollutnat Discharge Elimination System (NPDES) for Log Transfer Facilities in Alaska. Acessed August 10, 2005. http://state.ak.us/local/akpages/ENV.CONSERV/water/wwdp/pdfs/generalpermit_post1985.pdf

Environmental Protection Agency. 2000. Endangered Species Act-Section 7 Biological Opinion. Denny Way/Lake Union CSO Control Project. WSB-00-039.

Environmental Protection Agency. 2005. Combined Sewer Overflows. Guidance for Nine Minimum Controls. Office of Water. EPA 832-B-95-003.

Erbe, C. 2002. Underwater Noise of Whale-Watching Boats and Potential Effects on Killer Whales (*Orcinus orca*), Based on an Acoustic Impact Model. Marine Mammal Science 18: 394-418.

Evink, G.L., P. Garrett, D. Zeigler and J. Berry (eds.). 1996. Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. FL-ER-58-96. State of Florida Department of Transportation. Tallahassee, FL.

EVS Environmental Consultants. 2003. Status, Trends and Effects of Toxic Contaminants in the Puget Sound Environment: Recommendations. Prepared for: Puget Sound Action Team. Olympia, WA. EVS Project No. 02-1090-01.

Exponent. 2004. 2004 Monitoring Report for Sediment Remediation in Ward Cove, Alaska. Prepared for the Ketchikan Pulp Company. Ketchikan, AK.

Fabi, G., F. Luccarini, M. Panfili, C. Solustri, and A. Spagnolo. 2002. Effects of an Artificial Reef on the Surrounding Soft-bottom Community (Central Adriatic Sea). ICES Journal of Marine Sciences 59 Supplement:S343-S349.

Fahrig. L., J.H. Pedlar, S.E. Pope, P.D. Taylor, J.F. Wegner. 1995. Effect of Road Traffic on Amphibian Density. Biological Conservation. 73:177-82.

Fairgrieve, W.T. and M.B. Rust. 2003. Interactions of Atlantic salmon in the Pacific Northwest. V. Human health and safety. Fisheries Research 62:329-338.

Fayer, R., J.P. Dubey, and D.S. Lindsay. 2004. Zoonotic Protozoa: From Land to Sea. Trends in Parasitology 20(11):531-536.

Feldman, K.L., D.A. Armstrong, B.R. Dumbauld, T.H. DeWitt, and D.C. Doty. 2000. Oysters, Crabs, and Burrowing Shrimp: Review of an Environmental Conflict Over Aquatic Resources and Pesticide use in Washington State's (USA) Coastal Estuaries. Estuaries 23(2):141-176.

Ferguson, R.A and Tufts, B. L. 1992. Physiological Effects of Brief Air Exposure in Exhaustively Exercised Rainbow Trout (*Oncorhynchus mykiss*): Implications for 'Catch and Release' Fisheries. Canadian Journal of Fisheries and Aquatic Sciences 49, 1157–1162.

Forman R.T.T., Sperling D, Bissonette JA, et al. 2002. Road Ecology: Science and Solutions. Island Press. Washington, DC:

Forman. R.T.T. and L.E. Alexander. 1998 Roads and their Major Ecological Effects. Annual Review of Ecological Systems. 29:207-231.

Forman. R.T.T. and R.D. Deblinger. 2000. The Ecological Road-effect Zone of a Massachusetts (USA) Suburban Highway. Conservation Biology 14: 36-46.

Foster, K.L., F.W. Steimle, W.C. Muir, R.K. Kropp, and B.E. Conlin. 1994. Mitigation Potential of Habitat Placement: Concrete Artificial Reef in Delaware Bay – Preliminary Results. Bulletin of Marine Science 55(2-3):

Fowle, S.C. 1996. Effects of Roadkill Mortality on the Western Painted Turtle (*Chrysemys picta bellii*). In: Trends in Addressing Transportation Related Wildlife Mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar. G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.). FL-ER-58-96. State of Florida Department of Transportation, Tallahassee, FL.

Franson, J.C., S.P. Hansen, T.E. Creekmore, C.J. Brand, D.C. Evers, A.E. Duerr, and S. DeStefano. 2003. Lead fishing weights and other fishing tackle in selected waterbirds. Waterbirds 26(3):345-352.

Fraser, J.D., L.D. Frenzel, and J.E. Mathisen. 1985. The Impact of Human Activities on Breeding Bald Eagles in North-central Minnesota. Journal of Wildlife Management 49:585-592.

Freitas, C.E. and M.P. Petrere. 2001. Influence of Artificial Reefs on Fish Assemblage of the Barra Bonita Reservoir (Sao Paulo, Brazil). Lakes & Reservoirs: Research and Management 6(4):273-278.

Gaines, W.L., P.H. Singleton, and R.C. Ross. 2003. Assessing the Cumulative Effects of Linear Recreation Routes on Wildlife Habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-586. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, OR

Gallagher, S.P., and M.F. Gard. 1999. Relationship Between Chinook Salmon (*Oncorhynchus tshawytscha)* Redd Densities and PHABSIM-Predicted Habitat in the Merced and Lower American Rivers, California. Canadian Journal of Fisheries and Aquatic Sciences Vol. 56.

Gallgher, S.P., and M.F. Gard. 1999. Relationship Between Chinook Salmon (*Oncorhynchus tshawytscha)* Redd Densities and PHABSIM-Predicted Habitat in the Merced and Lower American Rivers, California. Canadian Journal of Fisheries and Aquatic Sciences Vol. 56.

Gardner, F., editor. 1981. Washington Coastal Areas of Major Biological Significance. Washington State Department of Ecology, Baseline Studies Program. Olympia, WA.

Garrett, M.G., J.W. Watson, and R.G. Anthony. 1993. Bald Eagle Home Range and Habitat Use in the Columbia River Estuary. Journal of Wildlife Management 57(1): 19-27.

Gatto, L. W., and W. W. Doe III. 1987. Bank Conditions and Erosion along Selected Reservoirs. Environmental Geology and Water Sciences 9(3):143-154.

Gatto, L. W., and W. W. Doe III. 1987. Bank conditions and erosion along selected reservoirs. Environmental Geology and Water Sciences 9(3):143-154.

Geist, D.R. and D.D. Dauble. 1998. Redd Site Selection and Spawning Habitat Use by Fall Chinook Salmon: The Importance of Geomorphic Features Of Large Rivers. Environmental Management, 22(5): 655-669.

Georgia Tech Research Corporation. 2005. Capping Primer. Hazardous Substances Research Centers/South and Southwest. Accessed October 18, 2005. http://www.hsrc.org/hsrc/html/ssw/capsummary.pdf.

Gibbs, M.T. 2004. Interactions Between Bivalve Shellfish Farms and Fishery Resources. Aquaculture 240:267-296.

Goodwin, C.L. 1978. Some Effects of Subtidal Geoduck (*Panope generosa*) Harvest on a Small Experimental Plot in Puget Sound, WA. Washington State Department of Fish and Wildlife. Progress Rep. 66. Olympia, WA.

Gregory, R.S. and C.D. Levings. 1998. Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon. Transactions of the American Fisheries Society 127:275-285.

Gregory, S.V. and P.B. Bisson. 1997. Degradation and Loss of Anadromous Salmonid Habitat in the Pacific Northwest. In: Pacific Salmon and their Ecosystems: Status and Future Options. D.J. Stouder, P.B. Bisson, and R.J. Naiman (eds), Chapman and Hall, New York, NY.

