Final Report

Ranking of Estuarine Habitat Restoration Priorities in Willapa Bay, WA

Coastal Resources Alliance
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The Final Report represents an amalgamation of the analysis and recommendations prepared by the FWCRU team, the GIS analysis and products provided by UW ONRC GIS, and the observations, comments, and corrections contributed by numerous stakeholders, scientists and managers. It was not possible in each and every instance to differentiate the major sources of sections of this report. An effort was, however, made to include all necessary scientific references to support our assumptions and conclusions. In addition to this Final Report, the deliverables submitted by CRA include:

"The Habitat Assessment and Criteria for Nearshore Prioritization" by Mariana Tamayo and Christian Grue of the UW Fish and Wildlife Cooperative Research Unit;

"Estuarine Ranking GIS Projects and Data for Willapa Bay," a DVD produced by Teresa Alcock and Keven Bennett of the University of Washington's Olympic Natural Resources Center; and

2 sets of hardcopy maps displaying the key themes used in the analysis of restoration of opportunities.

Introduction

The purpose of this project was to remedy a major deficiency of the WRIA 24 Strategic Plan for Salmon Recovery. Prior to this project, insufficient work had been done to evaluate and rank the relative importance of estuarine areas of Willapa Bay as habitat for salmon and steelhead or to devise specific projects directed at restoring key estuarine habitat. The WRIA 24 Strategic Plan and the WRIA 24 Limiting Factors report (Smith, C. J. 1999) very briefly mention a number of potential problems affecting estuarine habitat: the invasion of exotic smooth cordgrass, displacement of native eelgrass, the loss of LWD, and loss of wetlands from diking and filling. The Strategy however includes no specific ranking of nearshore and estuarine habitat in Willapa Bay or potential restoration activities. This project was designed to remedy this deficiency by 1) assembling existing historic information to allow ranking the value of estuarine habitat for fish; and 2) sponsoring a scientifically-grounded and community-based collaborative process for prioritizing specific portions of Willapa Bay in relation to their value for salmon and ranking restoration projects within those areas.

Summary of Project Deliverables

Habitat Assessment & Criteria for Ranking Restoration Opportunities

The University of Washington's Fish and Wildlife Cooperative Research Unit (FWCRU) was contracted to review the available literature and data on estuarine habitat in Willapa Bay and to prepare an initial habitat assessment. Dr. Mariana Tamayo of FWCRU prepared the first draft Habitat Assessment and Prioritization Criteria report. The report was presented to a panel of experts convened in Seattle on August 24, 2005. Members of the panel included Mariana Tamayo and Christian E. Grue of FWCRU; Jeff Cordell of the Wetland Ecosystem Team, UW School of Aquatic and Fishery Sciences; Brett Dumbauld and Lee McCoy of the USDA Agricultural Research Service, Hatfield Marine Science Center; Miranda Wecker and Teresa Alcock of the UW ONRC; and Ayesha Gray of NOAA's South Slough National Estuarine Research Reserve. The comments of this group were incorporated into a second draft and then circulated for broader peer review. Presentations were made to the Water Resources Coordinating Council in November 2005, December 2005 and January 2006. Copies of the final version of the FWCRU Habitat Assessment are being copied for submission and distribution.

In developing the criteria for ranking estuarine habitat restoration opportunities, FWCRU staff considered the recent work of a number of other WRIAs in addressing their estuarine or nearshore habitats. The Puget Sound Partnership has done a substantial amount of work to develop its Nearshore Program. However, because Puget Sound issues differ greatly from the challenges facing WRIA 24, FWCRU staff proposed basing the Willapa Estuarine Ranking Criteria on the conceptual model presented by the Hood Canal Coordinating Council (HCCC 2004). In that approach, estuarine or nearshore priorities were directly linked to the adjacent freshwater systems. That is, estuarine areas adjacent to the highest priority freshwater areas received the highest ranking. The FWCRU report described the broad ecological goals of the nearshore prioritization as: 1) maintenance of ecosystem processes and habitats essential for salmonids; 2) restoration or preservation of ecosystem connectivity (habitats that link freshwater and nearshore habitats); and 3) protection of native salmonid stocks. The following template of criteria was proposed:

Table 9. Criteria to rank and score nearshore project proposals.

Does the proposal address a priority need identified in the RFP?				Yes	No
Ranking Criteria		**Ranking**			**Points**
		1 point	**3 points**	**5 points**	
Landscape -Temporal Context	Nearshore Priority (NSP)	NSP-3	NSP-2	NSP-1	
	Spatial Scale	Low	Medium	High	
	Connectivity	Low	Medium	High	
	Ecological Scale	Low	Medium	High	
	Temporal Scale	Low	Medium	High	
Ecological Benefits	Uncertainty	High	Medium	Low	
	Risk	High	Medium	Low	
	Knowledge Gained	Low	Medium	High	
Total Points (40 points maximum)					
Monitoring	Monitoring Plan (All projects other than those for gaining critical information require a monitoring plan to be considered for funding)			Yes	No
	Implementation Monitoring (must be included in the monitoring plan to be considered for funding)			Yes	No
	Effectiveness Monitoring (must be included in the monitoring plan to be considered for funding)			Yes	No
	Performance Measures for Effectiveness Monitoring (must be included in the monitoring plan to be considered for funding)			Yes	No
Monitoring Plan - Comments & Recommendations					
Overall Project - Comments & Recommendations					

The FWCRU report also provided guidance in the interpretation of the more abstract terms used in the template in evaluating the "Landscape-Temporal Context." The following definitions were offered to help in the ranking process.

Landscape Context

Landscape context refers to how a given location "…is integrated with all other elements in the landscape, including the arrangement, size, shape, location, connectivity to other habitats, and accessibility of that habitat to [biological] resources" (Fresh et al. 2004). Below are key landscape characteristics that need to be considered when ranking recovery actions.

Spatial Scale – Actions need to be of the right size and scale to achieve the goals of the recovery project. Projects that encompass large areas are more likely to have greater ecological benefits. Therefore, the bigger the area an action targets, the higher the action is ranked.