Griffin, K. 1997. Commercial Oyster Cultivation and Eelgrass Ecology in Tillamook Bay, Oregon. A literature and synthesis for the Tillamook Bay National Estuary Project. Accessed October 25, 2005.

http://gisweb.co.tillamook.or.us/library/reports/CommercialOysterCultivationandEelgrass.pdf

Guichard, F., Bourget, E. & Robert, J.-L. 2001. Scaling the Influence of Topographic Heterogeneity on Intertidal Benthic Communities: Alternate Trajectories Mediated by Hydrodynamics and Shading. Marine Ecology Progress Series 217: 27-41.

Haas, M.E., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. Effects of Large Overwater Structures on Epibenthic Juvenile Salmon Prey Assemblages in Puget Sound, Washington. Prepared for Washington State Department of Transportation. University of Washington, School of Aquatic Fishery and Science. Accessed October 24, 2005. http://depts.washington.edu/trac/bulkdisk/pdf/550.1.pdf.

Haldane, C. P., M. A. Paul, R. L. Reuben and J. C. Side. 1992. Submarine Pipelines and the North Sea Environment. In: North Sea oil and the Environment. Cairns, W. J. (ed.). Elsevier Applied Science: 481–485.

Hamel, K. S. and J. K. Parsons. 2001. Washington's Aquatic Plant Quarantine. Journal of Aquatic Plant Management, 39: 72-75.

Hanson, J., M. Helvey, and R. Strach (editors). 2003. Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures. NOAA Fisheries, Southwest Region. Long Beach, CA.

Hartman G. F., J. C. Scrivener, M. J. Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implication for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 53:237–251 (Supplement 1).

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman, and M. K. Young. 1993. A Hierarchical Approach to Classifying Stream Habitat Features. Fisheries 18:(6)3–12.

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman, and M. K. Young. 1993. A Hierarchical Approach to Classifying Stream Habitat Features. Fisheries 18:(6)3–12.Hays, D.W., K.R. McAllister, S.A. Richardson, and D.W. Stinson. 1999. Washington State Recovery Plan for the Western Pond Turtle. Washington Department of Fish and Wildlife. Olympia, WA.

Hays, D.W., K.R. McAllister, S.A. Richardson, and D.W. Stinson. 1999. Washington State Recovery Plan for the Western Pond Turtle. Washington Department of Fish and Wildlife. Olympia, WA.

Hayteas, D.L. and D.A. Duffield. 2000. High Levels of PCB and *p,p'*-DDE Found in the Blubber of Killer Whales (*Orcinus orca*). Marine Pollution Bulletin 40(6): 558-561.

Heede, B.H. and J.N. Rinne. 1990. Hydrodynamic and Fluvial Morphologic Processes: Implications for Fisheries Management and Research. North American Journal of Fisheries Management. 10(3):249-268.

Heffernan, M. L. (1999) A review of the ecological implications of mariculture and intertidal harvesting in Ireland. Irish Wildlife Manuals, No. 7. Accessed October 25,

2005.
http://www.npws.ie/en/PublicationsLiterature/Allpublications/d6683.en.v1.0.t4.PDF

Hendricks, P. 2000. Harlequin Duck Research and Monitoring in Montana: 1999. Montana Natural Heritage Program. Helena, MT.

Henning, J. 2004. An Evaluation of Fish and Amphibian Use of Restored and Natural Floodplain Wetlands. Final Report EPA Grant CD-97024901-1. Washington Department of Fish and Wildlife. Olympia, WA.

Hickey, G. M. 1979. Survival of Fish Larvae After Injury. Journal of Experimental Marine Biology and Ecology, 37:1–7.

Hilton, J. and G. L. Phillips. 1982. The effect of boat activity on turbidity in a shallow broadland river. Applied Ecology 19:143-150.

Ho Ahn, J., S.B. Grant, C.Q. Surbeck, P.M. Digiacomo, N.P. Nezlin, and S. Jiang. 2005. Coastal Water Quality Impact of Stormwater Runoff from an Urban Watershed in Southern California. Environmental Science and Technology 39:5940-5953.

Horner, R. R., Booth, D. B., Azous, A. A., and May, C. W. 1996. Watershed Determinants of Ecosystem Functioning. In: Effects of Watershed Development and Management on Aquatic Ecosystems. L.A. Roesner (Editor). Engineering Foundation Conference, Proceedings, Snowbird, Utah, August 4-9, 1996, p. 251-274.

Hornig, S., A. Sterling, and S.D. Smith. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--ghost shrimp and blue mud shrimp. U.S. Fish and Wildlife Service Biol. Rep. 82(11.93). U.S. Army Corps of Engineers, TR EL-82-4.

Houghton, J.P. and L. Uhlig. 2004. A Tidal Habitat Restoration Success Story – the Union Slough Restoration Project. Proceedings 2003 Georgia Basin/Puget Sound Research Conference.

Huang, Y-w, D.L. Twidwell, and J. C. Elrod. 2003. Occurrence and effects of endocrine distrupting chemicals in the environment. Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 7(4):241-252.

Hueckel, G.J. and R. Buckley. 1982. Site Selection Procedures for Marine Habitat Enhancement in Puget Sound, Washington. Washington Department of Fisheries Technical Report 67. Olympia, WA.

Hunter, M.A. 1992. Hydropower Flow Fluctuations and Salmonids: A Review of the Biological Effects, Mechanical Causes, and Options for Mitigation. Washington State Department of Fisheries. Technical Report Number 119. Olympia, WA.

Hunter, M.A. 1992. Hydropower Flow Fluctuations and Salmonids: A Review of the Biological Effects, Mechanical Causes, and Options for Mitigation. Washington State Department of Fisheries. Technical Report Number 119. Olympia, WA.

Hurst, C. K., and A. Brebner. 1969. Shore erosion and protection, St. Lawrence River - Canada. XXII International Navigation Congress, Sec.1, Subj. 6, PP 45-56.

Jackson, R.G. 1986. Effects of Bark Accumulation on Benthic Infauna at a Log Transfer Facility in Southeast Alaska. Marine Pollution Bulletin, 17(6):258-262.

Jackson, S.D. 2000. Overview of Transportation Impacts on Wildlife Movement and Populations. In: Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. Messmer, T.A. and B. West, (eds). The Wildlife Society. Bethesda, MD

Jennings, M.T., M.A. Bozek, G.R. Hatzenbeler, E.E. Emmons, and M.D. Staggs. 1999. Cumulative Effects of Incremental Shoreline Habitat Modification on Fish Assemblages in North Temperate Lakes. North American Journal of Fisheries Management 19:18-27.

Johnson, C.S. 2002. Parasite in Cats Killing Sea Otters. NOAA Research Archive of Spotlight Feature Articles. Accessed November 15, 2005. http://www.oar.noaa.gov/spotlite/archive/spot_otter.html.

Jones, A.T. and R.W. Welsford. 1997. Artificial Reefs in British Columbia, Canada. Artificial Reef Society of British Columbia. Accessed October 16, 2005. http://www.artificialreef.bc.ca/Resources/tjones.html.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. In: Proceedings of the International Large River Symposium. D.P. Dodge (ed). Canadian Special Publication of Fisheries and Aquatic Sciences, 106: 110-127.

Kahl, R. 1991. Boating disturbance of canvasbacks during migration at Lake Poygan, WI. Wildlife Society Bull. 19(3):242-248.

Kerwin, J., 2001. Salmon and Steelhead Habitat Limiting Factors. Report for the Cedar – Sammamish Basin (Water Resource Inventory Area 8). Washington Conservation Commission. Olympia, WA.

Kilgore, K. J., S. T. Maynord, M. D. Chan, and R. P. Morgan II. 2001. Evaluation of Propeller-induced Mortality on Early Life Stages of Selected Fish Species. North American Journal of Fisheries Management 21:947–955.

King County Department of Parks and Natural Resources. 2003. Brightwater Final Environmental Impact Statement. Accessed October 21, 2005. http://dnr.metrokc.gov/wtd/brightwater/env/feis.htm.

King County Department of Parks and Natural Resources. 2004a. Endocrine Disrupting Chemicals in the Environment. Wastewater Treatment Division. Accessed November 15, 2005. http://dnr.metrokc.gov/WTD/community/edc/index.htm - 1.

King County Department of Parks and Natural Resources. 2004b. 2003/2004 Annual Combined Sewer Overflow Report. Accessed October 20, 2005. http://dnr.metrokc.gov/wtd/cso/index.htm#why.

King County Department of Parks and Natural Resources. 2005a. Industrial Waste Program Internet site. Accessed October 20, 2005. http://dnr.metrokc.gov/wlr/indwaste/.

King County Department of Parks and Natural Resources. 2005b. Stormwater Pollution Prevention Manual. Best Management Practices for Business and Residential Properties. Accessed October 20, 2005. http://dnr.metrokc.gov/wlr/dss/sppm.htm.

Kirkpatrick, B., T.C. Shirley, and C.E. O'Clair. 1998. Deep-Water Bark Accumulation and Benthos Richness and Log Transfer and Storage Facilities. Alaska Fishery Research Bulletin. Vol. 5 No. 2, Winter 1998.

Klein, M.L., S.R. Humphrey, and H.F. Percival. 1995. Effects of ecotourism on distribution of waterbirds in a wildlife refuge. Conservation Biology 9(6):1454-1465.

Komar, P.D. 1997. The Pacific Northwest Coast. Duke University Press. Durham, NC.

Kondolf, G.M., M. Smeltzer, and L. Kimball. 2002 . Freshwater Gravel Mining and Dredging Issues. Prepared for the Washington Departments of Fish and Wildlife, Ecology and Transportation. Olympia, WA.

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status Review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act. NOAA Tech. Memo. NMFSNWFSC-62. U.S. Department of Commerce.

Kropp, R.K. 2004. Review of Deep-sea Ecology and Monitoring as they Relate to Deep-sea Oil and Gas Operations. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RL01830. Battelle Marine Sciences Laboratory. Sequim, WA.

Lafferty K.D. 2001. Disturbance to wintering western snowy plovers. Biological Conservation. 101 (2001) 315-325.

Langston, W.J., G.R. Burt, B.S. Chesman, and C.H. Vane. 2005. Partioning, Bioavailability and Effects of Oestrogens and Xeno-oestrogens in the Aquatic Environment. Journal of the Marine Biological Association of the United Kingdom 85:1-31.

Lee, J. H., Bang, K.W., Ketchum, L.H., Choe, J.S., and Yu, M.J. 2002. First Flush Analysis of Urban Storm Runoff. The Science of the Total Environment. 293(1-3):163-175.

Lefcort, H., K.A. Hancock, K.M. Maur and D.C. Rostal. 1997. The effects of used motor oil, silt, and the water mold Saprolegnia parasitica on the growth and survival of mole salamanders (genus *Ambystoma*). Archives of Environmental Contamination and Toxicology 32(4):383-8.

Lequerrier, D., N. Niquil, A. Petiau, and A. Bodoy. 2004. Modeling the impact of oyster culture on a mudflat food web in Marennes-Oleron Bay (France). Marine Ecology Progress Series 273:147-162.

Lewis, J.C. and D. Kraege. 2004. Harlequin Duck (*Histrionicus histrionicus*). In: Management Recommendations for Washington's Priority Species, Volume IV: Birds. E.M. Larsen, J.M. Azerrad, and N. Nordstrom, editors. Accessed June 10, 2005: http://wdfw.wa.gov/hab/phs/vol4/harlduck.htm.

Lewis, L. J., J. Davenport, and T. C. Kelly. 2002. A Study of the Impact of a Pipeline Construction on Estuarine Benthic Invertebrate Communities. Estuarine, Coastal and Shelf Science 55:213–221.

Li, K. 2005. The Lake Washington Story, King County, Washington. Natural Resources and Parks, Water and Land Resources Division. Accessed November 15, 2005. http://dnr.metrokc.gov/wlr/waterres/lakes/Biolake.htm.

Liebezeit, J.R. and T.L. George. 2002. A Summary of Predation by Corvids on Threatened and Endangered Species in California and Management Recommendations to Reduce Corvid Predation. Calif. Dept. Fish and Game, Species Conservation and Recovery Program Rpt. 2002-02, Sacramento, CA.

Lintelmann, J., A. Katayama, N. Kurihara, L. Shore, and A. Wenzel. 2003. Endocrine Disruptors in the Environment. Pure and Applied Chemistry 75(5):631-681.

Lisle, T.E. 1989. Sediment Transport and Resulting Deposition in Spawning Gravels, North Coastal California. Water Resources Research, 25(6):1303-1319.

Lomax, D. 2003. Further Survey Results on Xenoestrogen Exposure of Benthic Fish in Puget Sound. Proceedings 2003 Georgia Basin/Puget Sound Research Conference. Olympia, WA.

Lonzarich, D.G., M.R. Lonzarich, and M.L. Warren, Jr. 2000. Effects of Riffle Length on the Short-term Movement of Fishes Among Stream Pools. Canadian Journal of Fisheries and Aquatic Sciences 57:1508-1514.

Lonzarich, D.G., M.R. Lonzarich, and M.L. Warren, Jr. 2000. Effects of Riffle Length on the Short-term Movement of Fishes Among Stream Pools. Canadian Journal of Fisheries and Aquatic Sciences 57:1508-1514.

Love, M.S. and A. York. 2005. A Comparison of the Fish Assemblages Associated with an Oil/gas Pipeline and Adjacent Seafloor in the Santa Barbara Channel, Southern California Bight. Bulletin of Marine Science, 77(1)101–117.

Luce C.H. and T.A. Black. 1999. Sediment Production from Forest Roads in Western Oregon. Water Resources Research. 35:8 2561–2570.

Macdonald, K., D. Simpson, B. Paulsen, J. Cox, and J. Gendron. 1994. Shoreline Armoring Effects on Physical Coastal Processes in Puget Sound, Washington. Coastal Erosion Management Studies Volume 5. Washington State Department of Ecology, Shorelands and Environmental Assistance Program. Olympia, WA.

Mason, C., W. Grogg, and S. Wheeler. 1983. Shoreline erosion study Pleasure Island, Texas. U.S. Army Corps of Engineers, Galveston, TX.

Matthiessen, P. 2003. Topic 4.5. Endocrine Disruption in Marine Fish. Pure and Applied Chemistry 75(11-12):2249-2261.

McAllister, K.R. and H.Q. White. 2001. Oviposition Ecology of the Oregon Spotted Frog at Beaver Creek, Washington. Final Report. Washington Department of Fish and Wildlife Olympia, WA.

McGarigal, K., R.G. Anthony, and F.B. Isaacs. 1991. Interactions of Humans and Bald Eagles on the Columbia River, Washington and Oregon USA, Estuary. Wildlife Monographs 115: 5-47.