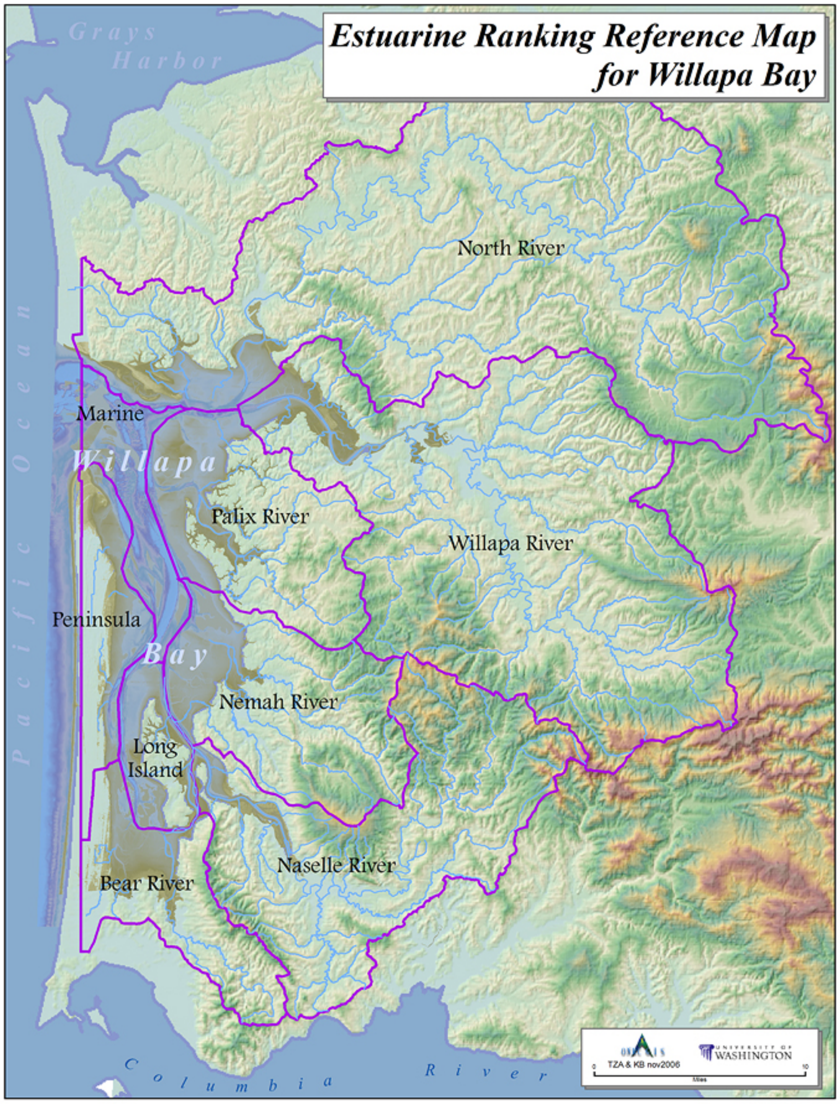
Ecological Scale – This relates to ecological processes in the nearshore. The more processes, habitats, species, and life histories an action involves, the higher the ranking. For example, dike removal that involves nearshore and riverine processes would be ranked higher than removal of individual creosoted pilings (Correa 2002). In addition, actions targeting rare or unique salmonid landscapes are also ranked high.

Connectivity – This is defined as "…the linkage [connection] between one habitat and other habitats" (Fresh et al. 2004). The greater the connectivity in an area, the higher the ecological benefits are likely to be. An action is ranked high if it targets an area with two or more habitats that are linked (e.g., an area where a salt marsh is linked to a mudflat) or an area that provides linkage between two or more habitats.

Temporal Scale – This refers to the benefits an action will have over time. In general, actions that protect or restore processes and habitats that are self sustaining and do not require long-term maintenance will receive a higher ranking. However, some valuable actions (e.g., *Spartina* removal) may require repeated and long-term maintenance.

The proposed criteria call for assessing the connectivity of estuarine habitat and freshwater habitat. In order to apply this approach to Willapa Bay's estuary, Willapa Bay was divided into "estuarine units." ONRC GIS used GIS analysis of the proximity of intertidal habitat to the adjacent terrestrial sub-basins in order to draw the boundaries of each estuarine unit. The terrestrial or freshwater "watershed" divisions were those used throughout the WRIA 24 Strategic Plan. The main channel of Willapa Bay was not associated with a particular sub-basin, because it was assumed that salmon from many watersheds use the main channel. We recognize that in certain cases, the dividing line between estuarine units was arbitrary. This was especially the case in areas distant from any river mouth. The conceptual scheme proposed by FWCRU would assume that these areas probably are less connected to any river and therefore would receive a lower ranking in any case.

The following map displays the boundaries of the Estuarine Units developed for WRIA 24 Strategic Plan.



GIS system & Maps

UW Olympic Natural Resources Center provided GIS technical support for this project. ONRC staff compiled and updated all the datasets relevant to analysis of estuarine conditions in Willapa Bay. Much of the basic data was assembled in the 1990s by the Willapa Alliance, a local non-profit organization. Over the past 10 years, ONRC has added to that GIS system archive with data themes assembled for work in support of spartina control in Willapa Bay. A significant amount of original GIS analysis was done by ONRC staff to support this project. This work is described in the sections to follow below. The work products generated by ONRC have been compiled into a set of hard copy maps and an accompanying DVD.

Stakeholder meetings

The Willapa Bay Water Resources Coordinating Council (WBWRCC) serves as the Citizens Advisory Group of the WRIA 24 Lead Entity. Project participants from CRA and FWCRU have made several presentations to this group of stakeholders as information and deliverables were developed. Presentations were made on November 1, 2005, Dec 6, 2005, Jan 16, 2006 and December 5, 2006. CRA also consulted the Pacific Coast Shellfish Growers Association, the Willapa Bay Regional Fisheries Enhancement Group, staff of the US Fish and Wildlife Service's Willapa National Wildlife Refuge, and staff of the Department of Fish and Wildlife in reviewing the map products and the approach to ranking proposed in this report.

Integration of the Recommendations in the WRIA 24 Strategic Plan

The final task in this project is to facilitate integration of the recommendations and findings of this analysis into the next revision of the WRIA 24 Strategic Plan. In the sections below, we summarize information on the Willapa estuary, the habitat types within the estuary that are of importance to salmon, and activities or stressors that may affect salmon. Restoration opportunities are highlighted and ranked. If approved by the Water Resources Coordinating Council, the recommendations may be inserted into the WRIA 24 Strategic Plan in the relevant watershed sections. That Strategic Plan has recently been revised to embrace the principle that "lowest elevation projects" should be ranked highest. That is, projects closest to the river mouths should receive more points than projects further upstream. Therefore, projects in estuarine units connected to high priority watersheds should score well.