McMichael, G.A., C.L. Rakowski, B.B. James, and J.A. Lukas. 2005. Estimated Fall Chinook Survival to Emergence in Dewatered Redds in a Shallow Side Channel of the Columbia River. North American Journal of Fisheries Management 25:876-884.

McMichael, G.A., J.A. Vucelick, C.S. Abernethy, and D.A. Neitzel. 2004. Comparing Fish Screen Performance to Physical Design Criteria. Fisheries 29(7):10-16.

McNeil, W.J. 2001. Intertidal and Estuarine Habitat Preferences by Under Yearling Chum and Chinook Salmon with Emphasis on Tillamook Bay Populations. Report prepared for the Flood Mitigation Group. Tillamook, OR.

Miller, B.S., B.B. McCain, R. C. Wingert, S.F. Borton, and K.V. Pierce. 1976. Ecological and Disease Studies of Demersal Fishes Near METRO Operated Sewage Treatment Plants on Puget Sound and the Duwamish River. Municipality of Metropolitan Seattle Puget Sound Interim Studies. FRI-UW-760B. University of Washington, Fisheries Research Institute. Seattle, WA.

Miller, J.R., and N.T. Hobbs. 2000. Recreational trails, human activity, and nest predation in lowland riparian areas. Landscape and Urban Planning. 50(4):227-236.

Miller, A.I., T.D. Counihan, M.J. Parsley, and L.G. Beckman. 2005. Columbia River Basin White Sturgeon. In: Our Living Resources - A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of the Interior, National Biological Service. Available at: http://biology.usgs.gov/s+t/noframe/e065.htm

Montgomery, D. R., and J. M. Buffington. 1998. Channel Processes, Classification, and Response Potential, in River Ecology and Management, edited by R. J. Naiman, and R. E. Bilby. Springer-Verlag Inc., New York, NY

Moore, P. G. 1978. Inorganic Particulate Suspensions in the Sea and their Effects on Marine Animals. Oceanography and Marine Biology Annual Review 15:225–363.

Morgan, R. P. II, R. E. Ulanowicz, V. J. Rasin, Jr., A. Noe, and G. B. Gray. 1976. Effects of Shear on Eggs and Larvae of Striped Bass *Morone saxatilis* and White Perch *M. americana*. Transactions of the American Fisheries Society 105:149–154.

Morton, A. B. and H. K. Symonds. 2002. Displacement of *Orcinus orca* (L.) by amplitude sound in British Columbia, Canada. ICES Journal of Marine Science.

Moyle, P.B. and J.A. Israel. 2005. Untested Assumptions: Effectiveness of Screening Diversions for Conservation of Fish Populations. Fisheries 30(5):20-28.

Muoneke M. I., W. M. Childress. 1994. Hooking mortality: a review for recreational fisheries. Reviews in Fisheries Science. 2:123–156.

Naiman, R.J., E.V. Balian, K.K. Bartz, R.E. Bilby, and J.J. Latrell. 2002. Dead Wood Dynamics in Stream Ecosystems. Pacific Southwest Research Station. USDA Forest Service General Technical Report. PSW-GTR-181.

Nair, S., V. Clark, and S. Milne. 2004. Making Waves: Artificial Reefs and Urban Open Space Management in New Zealand. New Zealand Tourism Research Institute, Auckland University of Technology. Aukland, New Zealand.

Nash, C.E. 2003. Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty. Fisheries Research 62:339-347.

Nash, C.E. and F.W. Waknitz. 2003. Interactions of Atlantic salmon in the Pacific Northwest. 1. Salmon enhancement and the net-pen farming industry. Fisheries Research 62:237-254.

Nash, R. F., G. G. Gallup, Jr., and M. K. McClure. 1970. The immobility reaction in leopard frogs (*Rana pipiens*) as a function of noise induced fear. Psychonometric Science 21(3):155-156.

National Marine Fisheries Service. 1994. Position Statement on Experimental Fish Guidance Devices. Southwest Region. Longbeach, CA.

NCDEM. 1991. Coastal Marinas: Field Survey of Contaminants and Literature Review. Report No. 91-03. North Carolina division of Environmental Management, Raleigh, NC.

Neff, J.M. 1979. Polycyclic Aromatic Hydrocarbons in the Aquatic Environment; Sources, Fates and Biological Effects. Applied Science Publishers LTD. London, UK.

Nelson, S. K. and T. H. Hamer. 1995. Nest Success and the Effects of Predation on Marbled Murrelets. In: Ecology and Conservation of the Marbled Murrelet. C. J. Ralph, G. L. Hunt, M. G. Raphael and J. F. Piatt, Eds.. General Technical Report PSW-GTR-152. U.S. Forest Service. Albany, CA.

Newcomb, C.P., and Jensen, J.O. 1996. Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. North American Journal of Fisheries Management 16:693-727.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. North American Journal of Fisheries Management 11:72-82.

Nichols, M., R.J. Diaz and L.C. Schaffner. 1990. Effects of Hopper Dredging and Sediment Dispersion, Chesapeake Bay Environmental Geology (Historical Archive) Volume 15, Number 1 Pages: 31 – 43

Nightingale, B. and C. Simenstad. 2001. Overwater structures: Marine issues. White Paper submitted to Washington State Departments of Fish and Wildlife, Ecology, and Transportation. Accessed October 24, 2005. http://wdfw.wa.gov/hab/ahg/overwatr.htm.

NOAA National Marine Fisheries Service. 2002. Biological Opinion. Columbia River Federal Navigation Channel Improvements Project. OHB1999-0270-RI.

Nobriga, M.L., Z. Matica, and Z.P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparision among Open-Water Fishes. American Fisheries Society Symposium 29:281-295.

Northwest Fisheries Science Center. 2001. Juvenile Salmon Health. Northwest Fisheries Science Center Issue Paper NWFSC Issue Paper EC 6505 (HQ ID 297/312). Accessed November 22, 2005.
http://www.nwfsc.noaa.gov/publications/issuepapers/pdfs/ec6505.pdf.

Northwest Fisheries Science Center. 2001. Marine Fish Health. Northwest Fisheries Science Center Issue Paper NWFSC Issue Paper EC 6501 (HQ ID 277). Accessed

November 15, 2005. http://www.nwfsc.noaa.gov/publications/issuepapers/pdfs/ec6501.pdf.

Nudds R.L. and D.M. Bryant. 2000. The energetic cost of short flights in birds. Journal of Experimental Biology 203: 1561–1572.

Olivieri, V.P., C.W. Kruse, K. Kawata, and J.E. Smith. 1977. Microorganisms in Urban Stormwater. EPA-600/2-77-087.

Pacific Coast Shellfish Growers Association. 2001. Environmental Policy. Olympia, WA

Page, G.W., Stenzel, L.E., 1981. The breeding status of the snowy plover in California. Western Birds 12(1):1–40.

Palermo, M.R., T.A. Thompson, and F. Swed. 2002. White paper no. 6b – In-situ Capping as a Remedy Component for the Lower Fox River. Accessed October 18, 2005. http://www.aehs.com/journals/humanandecojournal/teachingtool/wisconsin/RS%20White%20Paper%20No%206B.pdf.

Palsson, W.A. 2001. Marine Refuges Offer Haven for Puget Sound fish. Washington State Department of Fish and Wildlife. Accessed October 17, 2005. http://wdfw.wa.gov/science/articles/marine_sanctuary/index.html.

Pantell, S.E. 1993. Seawater Desalination in California. California Coastal Commission. Accessed October 20, 2005. http://www.coastal.ca.gov/desalrpt/dtitle.html.

Parsons K.C. and J. Burger. 1982. Human disturbance and nestling behavior in night herons. Condor. 84:184-187

Pauley G. B., G. L. Thomas. 1993. Mortality of anadromous coastal cutthroat trout caught with artificial lures and natural bait. North American Journal of Fisheries Management. 13:337–345.

Pearl, C.A. and M.P. Hayes. 2004. Habitat Aassociations of the Oregon Spotted Frog (*Rana pretiosa*): A Literature Review. Final Report. Washington State Department of Fish and Wildlife. Olympia, WA.

Pease, B.C. 1974. Effects of Log Dumping and Rafting on the Marine Environment of Southeast Alaska. USDA Forest Service General Technical Report PNW-22.

Pentec Environmental. 2000. Hylebos Waterway Wood Debris Program Operation, Maintenance and Monitoring Plan. Edmonds, WA.

Poff, N.L. and D.D. Hart. 2002. How Dams Vary and Why it Matters for the Emerging Science of Dam Removal. BioScience Vol. 52 No. 8.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime. A Paradigm for River Conservation and Restoration. BioScience 47(11):769-784.

Poole, G.C., and C.H. Berman. 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. Environmental Management 27(6):787-802.

Pope. S.E., L.Fahrig, H.G. Merriam. 2000. Landscape Complementation and Metapopulation Effects on Leopard Frog Populations. Ecology, 81(9):2498-2508.

Posey, M.H. 1986a. Predation on a burrowing shrimp: distribution and community consequences. Journal of Experimental Marine Biology and Ecology 103:143-161.

Posey, M.H. 1986b. Changes in a benthic community associated with dense beds of a burrowing deposit feeder, *Callianassa californiensis*. Marine Ecology Progress Series 31: 15-22.

Poston, T. 2001. Treated Wood Issues Associated with Overwater Structures in Marine and Freshwater Environments. White Paper submitted to Washington State Departments of Fish and Wildlife, Ecology, and Transportation. Accessed October 24, 2005. http://wdfw.wa.gov/hab/ahg/overwatr.htm.

Powell, A.N., J.M. Terp, C.L. Collier, and B.L. Peterson. 1995. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1995. Report to the California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Carlsbad, CA, and Portland, OR. 24 pp.

Power, E.A. and T.G. Northcote. 1991. Effects of Log Storage on the Food Supply and Diet of Juvenile Sockeye Salmon. North American Journal of Fisheries Management. 11:413-423.

Powers, P.D. and J.F. Orsborn. 1985. Analysis of Barriers to Upstream Fish Migration. Part 4 of 4. An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. Report to Bonneville Power Administration. Washington State University, Albrook Hydraulics Laboratory. Pullman, WA.

Puget Sound Action Team. 2005. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. March 29 to 31, 2005. Seattle, Washington. Puget Sound Action Team Olympia, WA. Accessed October 26, 2005. http://www.psat.wa.gov/Publications/05_proceedings/

Puget Sound Action Team. 2005. Shared Waters: The Vulnerable Inland Sea of British Columbia and Washington. Accessed November 29, 2005. http://www.psat.wa.gov/shared/bcwaswl.html#habitat_loss.

Puttick, G.M. 1979. Foraging behaviour and activity budgets of Curlew Sandpipers. Ardea 67, 111–122.

Raphael, M.G., D.E. Mack, J. M. Marzluff and J. M. Luginbuhl. 2002. Effects of Forest Fragmentation on Populations of the Marbled Murrelet. Studies in Avian Biology, 25 (1):221–235.

Redding J. M., C. B. Schreck, G. H. Everest. 1987. Physiological effects on coho salmon and steelheads of exposure to suspended solids. Transactions of the American Fisheries Society. 116:737–744.

Reese D.A. and H.H. Welsh. 1997. Use of Terrestrial Habitat by Western Pond Turtles, *Clemmys marmorate*: Implications for Management. pp 352-357 *in* J. Van Abbema, editor. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles--an International Conference. State University of New York, Purchase, New York

Reese, D.A. 1996. Comparitive Demography and Habitat Use of Western Pond Turtles in Northern California: The Effects of Damming and Related Alterations. PhD dissertation. University of California at Berkeley. Berkeley, CA.

Reh, W. and A. Seitz. 1990. The Influence of Land Use on the Genetic Structure of Populations of the Common Frog *Rana temporaria*. Biological Conservation 54:239-249.

Reid, R. and K. Holland. 1997. The Land By the Lakes. Nearshore Terrestrial Ecosystems. State of the Lakes Ecosystem Conference 1996. Background Paper. EPA 905-R-97-015c.

Reijnen, R., T Foppen, C. Ter Braak and J. Thissen. 1995. The Effects of Car Traffic on Breeding Bird Populations in Woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology. 32: (1)187-202.

Reijnen. R. and R. Foppen. 1997 Disturbance by Traffic of Breeding Birds: Evaluation of the Effect and Considerations in Planning and Managing Road Corridors. Biodiversity and Conservation. 6:567-581.

Rezai, H., H.M. Ibrahim, B.A.G. Idris and M.R.M. Kushairi. 1999. Some Effects of Submarine Pipeline Construction on the Sessile Zoobenthic Community of Redang Island. Hydrobiologia 405:163–167.

Richards, D.C. 2002. The New Zealand Mud Snail Invades. Aquatic Nuisance Species Digest. 4(4):42-44.

Richardson, W. J., Greene, C. R. Jr, Malme, C. I., and Thomson, D. H. 1995. Marine mammals and noise. Academic Press, San Diego, CA..

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. Conservation Biology, 10(4):1163-1174.

Robertson, G.J. and R.I. Goudie. 1999. Harlequin Duck (*Histrionicus histrionicus).* In: The Birds of North America, No. 466. A. Poole and F. Gill, editors. The Birds of North America, Inc., Philadelphia, PA..

Rodgers, J., Jr. and S. Schwikert. 2002. Buffer-zone distances to protect foraging and loafing waterbirds from disturbance by personal watercraft and outboard- powered boats. Conservation Biology 16(1):216-224.

Rodgers, J.A., and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9:89-99.

Rodrıguez-Prieto, I., Fernandez-Juricic, E., 2005. Effects of direct human disturbance on the endemic Iberian frog Rana iberica at individual and population levels. Biological Conservation 123:1–9.

Rondorf, D.W., G.A. Gray, and R.B. Fairley. 1990. Feeding Ecology of Subyearling Chinook Salmon in Riverine and Reservoir Habitats of the Columbia River. Transaction of the American Fisheries Society 119:16-24.

Ross, P.S., G.M. Ellis, M.G. Ikonomou, L.G. Barrett-Lennard, and R.F. Addison. 2000. High PCB Concentrations in Free-Ranging Pacific Killer Whales, *Orcinus orca*: Effects of Age, Sex and Dietary preference. Marine Pollution Bulletin 40(6): 504-515.

Rothaus, D.P. Fish and Wildlife Biologist. Washington State Department of Fish and Wildlife, Fish Program. Personal Communication: December 21, 2004.

Rowe, C.L. and W.A. Dunson. 1995. Impacts of Hydroperiod on Growth and Survival of Larval Amphibians in Temporary Ponds of Central Pennsylvania, USA. Oecologia 102:397-403.

Rowe, C.L. and W.A. Dunson. 1995. Impacts of hydroperiod on growth and survival of larval amphibians in temporary ponds of Central Pennsylvania, USA. Oecologia. 102:397-403.