Description of the Willapa Estuary

Estuaries are most commonly defined as semi-enclosed coastal bodies of water having a free connection with the open sea and within which seawater is diluted measurably by freshwater from land drainage…

Estuaries are crucial habitat for young salmon, or smolts, during their migration from rivers to the ocean. Smolt survival can be affected by changes in water quality in the estuary, as well as habitat quality and size. (Litle and Parrish. 2003)

As a transition zone between freshwater and marine ecosystems, estuaries are highly productive areas that offer habitat of special importance to the early life stages of many marine animals. Estuaries are categorized according to their physical shape and the forces that created them. Oceanographers describe Willapa Bay as a coastal plain or "drowned river" estuary, the type most common along the West Coast. Drowned river estuaries are remnant river mouths subsumed by sea level rise within the past 10,000 years. (Litle and Parrish. 2003). Bounded by the Long Beach Peninsula-- a large bar formed from Columbia River sediments, Willapa Bay's estuary also has some of the features of a bar-built estuary. An inventory of the major US estuaries published by the National Oceanic and Atmospheric Administration (NOAA) in 1990 presented basic data on the major estuaries of the US Coast including Willapa Bay (United States Department of Commerce 1990). Measurements were compared on: the estuarine drainage area, the total watershed drainage area, the water surface area, the volume, the tidal range, the salinity regime, and the freshwater inflow. Scientists use these factors to compare estuaries and to determine how vulnerable they may be to the impacts of human activities.

Some of these characteristics highlight the special nature of Willapa Bay. For example, the estuarine drainage area, or EDA, is defined as the land and water portion of a watershed that drains directly into estuarine waters (United States Department of Commerce. 1990). Unlike most of the other large estuaries in the US, Willapa's EDA coincides with its entire watershed of approximately 1,100 sq mi. (2,849 sq km). The compact nature of the Willapa watershed means that activities in a relatively small area need to be managed in order to protect the estuary. In contrast, the Columbia River estuary drainage area of 5,600 sq mi (14,503 sq km) is less than 3% of the total watershed of 257,700 sq mi. (667,440 sq km).

Another parameter, estuarine water surface area, is approximated at mean tide level and used to estimate the estuary's volume, its flushing rate, and its susceptibility to pollutants. Willapa Bay's water surface area is estimated at 92 sq mi. (238 sq km). With an average depth of 16 ft, its volume is 42 billion cu ft. Based on these physical features, the National Ocean Service of NOAA has rated Willapa Bay as of medium susceptibility to pollutants. (United States Department of Commerce 1990). A study conducted in 1992 by the US Geological Survey, the WA Department of Ecology and the Pacific County Department of Community Development evaluated the flow and quality of groundwater under the Long Beach Peninsula-- the area with the most intense residential development. That study showed that, on average, roughly 80 inches of rain falls on Pacific County each year. Hydrologic data collected by the study showed that 2/3 of Long Beach Peninsula groundwater is eventually discharged into Willapa Bay, while only 1/3 moves into the ocean. Although the area's heavy rainfall generates episodes of tremendous runoff that can deliver contaminants into Willapa Bay, these seasonally high levels of precipitation are also seen as beneficial; they allow natural recharge of the aquifer and increase the flushing action of the tides. (Thomas, B. 1995).

In 2003, a report from the Pacific Northwest Coastal Ecosystems Regional Study (PNCERS) presented additional information on the Willapa Bay estuary. (Litle, Kate and J. Parrish, 2003) The PNCERS report stated that the Willapa Bay estuary extends over 139 sq mi (360 sq km), of which about 86 sq mi (224 sq km) is mudflat and roughly 54 sq mi (140 sq km) is sub-tidal. UW ONRC GIS staff recalculated various measurements of Willapa Bay using more recent high resolution bathymetry data compiled during a 2003 LiDAR survey. ONRC GIS also integrated into the analysis advances in the understanding of the variable effect of tidal currents on water levels at different points in Willapa Bay. The new analysis showed that the water surface area [area encompassed using the Mean High Water (MHW) line as the perimeter] is approximately 136 sq mi

(353 sq km). The inter-tidal zone is defined as the area above mean lower low water (MLLW) and below mean higher high water (MHHW). Based on the 2003 data, 84 sq mi (217 sq km) of the bay is inter-tidal. The sub-tidal zone is defined as areas below MLLW. Based on the 2003 data, 57 sq mi (148 sq km) of the bay is sub-tidal. These measurements are slightly different from those presented by the PCNERS publication, and significantly different from the information presented in the 1990 NOAA document. The methodology used in the other reports is not known. Using 2003 data, ONRC GIS also calculated shoreline length as well as the length of the inter-tidal sloughs. The shoreline is defined as the MHW line. Willapa Bay's shoreline is 364 miles long.

The expansive inter-tidal mudflats of Willapa Bay are among its most differentiating and defining features. They are also the basis for its unusual productivity to human communities. The inter-tidal zone supports a variety of habitats including open, mud and sand flats, oyster reefs, salt marsh habitat, and eelgrass meadows. Its oysterbeds are currently the most productive growing grounds in the United States. Its mudflats are among the ten most important fueling areas for migratory birds along the Pacific Flyway. Willapa's sub-tidal system of three main channels and associated complex of smaller drainage channels deliver oceanic nutrients and plankton to feeding areas on the tide flats. The side channels provide fish a route to access the mudflats as well as cover from large predators during low tides.

Since 2003, a number of major oceanographic studies focused on the dynamics of Washington's coastal ocean and two major estuaries, Willapa Bay and Grays Harbor. Detailed explanations of the various ocean currents, the influence of the Columbia River Plume, and their impact on the productivity of Willapa Bay have been published. This work showed that the ocean plays the dominant role year round in supplying nutrients and marine organisms that underlie the productivity of Willapa Bay. *Unlike most East Coast estuaries, some PNW estuaries may be considered as extensions of the coastal ocean during the growing season because river outflow is low and flushing by the coastal ocean is high*. (Banas & Hickey 2003) Research has shown that most of Willapa Bay's nutrients come from ocean waters brought from the bottom to the surface by seasonal coastal upwelling. Upwelling is driven by the prevailing winds during the spring and summer. These nutrient-enriched waters are forced into Willapa Bay by both winds and tidal currents. Studies have shown that the plankton species found in the Bay are almost entirely of oceanic origin. The evidence compiled by this research also confirmed what oystergrowers have long known by observation: the closer to the ocean, the higher the productivity of Willapa Bay. (Banas 2005). The beds used by growers to fatten oysters before sale are all in the northern half of Willapa Bay.