SanClements, M.D. 2003. Effects of Shading by Bridges on Estuarine Wetlands. Masters Thesis. North Carolina State University. Raleigh, NC.

Sandercock, F.K. 1991. Life History of Coho Salmon (*Oncorhynchus kisutch*). In Pacific Salmon Life Histories. Edited by C. Groot and L. Margolis. University of British Columbia Press. Vancouver, BC, Canada.

Schevill, W.E. 1968. Quiet Power Whaleboat. Journal of the Acoustical Society of America, 44(4):1157-1158.

Schlosser, I.J. 1991. Stream Fish Ecology: A Landscape Perspective. BioScience. 41(10):704-712.

Schoelhamer, D. H. 1996. Anthropogenic Sediment Resuspension Mechanisms in a Shallow Microtidal Estuary. Estuarine Coastal and Shelf Science, 43:533–548.

Schrieber R. W. 1979 Reproductive performance of the Eastern Brown Pelican Pelecanus ccidentalis. Natural History Museum Los Angeles County Contrib. Science 3(17): l-43

Sedell, J.R., F.N. Leone, and W.S. Duval. 1991. Water Transportation and Storage of Logs. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication. 19:325-368

Seliskar, D.M., and J.L. Gallagher. 1983. The Ecology of Tidal Marshes of the Pacific Northwest Coast: A Community Profile. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C. FWS/OBS-82/32.

Semlitsch, R D. 2000. Principles for Management of Aquatic-breeding Amphibians. Journal of Wildlife Management, 64(3):615-631.

Shafer, M.L. 1981. Minimum Population Sizes for Species Conservation. BioScience 31(2):131-134.

Shelter, D. S., and L. N. Allison. 1955. Comparison of mortality between fly-hooked and worm-hooked trout in Michigan streams. Michigan Department of Conservation, Institute of Fish Research Miscellaneous Publication 9. Ann Arbor, MI.

Short, K. S. and R. Walton. 1992 The transport and fate of suspended sediment plumes associated with commercial geoduck harvesting - final report. Washington State Department of Natural Resources. Olympia, WA.

Shreffler, D.K., C.A. Simenstad, and R.M. Thom. 1990. Temporary Residence of Juvenile Salmon in a Restored Estuarine Wetland. Canadian Journal of Fisheries and Aquatic Sciences 47(11):2079-2084.

Shreffler, D.K., R.M. Thom, M.J. Scott, K.F. Wellman, M.A. Walters, and M. Curran. 1995. National Review of Non-corps Environmental Restoration Projects. IWR Report 95-R-12. U.S. Army Corps of Engineers, Institute for Water Resources. Vicksburg, VA.

Simenstad, C.A. 1984. The Ecology of Estuarine Channels of the Pacific Northwest Coast: A Community Profile. U.S. Fish Wildl. Serv. FWS/OBS-83/05. 181 pp.

Simenstad, C.A. 2000. Commencement Bay Aquatic Ecosystem Assessment. Ecosystem-Scale Restoration for Juvenile Salmon Recovery. School of Fisheries. University of Washington. Seattle, WA.

Simenstad, C.A. and K.L. Fresh. 1995. Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries: scales of disturbance. Estuaries 18(1A):43-70.

Simenstad, C.A., B.E. Feist, J. Morlan, and P.B. Williams. 1999. Assessment of Potential Dike-breach Restoration of Estuarine Wetlands in Tillamook Bay, Oregon. Report prepared for the Tillamook Bay National Estuary Project. Garibaldi, OR.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of Ferry Terminals on Juvenile Salmon Migration Along Puget Sound Shorelines, Phase I: Synthesis of State of Knowledge. Prepared for Washington State Department of Transportation Commission. Accessed October 24, 2005. http://depts.washington.edu/trac/bulkdisk/pdf/472.1.pdf.

Smith, J.J., and H.W. Li. 1983. Energetic factors influencing foraging tactics of juvenile steelhead trout, *Salmo gairdneri*. In: Predators and prey in fishes. D.L.G. Noakes, D.G. Lindquist, G.S. Hellfman, and J.A. Ward, editors. Dr. W. Junk, The Hague, Netherlands

Soule M.E. (ed). 1987. Viable Populations for Conservation. Cambridge University Press. Cambridge, UK.

Stalmaster, M. V. 1987. The Bald Eagle. Universe Books. New York, NY.

Stalmaster, M. V., and J. L. Kaiser. 1998. Effects of recreational activity on wintering bald eagles. Wildlife Monographs; No. 137.

Stanford, J.A. and J.V. Ward. 1993. An Ecosystem Perspective of Alluvial Rivers: Connectivity and the Hyporheic Corridor. Journal of the North American Benthological Society, 12(1): 48-60.

Stenton-Dozey, J., T. Probyn, and A. Busby. 2001. Impact of mussel (*Mytilus galloprovincialis*) raftculture on benthic macrofauna, in situ oxygen uptake, and nutrient fluxes in Saldanha Bay, South Africa. Canadian Journal of Fisheries and Aquatic Science 58:1021-1031.

Stern, M.A., K.A. Kristensen, and J.F. Morawski. 1990. Investigations of Snowy Plovers at Abert Lake, Lake County, Oregon. The Nature Conservancy, Portland, OR.

Stinson, D. W., J. W. Watson, and K. R. McAllister. 2001. Washington State status report for the bald eagle. Washington Dept. Fish and Wildlife, Olympia, WA.

Stonick, C. 1999. Screening survey of carbaryl (Sevin™) and 1-naphthol concentrations in Willapa Bay sediments. Washington Department of Ecology Watershed Ecology Section Publication number 99-323..

Struck S.D., C.B. Craft, S.W. Broome, M.D. Sanclements and J.N. Sacco. 2004. Effects of Bridge Shading on Estuarine Marsh Benthic Invertebrate Community Structure and Function. Environmental Management 34:1:99-111.

Sutherland, A.J., and D.G. Ogle. 1975. Effect of jet boats on salmon eggs. New Zealand Journal or Marine and Freshwater Research 9(3):273-282.

Taebi, A. and R. L. Droste. 2004. First Flush Pollution Load of Urban Stormwater Runoff. Journal of Environmental Engineering 3(4):301-309.

Thom, R.M. and R.G. Albright. 1983. Benthic Intertidal Biota Near Nichols Brothers Boat Ramp, Holmes Habor, Washington. Report prepared for the Nichols Brothers Boat Builders. Freeland, WA.

Thom, R.M. G.W. Williams, and H.L. Diefenderfer. 2005. Balancing the Need to Develop Coastal Areas with the Desire for an Ecologically Functioning Coastal Environment: Is Net Ecosystem Improvement Possible? Restoration Ecology 13:193-203.

Thom, R.M., D.K. Shreffler, and K. Macdonald. 1994. Shoreline Armoring Effects on Coastal Ecology and Biological Resources in Puget Sound, Washington. Coastal Erosion Management Studies Volume 7. Washington State Department of Ecology, Shorelands and Environmental Assistance Program. Olympia, WA..

Thom, R.M., L.D. Antrim, A.B. Borde, W.W. Gardiner, D.K. Shreffler, P.G. Farley, J.G. Norris, S. Wyllie Echeverria, and T.P. McKenzie. 1998. Puget Sound's Eelgrass Meadows: Factors Contributing to Depth Distribution and Spatial Patchiness. Puget Sound Research Conference. March 12-13, 1998. Puget Sound Action Team. Seattle, WA.