Willapa Bay shows much less the influence of riverine inputs. Between 30% and 50% of the water volume of the Bay is exchanged with each tide cycle. With little to no snowfall each year, streamflow and riverine nutrient inputs are dependent on local rainfall and thus very limited during the summer when plankton species are growing. Studies indicated that riverine nutrients are only significant close to the mouths of the larger rivers in the Bay. Oceanographers have pointed out that local rainfall is generally a product of the same ocean conditions that drive nearshore upwelling and downwelling events. The large scale winds that cause upwellings and plankton blooms are correlated with the fair dry weather conditions of summer, whereas the winter winds that lead to rain are accompanied by downwelling events. The influence of the Columbia River plume intrusions into Willapa Bay has also been more fully explained in a recently publish article. (Hickey and Banas 2003). The effect of the Columbia River plume on Willapa Bay is most pronounced during the late spring and early summer when snowmelt flows are still running high in the Columbia and the extreme winter rainfall that feeds Willapa Bay rivers has ended. (Banas et al 2004).

Estuarine Habitat, Stressors, & Restoration Opportunities

After more than a decade of focus on uplands and riparian habitat restoration, policy makers have broadened their attention and now seek to encompass the restoration of estuarine and nearshore habitat. In 1998, the Western Washington Office of the US Fish and Wildlife Service prepared a literature review of the available scientific information on salmon utilization of estuaries. (Aitkin, J. K. 1998). Estuaries provide the habitat for anadromous fish to make the transition between life in salt and freshwater environments. Adult salmon undergo the physiological transition necessary to survive in freshwater and reach the upstream spawning beds. Juvenile salmon make the physiological transition needed to adjust to saltwater. Juveniles also spend time in he estuary foraging and growing. They also need refuge from predators and protection from currents and high flows. The available literature indicates that different salmon species use estuarine habitat in complex and various ways. Chinook are considered the most dependent on estuarine habitat, chum second most dependent and coho least dependent. The USFWS Literature Review generalized what is know about the status of estuarine habitat in the Pacific Northwest. It reported that a large percentage of estuarine habitat has been lost to diking, channelization, and dredging and filling. Washington is estimated to have lost between 45% and 62% of its pre-settlement estuarine habitat. The Literature Review also indicated that few studies have been done to evaluate whether salmon actually use estuarine habitat that has been restored. The studies cited were cautiously encouraging; they showed evidence of extensive use of restored estuarine habitat.

Experts consulted in the course of this project warned that the conclusions drawn from studies of Puget Sound and other ecosystems cannot be transferred without caution to Willapa Bay. We make reference to the work that has been done to look specifically at how salmon use estuarine habitat in Willapa Bay, but that body of literature and the datasets available to support it are far from voluminous and robust. The scientists who have conducted this kind of work report that the challenges are daunting. The size of the bay, its currents, and its variability all make research of this kind difficult and expensive. Because Willapa Bay currently has no listed salmon species, there is little money available to study its stocks. Although we would argue that the state and federal priorities for research are shortsighted, they are understandably driven by Endangered Species Act (ESA) listings.

In the following sections, the report will include an assessment of the condition of Willapa Bay's estuarine habitat based on the literature available that is specific to

Willapa Bay. In general, Willapa Bay is a highly productive estuary with no heavy industry and relatively little residential development along its shoreline. Pacific County's remote location from the state's transportation core has limited its economic development and kept its population small. Pacific County's competitive economic advantage is in its beautiful surroundings, its rich conifer growing soils, and the productivity of the ocean and estuary. Its salmon runs are among the healthiest in the region. Whatever is done to restore Willapa Bay's estuarine habitat will likely be of benefit to a range of native marine species. Restoration of estuarine habitat will also be of value to local communities who stay here because of the quality and productivity of the marine environment.

Much of this document reflects the ideas and concepts generated in other WRIAs that are grappling with assessment and restoration of their estuarine environments. Some of the stressors in other WRIAs are of less or no concern in Willapa Bay. The Puget Sound Nearshore Assessment includes elaborate analysis of alterations of Puget Sound's shoreline. Extensive installations of rip rap, bulkheads, and other armoring prevent erosion and protect waterfront residences. Willapa's shoreline has been modified with dikes, but there is little armoring. In Puget Sound, numerous overwater structures, heavy industry along the shoreline, and multiple large marinas are of concern. Willapa Bay has few docks, no heavy industry and no large marinas. Point source and non-point pollution have to be considered in Puget Sound. Of the rivers in WRIA 24, only the Willapa River has been repeatedly designated as an impaired waterbody. The Palix River occasionally receives that designation, probably for natural inputs of fecal materials. Work is underway to remedy those issues through the TMDL process.

The FWCRU panel recommended that the recommendations in this report also reflect the limited array of restoration techniques currently available. For example, experts pointed out that, although eelgrass loss could be considered a significant limiting factor, there are no reliable methods to restore eelgrass habitat. Projects to date that have attempted planting of eelgrass have not been shown to be successful. The most reliable method of estuarine restoration is dike removal or breaching. Once saltwater influence has been restored to diked wetlands, natural processes are initiated that eventually lead to enhanced habitat value and increased use by salmon.

WRAC Study: Estuarine Habitat Type and Use by Salmon

The scientific research project of greatest direct relevance to understanding salmon's use of key estuarine habitat types in Willapa Bay was launched in 1999 with funding from the Western Regional Aquaculture Center (WRAC). The project had three objectives: 1) to explore the impacts of aquaculture on eelgrass; 2) to compare species diversity, density, and biomass across habitat types; 3) to compare densities and behavior of juvenile salmon and Dungeness crabs across habitat types. The results of the work done to evaluate aquacultural practices and their impacts on eelgrass study are discussed in the section on eelgrass below. Surveys and experiments done in connection to Objective 2 indicated that the "habitat structure" occurring in both eelgrass and oysterbeds was clearly important in supporting abundant populations and diverse species assemblages. Researchers found less species diversity associated with to the simpler habitat of unvegetated mudflats. Complex habitat structure found in eelgrass and oyster beds was particularly important for "epibenthic meiofauna and for harpacticoid copepods, which have been previously shown to be important components in the diet of juvenile salmon." (Dumbauld et al 2004).

In relation to Objective 3, researchers attempted to compare the relative importance to salmon of habitat types (eelgrass, oysterbeds, and unvegetated mudflats) for feeding and for protection from predation. The studies of feeding behavior indicated that benthic (ie bottom) habitat type had no significant influence on juvenile salmon distribution and diet composition. Most prey items identified in the fish stomachs derived from pelagic sources. Experiments were conducted to test whether salmon use habitat structure for cover. Results showed that when exposed to a artificial predator, large chinook smolts preferred structured habitat over open mudflats. Of the structured habitats, eelgrass was favored over oyster clusters. Smaller Chinook smolts displayed no preference based on habitat types. The results of the WRAC studies have not been fully analyzed. More of the conclusions will be published in the next several years. Investigators also recognized that much more work must be done to develop any level of confidence in our understanding of how salmon use the Willapa Bay estuary.

The following sections summarize the best available information on the condition and limiting factors affecting the three major estuarine habitat types in Willapa Bay: mud and sand flats, eelgrass meadows, and salt marshes. Much of this information is derived or extracted from the FWCRU Habitat Assessment. Additional analyses and information has been included by CRA.

Mud and Sand Flats

Flats are usually defined as gently sloping inter-tidal or shallow sub-tidal areas (Kerwin 2002). They may have sand, mud, pebbles, cobbles, or a mixture of sediment types. Mudflats have unconsolidated sediment of mainly silt and clay, which are usually rich in organic content (Simenstad et al. 1991). Sandflats consist of unconsolidated particles of mostly sand (Simenstad et al. 1991). Location in the Bay greatly affects both sediments and depositional processes. (Clifton et al. 1989). A distribution map of sediments in Willapa Bay is included in the GIS system. The entrance and northern part of Willapa Bay are characterized by sandy sediments and a higher energy environment exposed to oceanic waves, strong tidal currents, and storm effects. The central part of Willapa Bay also has sandy sediments, but the strongest tidal currents are found largely in the main channels. In contrast, the southern part of Willapa Bay has muddy or mixed sandy/muddy sediments, with slower tidal currents and reduced wave activity. (Clifton et al. 1989).

Kerwin (2002) summarized some of the ecological functions of estuarine flats in Washington. Among the functions he listed are a) primary production; b) nutrient cycling; c) habitat for juvenile and adult fish; d) deposition of detritus (sink); e) prey production for juvenile salmon, flatfish and shorebirds; f) wave dissipation for estuarine marshes; g) predator protection for sand lance (*Ammodytes hexapterus*); and h) shellfish production. Given the very limited nature of the empirical information about how salmon use estuarine flats in Willapa Bay, it is difficult to rank the relative importance of various mud and sand flats in WRIA 24. There is one obvious stressor that has caused baywide change to Willapa Bay's estuarine sand and mudflats and the loss of as much as 1,000 acres of mudflats-- the invasion of *Spartina alterniflora*.

Mudflat Stressor: Smooth Cordgrass *(Spartina alterniflora)*

Spartina alterniflora, or smooth cordgrass is native to the east and Gulf coasts of the United States. Records indicate that *Spartina* was probably introduced into Willapa Bay in the late 1800s when it was used as packing material in shipments of oyster spat coming from the east coast of North America. (Sayce 1988). *Spartina* spread slowly for the first 100 years; however after 1995, the rate spread around Willapa Bay accelerated. According to the Federal Environmental Assessment conducted in 1997, *"widespread colonization by Spartina induces major modifications of physical, hydrological, chemical, and biological estuarine functions. Spartina displaces eelgrass (Zostera spp.) on mudflats and native vegetation in saltmarshes. As Spartina becomes dominant in the tideland, mudflats are raised and channels are deepened. This is turn eliminates the gently sloping bare intertidal zone that lies between the saltmarsh and the tidal channels."* *Spartina* has successfully invaded every substrate type in Willapa Bay including sand, silt, clay, loose coble and gravel, and is found in all but the lowest intertidal zone. (United States Fish and Wildlife Service 1997)

Maps of each estuarine unit show the maximum extent of the infestation of *Spartina* in Willapa Bay reached at the end of the summer of 2004. At that time, *Spartina* had infested approximately 18,000 acres, with outliers on another several thousand acres. Since 2004, years of large-scale chemical applications have reduced the distribution of *Spartina*. The interagency control program estimates that the infestation has been reduced by more than 70%. The large-scale control effort calls for repeated treatment of the full extent of the infestation. Treatments rarely produce 100% kill rate, so crews will return to retreat any surviving plants year after year.

Spartina eradication will remain of obvious importance to the goal of preserving and restoring the open sand and mudflats of Willapa Bay. We do not however expect that *Spartina* control efforts will be proposed for SRF Board projects in the near term. Sufficient funding has been available from other state and federal sources to address *Spartina* control in Willapa Bay. Legislation enacted in 1995 calls for the complete restoration of intertidal lands. (RCW 17.26.011). Thus far, management goals have been limited to eradication of the invading plants. Research currently underway shows an impressive return of shorebirds to feed in some of the mudflats in which the *Spartina* has been eliminated. (Patten 2006). In the northern areas of the Bay, where tidal action is sufficiently energetic, pre-invasion elevation levels will likely return after the *Spartina* has been killed. In the southern areas of the Bay, tidal action will likely be insufficient to restore pre-invasion elevation levels.

☆ Restoration Recommendation: Spartina Control

We recommend that the WRIA 24 Strategic Plan acknowledge the deleterious impact of Spartina on the estuarine flats of Willapa Bay. After the Spartina eradication program has been completed, policy makers should assess the level of natural restoration that has taken place in the areas of greatest significance for salmon. In some areas that have experienced substantial accretion, more active intervention may be necessary to dredge out the fill caused by Spartina. Policy makers should also review the feasibility and cost of restoration work in light of any advances made in the techniques available. At that time, a ranking process should be conducted.

Eelgrass

Eelgrass meadows provide multiple ecological functions including: primary production; nutrient cycling; deposition of organic matter; buffering from waves and currents; nursery and foraging habitat for fish and invertebrates; and feeding habitat for birds. (Phillips 1984). Two species of eelgrass are present in Willapa Bay. *Zostera marina*, the native eelgrass, is most often found in the low inter-tidal and shallow sub-tidal zones. *Zostera japonica*, the non-native species, normally occurs in the mid and upper inter-tidal zones (Dumbauld and Wyllie-Echeverria 2003).

Studies have shown that elevation in the inter-tidal zone is only one of the factors that affect eelgrass distribution from year to year. (Thom et al. 2003). Eelgrass density and distribution were also influenced by estuarine salinity and water temperature. The study also found that in Willapa Bay, "large-scale changes in climate and nearshore ocean conditions" (e.g., El Niño, La Niña) may have a strong regional effect on the abundance of *Z. marina*, which can vary annually by 700% (Thom et al. 2003). Such high levels of annual variability make it extremely difficult to establish any credible "norms" in relation to an appropriate or healthy level of eelgrass distribution in Willapa Bay. Acknowledging this variability, seagrass experts have generated a reference map depicting *potential* habitat of *Z. marina* in Willapa Bay based on the maximum and minimum tidal elevations each species inhabits. (Thom et al. 2003). ONRC GIS has provided maps showing the extent of potential eelgrass habitat within each estuarine unit. Slightly different maximum and minimum depth ranges were proposed for *Z. marina* by the Thom team and the Borde team. Potential eelgrass habitat for *Z. japonica* was based on the depth ranges set forth by Gwozdz (unpublished). ONRC GIS once again used 2003 LiDAR survey data as the underlying bathymetry layer. A map showing the actual distribution of eelgrass species in Willapa Bay is currently under development. Field surveys by researchers with the US Department of Agriculture began in 2005 as part of an effort to assess alternative methods for control of burrowing shrimp (see the discussion below.)