Toft, J., C. Simenstad, J. Cordell, L Stamatiou. 2004. Fish Distribution, Abundance, and Behavior at Nearshore Habitats along City of Seattle Marine Shorelines, with an Emphasis on Juvenile Salmonids. University of Washington, Wetland Ecosystem Team. Seattle, WA.

Trombulak, S.C. and C.A. Frisell. 2000 Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14(1):18-30.

U. S. Army Corps of Engineers. 1994. Cumulative impacts of recreational boating on the Fox River - Chain O' Lakes area in Lake and McHenry Counties, Illinois: Final Environmental Impact Statement. Environ. and Social Anal. Branch, U.S. Army Corps of Eng., Chicago, IL.

U. S. Department of Agriculture Forest Service. 2002. Draft Environmental Impact Statement by Cross-Country Off-Highway Vehicles. Federal Register: September 26, 2002 (Volume 67, Number 187).

U.S. Army Corps of Engineers. 1983. Dredging and Dredged Material Disposal. Engineering and Design. EM 1110-2-5025.

U.S. Army Corps of Engineers. 1989. Environmental Engineering for Coastal Protection. Engineering and Design. EM 1110-2-1204. U.S. Army Corps of Engineers. Washington, DC.

U.S. Army Corps of Engineers. 1995. Design of Coastal Revetments, Seawalls, and Bulkheads. Engineering and Design. EM 1110-2-1614. U.S. Army Corps of Engineers. Washington, DC.

U.S. Army Corps of Engineers. 2005. Regional General Permits. Accessed September 13. http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=REG&pagename=mainpage_RGPs

U.S. Army Corps of Engineers. 2005a. Wyckoff/Eagle Harbor Superfund Site. Harbor Remediation. Accessed October 18, 2005. http://www.wyckoffsuperfund.com/harborremediation.htm.

U.S. Army Corps of Engineers. 2005b. Wyckoff/Eagle Harbor Superfund Site. Habitat Mitigation. Accessed October 18, 2005. http://www.wyckoffsuperfund.com/habitat.htm

U.S. Army Corps of Engineers. 1991. Design requirements for capping. Dredging Research Notes Technical Note 5-03. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers. 2002. Biological Assessment. Pacific Sound Resources Superfund Site. Final. Prepared with the U.S. Environmental Protection Agency. Accessed October 18, 2005. http://www.nws.usace.army.mil/ers/reposit/PSR_BA.pdf.

U.S. Environmental Protection Agency. 2005. Management Measures for Marinas and Recreational Boating. EPA website document. http://epa.gov/cgi-bin/epaprintonly.cgi

U.S. Environmental Protection Agency. 2005. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675 Accessed November 30, 2005. http://www.epa.gov/fedrgstr/EPA-WATER/2005/April/Day-14/w7468.htm

U.S. Fish and Wildlife Service. 1999. Status Assessment and Conservation Plan for the Black Tern in North America. US Fish and Wildlife Service, Mountain-Prairie Region. Accessed February 21, 2005: http://www.r6.fws.gov/blacktern/.

U.S. Fish and Wildlife Service. 2003. Biological Opinion for USDA Forest Service Fish Passage Restoration Activities in Eastern Oregon and Washington 2004-2008. FWS Reference Numbers: 1-3-03-PF-1243 and 1-7-03-F-0379. U.S. Department of the Interior, Fish and Wildlife Service. Oregon Fish and Wildlife Office. Portland, OR.

U.S. Fish and Wildlife Service. 2005. Sacramento Fish and Wildlife Office Species Account: California Brown Pelican (*Pelecanus occidentalis californicus*). Accessed

March 14, 2005:
http://www.fws.gov/pacific/sacramento/es/animal_spp_acct/ca_brown_pelican.html.

U.S. Fish and Wildlife Service. 2005a. National Wetlands Inventory. Accessed March 14, 2005: http://www.fws.gov/nwi/metadata.htm.

U.S. Forest Service. Biological Assessment for USDA Forest Service Fish Passage Restoration Activities Affecting ESA-listed Animal and Plant Species found in eastern Oregon and the whole of Washington. U.S. Forest Service, Region 6. Accessed September 13, 2005 http......

URS Greiner, Inc. and Berger/ABAM Engineers, Inc. 2000. Midway Sewer District Submarine Outfall Replacement, Des Moines, Washington. Biological Assessment. Prepared for The Midway Sewer District. Des Moines, WA.

Utne-Palm, A. C. 2002. Visual Feeding of Fish in a Turbid Environment: Physical and Behavioural aspects. Marine and Freshwater Behavior and Physiology, 35:111–128.

Van Gelder, J.J. 1973. A Quantitative Approach to the Mortality Resulting from Traffic in a Population of *Bufo bufo.* L. Oecologia (Berl.) 13:93-95.

Veen, J. 1977. Functional and Causal Aspects of Nest Distribution in Colonies of the Sandwich Tern. Behaviour Supplement 20.

Vermaat, J.E., and R. J. de Bruyne. 1993. Factors limiting the distribution of submerged waterplants in the lowland river Vecht (The Netherlands). Freshwater Biology 30:147-157.

Vermeer K. 1973. Some Aspects of Nesting Requirements of Common Loons in Alberta. The Wilson Bulletin. Vol. 85, No. 4.

Vines, C. A., T. Robbins, F. J. Griffin, and G. N. Cherr. 2000. The Effects of Diffusible Creosote Derived Compounds on Development in Pacific Herring (*Clupea pallasi*). Aquatic Toxicology 51:225-239.

Vogt, R.C. and J. J. Bull. 1984. Ecology of Hatchling Sex Ratio in Map Turtles. Ecology 65(2): 582-587.

Wagner, P., J. Nugent, W. Price, R. Tudor, and P. Hoffarth. 1999. 1997-99 Evaluation of Juvenile Fall Chinook Stranding on The Hanford Reach. U. S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number 1997-104.

Wagner, P., J. Nugent, W. Price, R. Tudor, and P. Hoffarth. 1999. U. S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number 1997-104, Contract Number 1997BI30417, GCPUD Contracts Document 430-647, 88 electronic pages (BPA Report DOE/BP-30417-1)

Wahl, T.R., B. Tweit, and S.G. Mlodinow (eds). 2005. Birds of Washington: Status and Distribution. Oregon State University Press. Corvallis, Oregon.

Waknitz, F.W., R.N. Iwamoto, and M.S. Strom. 2003. Interactions of Atlantic salmon in the Pacific Northwest. IV. Impacts on the local ecosystems. Fisheries Research 62:307-328.

Waknitz, F.W., T.J. Tynan, C.E. Nash, R.N. Iwamoto, and L.G. Rutter. 2002. Review of potential impacts of Atlantic salmon culture on Puget Sound Chinook salmon and Hood Canal summer-run chum salmon evolutionarily significant units. U.S. Dept. Commerce. NOAA Tech. Memo. NMFS-NWFSC-53, 83p.

Walton, J.M. 1982. The Effects of an Artificial Reef on Resident Flatfish Populations. Marine Fisheries Review 44(6-7):45-48.

Ward D. L., A. A. Nigro, R. A. Farr, and C. J. Knutsen. 1994. Influence of waterway Development on Migrational Characteristics of Juvenile Salmonids in the Lower Willamette River, Oregon. North American Journal of Fisheries Management. 14:362-371.