Stressors to Eelgrass and Recommendations

Spartina & Eelgrass

The previous discussion summarized the landscape-scale impacts of *Spartina* in Willapa Bay. Among its many known impacts, *Spartina* displaces eelgrass. Therefore, *Spartina* is listed as a stressor to eelgrass as well as mud and sand flats.

✰ ***Restoration Recommendation: Spartina Control***

We recommend that the WRIA 24 Strategic Plan acknowledge the deleterious impact of Spartina on eelgrass in Willapa Bay. After the Spartina eradication program has been completed, policy makers should assess the level of natural restoration that has taken place in the areas of greatest significance for salmon. For example, areas that should be conducive to the growth of eelgrass may be considered for restoration project work. Policy makers should also review the feasibility and cost of restoration work in light of any advances made in the techniques available. At that time, a ranking process should be conducted.

Aquacultural Practices & Eelgrass

Willapa Bay is currently the most productive oyster growing area in the United States. Large-scale harvests have been sustained here for more than a century. Growers employ active management of oysters and their beds and are considered farmers of the estuary. They have long been champions and defenders of the quality and productivity of Willapa Bay. The economic importance of aquaculture and its obvious overall benefits to the ecology of Bay make it vital that any evidence of negative impacts should be weighed in the context of the larger picture. The larger picture includes the benefits to species diversity of the habitat structure provided by oysterbeds. It also includes the many contributions made by the oyster industry in vigorously defending water quality. Evaluation of the severity of any impacts of aquacultural activities should take into account the spatial scale (the number of acres impacted by a practice) and the temporal scale (the duration of impacts). Changes associated with human activities carry with them a mix of costs and benefits depending on the species considered. Authors of the WRAC study pointed out that the simple “no net loss” policy aimed at protecting estuarine wetlands and eelgrass beds can inadvertently discount the ecological value of oyster beds and open mudflat habitats.

As mentioned above, the WRAC study explored the various potential impacts of oyster aquaculture operations on eelgrass habitat. It included a survey of sites throughout Willapa Bay to compare the status of eelgrass meadows inside and outside cultured oysterbeds. Sites were selected to allow comparison of an array of practices associated with the two primary types of aquaculture operations: bottom culture and long-line culture. Practices studied included planting, eelgrass mowing, harrowing, harvest dredging, and hand harvesting. The results showed that all forms of oyster culture were associated with some level of reduction in eelgrass density, with the greatest declines associated with dredging operations. Hand picking and long-line culture also appeared to have some impact on eelgrass densities.

WRAC study investigators also looked more closely into the duration of the practice with the greatest impacts—dredging. Using experimental treatments, researchers found that the impacts of dredging on eelgrass are temporary. The recovery time depended on the substrate type. Within less than a year, eelgrass growing on sandy substrate recovered, while eelgrass on muddy substrate recovered in roughly 2 years. The results of the WRAC study led researchers to conclude *that "With the exception of changes in practices like switching from on-bottom culture to off-bottom culture in some locations, the press (oyster addition) and pulse (planting and harvest operations) disturbances of oyster culture have not changed materially for decades (Ruesink et al. 2006), so there is no reason eelgrass would necessarily be worse off now than in the past. Indeed, there is scientific evidence that native eelgrass fluctuates with environmental conditions (Thom et al 2003) and compelling anecdotal evidence that it has been expanding its distribution in Willapa Bay and other West coast open coast estuaries… Light however does seem to limit growth in PNW estuaries and thus eelgrass may even shade itself when dense. This mechanism may explain why eelgrass grew faster in ground cultured oyster beds in Willapa Bay. While growth was faster, overall production was still lower due to reduced eelgrass density."* (Brett Dumbauld 2006).

In sum, the WRAC report indicates that eelgrass density is reduced by aquaculture operations, but even the most intense impacts associated with dredge harvesting are probably short-lived. Initial declines in eelgrass were followed by subsequent recoveries. More publications are anticipated from the WRAC study. Follow-up research projects have been launched. The Pacific Coast Shellfish Growers Association is currently pursuing funding to initiate a industry-wide process to revise their voluntary Environmental Code of Practices in light of the information produced by the WRAC study.

✰ *Restoration Recommendation: Aquacultural Practices*

WRIA 24's Strategic Plan for Salmon Recovery should include enthusiastic support for the development of additional provisions of the voluntary Environmental Code of Practices for Shellfish Aquaculture. The revisions should provide guidance to shellfish growers regarding ways to increase the ecological benefits of aquaculture and to avoid or reduce the harmful impacts on estuarine habitats. Focus should be directed at habitats of greatest importance to salmon including eelgrass meadows located along the edge of fish migration channels.

Burrowing Shrimp & Eelgrass

The shellfish aquacultural practice that has been the subject of the most extensive research is the control of burrowing shrimp. Two species of burrowing shrimp-- ghost shrimp *(Neotrypaea californiensis)* and mud shrimp *(Upogebia pugettensis)*-- are indigenous to Willapa Bay. In the 1940s, oystergrowers noticed a dramatic increase in their numbers. As the shrimp feed and burrow into the inter-tidal substrate, sediments are stirred up and the substrate is softened and weakened. Oysters sink into the loosened substrate and suffocate. (Feldman et al., 2000; Dumbauld et al., 1997). Since the 1960s, the pesticide carbaryl has been applied to an increasingly limited number of oysterbeds in Willapa Bay to control shrimp populations. With the heightening of concern over non-target impacts of pesticides in water bodies, scrutiny of this practice has intensified. Lawsuits and challenges to the required permits have driven agencies to sponsor new studies of carbaryl and repeat old studies using new methods. Despite all the controversy, the weight of the scientific evidence shows that there are few if any long term environmental impacts of the use of carbaryl. (Feldman et al., 2000) Recent studies have been conducted by the FWCRU to specifically assess the risks to juvenile salmon. They have also indicated that the risks are negligible. (C.Grue 2006.)