Washington Administrative Code, Chapter 173. Washington Administrative Code Water Quality Standards for the State of Washington

Washington Department of Ecology 2004 Water Quality Program. Accessed November 30, 2005. http://www.ecy.wa.gov/programs/wq/links/plants.html

Washington Department of Ecology. An Overview of the Model Toxins Control Cleanup Act (MTCA), Washington Administrative Code, Chapter 173-340. Accessed November 30, 2005. http://www.ecy.wa.gov/programs/tcp/cleanup.html

Washington Department of Fish and Wildlife. 2001. Washington State Aquatic Nuisance Species Management Plan. Coordinated by Pamala Meacham of the Washington Department of Fish and Wildlife for The Washington Aquatic Nuisance Species Coordinating Committee Olympia, WA.

Washington Department of Fish and Wildlife. 2005. Warmwater Fish. Warmwater Enhancement Program. Accessed October 14, 2005. http://wdfw.wa.gov/fish/warmwater/.

Washington Department of Fisheries and Washington Department of Natural Resources. 1989. Plan for Management of Sand Shrimp Harvest. Shellfish Program and Division of Aquatic Lands. Olympia, WA.

Washington Department of Natural Resources and Washington Department of Fish and Wildlife. 2001. Final Supplemental Environmental Impact Statement for the State of Washington Commercial Geoduck Fishery. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Washington Department of Natural Resources. 2007. Covered Species Technical Paper. Washington State Department of Natural Resources. Olympia, WA.

Washington Department of Natural Resources. 2005a. Covered Habitat Technical Paper. Washington State Department of Natural Resources. Olympia, WA.

Washington Department of Natural Resources. 2005b. Covered Activities Technical Paper. Washington State Department of Natural Resources. Olympia, WA.

Washington Department of Natural Resources. 2005c. Habitat Classification and Activities Effects Report. Washington State Department of Natural Resources. Olympia, WA.

Washington Department of Natural Resources. 2005. Aquatic Reserves Program. Accessed October 17, 2005. http://www.dnr.wa.gov/htdocs/aqr/reserves/index.html.

Washington Department of Transportation. 2004. Highway Runoff Manual. Washington State Department of Transportation. Olympia WA.

Washington State Department of Fish and Wildlife. 1999. Gold and Fish - Rules and Regulations for Mineral Prospecting and Placer Mining in Washington State. Publication GF-1-99. Accessed September 13, 2005. http://www.wdfw.wa.gov/hab/goldfish/prospect.pdf

Washington State Department of Transportation. 2004. Best Management Practices Field Guide for ESA § 4 (d) Habitat Protection. 2004. Washington State Department of Transportation, Maintenance and Operations Division. Accessed November 11, 2005. http://www.wsdot.wa.gov/maintenance/pdf/BMP_Field_Guide.pdf

Washington State Department of Transportation. 2005. Eelgrass Protection Project. Accessed September 13, 2005. http://www.wsdot.wa.gov/ferries/your_wsf/corporate_communications/clinton_enviro/

Watkins, W.A.1986. Whale Reactions to Human Activities in Cape Cod Waters. Marine Mammal Science, 2:251-262.

Watson, J. W., and D. J. Pierce. 1998. Ecology of bald eagles in western Washington with an emphasis on the effects of human activity. Final Report. Washington Dept. of Fish and Wildlife, Olympia, WA.

Watson, J.W., D. Mundy, J.S. Begley, and D. J. Pierce. 1996. Responses of nesting bald eagles to the harvest of geoduck clams. Final Report. Washington State Department of Fish and Wildlife. Olympia, WA.

Weis, J. S., P. Weis, and T. Proctor. 1998. The Extent of Benthic Impacts of CCA-treated Wood Structures in Atlantic Coast estuaries. Archives of Environmental Contamination and Toxicology 34:313-322.

Weisberg, S.B., W.H. Burton, F. Jacobs, and E.A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge-Wire Screens. North American Journal of Fisheries Management 7:386-393.

Weitkamp, L.A., R.C. Wissman, C.A. Simenstad, K.L. Fresh, and J.G. Odell. 1992. Gray whale foraging on ghost shrimp (*Callianassa californiensis*) in littoral sand flats of Puget Sound, U.S.A. Canadian Journal of Zoology 70:2275-2280.

West, J.E., R.M. Buckley, D.C. Doty. 1994. Ecology and Habitat Use of Juvenile Rockfishes (*Sebastes* spp.) Associated with Artificial Reefs in Puget Sound, Washington. Bulletin of Marine Science 55(2-3):344-350.

West, J.E., R.M. Buckley, D.C. Doty. 1994. Ecology and Habitat Use of Juvenile Rockfishes (*Sebastes* spp.) Associated with Artificial Reefs in Puget Sound, Washington. Bulletin of Marine Science 55(2-3):344-350.

Wilber, D.H. and D.G. Clarke. 2001. Biological Effects of Suspended Sediments: A Review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management 21:855-875.

Wilber, D.H. and D.G. Clarke. 2001. Biological Effects of Suspended Sediments: A Review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management 21:855-875.

Wilding, T.A. and M.D.J. Sayer. 2002. Evaluating Artificial Reef Performance: Approaches to Pre- and Post-deployment Research. ICES Journal of Marine Sciences 59 Supplement:S222-S230.

Wiles, G. J. 2004. Washington State Status Report for the Killer Whale. Washington Department Fish and Wildlife. Olympia, Washington. 106 pp.

Williams G. D., R. M. Thom, D. K. Shreffler, J. A. Southard, L. K. O'Rourke, S. L. Sargeant, V. I. Cullinan, R. Moursund, and M. Stamey. 2003. Assessing Overwater Structure-Related Predation Risk on Juvenile Salmon: Field Observation and Recommended Protocols. Prepared for Washington State Department of Transportation Commission, Olympia, WA.

Williams R., Trites A.W., Bain D. 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats:opportunistic observations and experimental approaches. Journal of Zoology 256:255–270.

Williams, G.D. and R.M. Thom. 2001. Marine and Estuarine Shoreline Modification Issues. Submitted to Washington Departments of Fish and Wildlife, Ecology, and Transportation. Olympia, WA.

Williams, R., A. W. Trites, and D. E. Bain. 2002. Behavioural Responses of Killer Whales (*Orcinus orca*) to Whale-watching Boats: Opportunistic Observations and Experimental Approaches. Journal of Zoology, 256:255-270.

Wright, S.K., D.D. Roby, and R.G. Anthony. 2002. California Brown Pelicans nesting in the Pacific Northwest?: Potential for a major northward expansion in breeding range. Abstract Pacific Seabirds 29:71-72.

Young, R. J. and G. I. Mackie. 1991. Effects of Oil Pipeline Construction on the Benthic Community Structure of Hodgson Creek, Northwest territories. Canadian Journal of Zoology 69:2154–2160.

Yousef, Y. A., W. M. McLellon, and H. H. Zebuth. 1980. Changes in phosphorus concentrations due to mixing by motor boats in shallow lakes. Water Research 14:841-852.

Zevenbergen, L.W., J.H. Hunt, M.S. Byars, B.L. Edge, E.V. Richardson, and P.F. Lagasse, 1997 Tidal Hydraulic Modeling For Bridges User's Manual. Pooled Fund Study SPR-3(22), Ayers Associates, Fort Collins, CO.

Zimmerman, A.L., J.A. Dechant, D.H. Johnson, C.M. Goldade, B.E. Jamison, and B.R. Euliss. 2002. Effects of management practices on wetland birds: Black Tern. Northern Prairie Wildlife Research Center, Jamestown, ND.