Extensive research has shown that carbaryl has no irreversible physiological effects on aquatic flora. In light of its rapid degradation, it is even more unlikely to harm estuarine plants. (Feldman et al 2000). Quite to the contrary, the evidence points to the benefits of carbaryl applications to eelgrass. Oystergrowers have long noticed that eelgrass is rarely found on mudflats with high numbers of burrowing shrimp. These areas of dense shrimp numbers are often described by growers as "shrimp deserts" because they appear barren of life. A research project was conducted to examine and document the effect of carbaryl treatments on eelgrass abundance. The data showed that carbaryl treatments reduced shrimp numbers which in turn enhanced native seagrass (*Z.marina*) abundance. (Dumbauld and Echeverria. 2003). By reducing or eliminating bioturbation caused by the shrimp, carbaryl allowed the survival of oysters and the development of three dimensional habitat architecture. Authors of the study reported that *"in this case we have shown that this practice likely enhances seagrass distribution in Washington's coastal estuaries and as such would be viewed as a beneficial practice if the no net loss policy were the only concern."* Research has also been done to verify that dense burrowing shrimp beds support far less species diversity than adjacent structured habitats. (Ferarro & Cole 2006). Carbaryl treatments, by reducing these problematic densities of shrimp, appeared to deliver multiple benefits for species diversity, for eelgrass habitat, as well as for oysters.

✰ *Restoration Recommendation: Burrowing Shrimp Control*

WRIA 24's Strategic Plan for Salmon Recovery should include recognition of the deleterious effect of excessive numbers of burrowing shrimp on eelgrass and oysterbeds—both valued because they offer structured estuarine habitats that support salmon. Of particular importance is burrowing shrimp control in structured habitats along the edges of channels used by migrating salmon.

Saltwater Wetlands

Loss of saltwater wetlands habitat is considered one of the most common "limiting factors" blamed for the decline of nearshore or estuarine salmon habitat. Wetlands loss occurs when a dike is built isolating areas from the reach of tidal waters. The earliest accounts of the history of diking and filling in Willapa Bay was prepared by Arnold Shotwell in 1977 while working for the Pacific County Planning Department. Shotwell reported that the low dikes were built by early settlers to allow summer pasturing of livestock. Between 1912 and 1920, higher dikes were installed by Diking Districts established to encourage development of year-round agriculture and construction of roads, towns and industry. Dikes were also built to create more freshwater wetlands habitat for migratory birds. The Willapa National Wildlife Refuge maintains one of the largest tracts of diked freshwater wetlands in the area for that purpose. Shotwell estimated that, of the approximately 12,354 acres (5,000 hectares) of estuarine wetlands that existed in Willapa Bay around 1906, only 50% remained as of 1975.

In the 1999 Limiting Factors Analysis prepared for WRIA 24, another evaluation of "wetlands loss" in Willapa Bay was done. (Smith 1999) This assessment used data from the Willapa Alliance (1998) to provide estimates and maps of wetland loss for six sub-estuaries in Willapa Bay. This assessment indicated that only 22% of the original estuarine wetlands in Willapa Bay had been lost. The reasons for the large difference between the Shotwell analysis and the Smith analysis are not clear.

ONRC GIS conducted an analysis of wetlands loss for this project using the best available datasets and GIS technology. According to ONRC's calculations, Willapa Bay originally contained approximately 14,620 acres of saltwater wetlands. Now there are 5,277 acres. This represents a 64% loss of estuarine wetlands. To reach this conclusion, ONRC used a 2003 LiDAR survey of the Bay conducted by NOAA's Coastal Services Center in Charleston South Carolina as the underlying bathymetric data. ONRC developed a methodology for relating this highly accurate bathymetric data with the tidal datum provided by NOAA. ONRC also referred to a baywide series of aerial photography taken of the shoreline in 2005. Dikes are clearly visible in the photographs. ONRC also incorporated the latest datasets from the Department of Transportation on the location of shoreline culverts and tidegates as well as data from the National Wetlands Inventory. After generating maps displaying the location of fully impounded and partially impounded wetlands, ONRC clipped an ownership data layer to show the names of owners of impounded wetlands.

Saltwater Wetlands Restoration Techniques

The expert panel assembled by FWCRU expressed little confidence in any estuarine restoration techniques other than saltwater wetlands restoration through dike breaching or removal. They referred to a growing literature establishing the value of creating additional saltwater wetlands acreage by restoring tidal hydrology. (Beamer et al. 2005). Key ecosystem processes are changed when saltwater influence is restored including tidal hydrology, cycling of organic matter, and sediment movements. New off channel habitat will be available to fish. Oceanic nutrients will be added. New plant communities will grow and make organic matter and prey items available. Analysis of nearshore restoration work in Puget Sound has led managers to consider a number of factors important in relation to the success of projects to create saltwater wetlands. Factors to consider are where the dike may be removed, how much of the dike may be removed, the size of the new wetland, and where in the estuary the new wetland is located. (Beamer et al. 2005).

The FWCRU Panel questioned whether there is any solid evidence that lack of saltwater wetlands habitat is in fact limiting fish production in Willapa Bay. After all, Willapa Bay still has very large tracts of high quality saltwater wetlands. We recognize that there is no scientific research establishing that historic loss of saltwater wetlands acreage has caused the decline in salmon runs in Willapa Bay or that restoration will lead to increases in salmon runs. However, it may be helpful to consider the results of an assessment of salmon stocks in Willapa Bay conducted by the Willapa Alliance. (Suzumoto 1992). The Suzumoto report assembled a great deal of evidence showing a substantial decline in chum runs. He estimated that present Chum runs were roughly 30% of their historic numbers. Coho and Chinook numbers, in contrast, were maintained at levels consistent with historic numbers through artificial propagation. Chum salmon is one of the species most dependent on estuarine habitat including saltwater wetlands. There is intense and widespread interest in increasing chum runs throughout Willapa Bay. Because of the importance of low elevation habitat to chum, restoration of estuarine habitat will probably serve that interest.

✩ Restoration Recommendations: Saltwater Wetlands Restoration

WRIA 24's Strategic Plan for Salmon Recovery should include recognition of the high level of success associated with dike breaching or removal to restore saltwater wetlands. Of particular importance are restoration opportunities in the two rivers that were ranked the most important in the Strategic Plan: the Naselle and the Willapa Rivers. The ranking criteria recommended by the FWCRU team reaffirms the selection of these two rivers based on the presence of all species of salmon found in the Willapa system. Wetlands restoration opportunities are ranked in accordance with the size of the contiguous area available for restoration and the degree of improvement that is possible. The largest parcels that are currently fully impounded present the potential for greatest addition of new habitat and most substantial improvement over present conditions. Very large parcels that are partially impounded may also provide excellent opportunities. The willingness of the landowners to cooperate with restoration projects has not been assessed, unless noted in the comments.

Naselle River Estuarine Unit Projects

The Naselle River Unit presents a number of opportunities for saltwater wetlands restoration projects. There are 412 acres of fully impounded wetlands, and 306 acres of partially impounded wetlands. The following table presents the restoration projects starting with the highest ranked.

Naselle River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
North of Smith Creek & west of Parpala Rd.	*124 acres*	*TNC, Gray, Hazen, Ring*	
Southern reach, west shoreline, north of Naselle oxbow	*89 acres*	*Matthew, Skyline Land Corp, WA,*	
Southern reach, west shoreline, Naselle oxbow	*61 acres*	*Strange, Skyline Land Corp, unlisted, Evans*	
North of Smith Creek, east of Parpala Rd	*57 acres*	*Hazen, Preston, Crawford, Trent, Cenci, Bear*	*Residential development on hill top*
South of Smith Creek, west of Parpala Rd	*41 acres*	*Ring Pacific, Cathlamet Timber Co*	
North of Ellsworth Slough, south of Parpala Rd	*18 acres*	*TNC, Mid-Valley Resources Inc*	
Clearwater Creek	*14 acres*	*Wilson, Kess, Carlson*	*Residential development*

Partially Impounded

Location	*Size*	*Owners*	*Comments*
South of Smith Creek & east of Parpala Rd.	*144 acres*	*Nordlum, Erickson, Meyer, Moore*	
Southern reach, east shoreline, Naselle oxbow	*126 acres*	*Meyer, Le Masters, Largin, Herrold, Hunter*	
Stanley Pt	*37 acres*	*US, Herrold, Jordan*	

Willapa River Estuarine Unit Projects

The Willapa River Unit presents a number of opportunities for saltwater wetlands restoration projects. There are 1935 acres of fully impounded wetlands, and 467 acres of partially impounded wetlands. The following table presents the restoration projects starting with the highest ranked.

West Section Willapa River Estuarine United: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
North Shoreline Willapa River West of SR 105 Johnson Slough to Mailboat Slough	*697 acres*	*Camenzind, Bale, Runyon, Port of Willapa, Harmer,Lostal, Haueter, Dunsmoor, WDFW,*	
Rose Ranch Willapa South Shoreline Willapa River N of US 101	*424 acres*	*Rose, WDFW, Keller, Lorentson, Strunk, Raymond Church of Nazerene, Rucker,, Anderson, Bascom, Doten, ,*	
Johnson Slough North Shoreline Willapa River North of Airport Access Rd East of SR 105	*303 acres*	*Bale, Camenzind, Port of Willapa*	*188 acres possible stand alone could also combine with 697 acres*
Far West edge Willapa River North Shoreline	*49 acres*	*Burkhalter*	
West edge Willapa River North Shoreline	*22 acres*	*Burkhalter, Rayonier*	
West edge Willapa River North Shoreline	*15 acres*	*Rayonier*	
South of Potter Slough West of US101	*14 acres*	*WDFW, Weyerhaeuser, Iron Lady*	

East Section Willapa River Estuarine Unit: Fully & Partially Impounded Parcels

Location	*Size*	*Owners*	*Comments*
Upstream South Fork Willapa River	*166 acres*	*Runge, Lignoski, WDFW, Weyco Bannish,Gunther, Jergensen, Hatfield, Lund, Antilla, DNR, Elcher*	
Elk Creek North Shore NE of Raymond	*130 acres*	*Davis, Plakinger, Smith, Pacific Count, Murdoch*	*Partially impounded*

North River Estuarine Unit Projects

The North River Unit presents a number of opportunities for saltwater wetlands restoration projects. There are 1779 acres of fully impounded wetlands, and 26 acres of partially impounded wetlands. The following table presents the restoration projects starting with the highest ranked.

East Section North River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
Cedar River North of SR 105	*574 acres*	*Green Diamond, Tucker, Cascade Land Conserv.*	
North River Flood Plain	*324 acres*	*Weyerhaeuser, WDFW*	*Weyco wants to sell*
Freshwater Creek	*43 acres*	*Green Diamond, WDFW*	
Norris Slough	*41 acres*	*Green Diamond*	

West Section North River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
Kindred & Teal Duck Slough	*492 acres*	*Larson, Tucker, Weyco, Blake,Shoalwater Tribe, Green Diamond*	*Fully impounded, Weyco maintains dike*
North Kindred Slough	*118 acres*	*Green Diamond, Shoalwater Tribe*	*Depends on Kindred Slough*
North Teal Duck Slough	*41 acres*	*Tucker, Green Diamond,*	*Depends on Teal Duck Slough*

Palix River Estuarine Unit Projects

The Palix River Unit presents a number of opportunities for saltwater wetlands restoration projects. There are 911 acres of fully impounded wetlands, but no acres of partially impounded wetlands. The following table presents the restoration projects starting with the highest ranked.

North East Section Palix River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
East of Wilson Point West of US 101	*79 acres*	*Harbor Rock, Bowman, Delundian, Graham, Abrams, Lavalee, Thorsteinsson*	
East of Wilson Point East of US 101	*21 acres*	*Weyerhaeuser, WDFW, Shaudys*	*Depends on West of US 101*
East of Wilson Point East of US 101	*5 acres*	*Weyerhaeuser*	*Depends on West of US 101*
Hansen Creek	*8 acres*	*Halvorsen, Econoforest Int'l, Goodin, Gilllies*	
Fruit Growers	*6 acres*	*Fruit Growers Supply*	

SouthWest Section Palix River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
Rose Ranch Palix ***[+ 7 more acres]***	***590 acres***	***Rose, Lake of the Woods, Lagregren, , Stearns, Disney, Fuller*** ***[Patterson, Erickson Gow, Roach, Anderson, Hartman, Patrick]***	***Rose Ranch not interested at this time***
Niawiakum	***56 acres***	***Weyerhaeuser, Massin, Halpin, Shaudys, Smith***	
South Fork Palix	***55 acres***	***Rose, McCohnay, Ortquist, Rayonier***	

Nemah River Estuarine Unit Projects

The Nemah River Unit presents a limited number of opportunities for saltwater wetlands restoration projects. There are 104 acres of fully impounded wetlands, and 176 acres of partially impounded wetlands. The following table presents the restoration projects starting with the highest ranked.

North East Section Palix River Estuarine Unit: Fully Impounded Parcels

Location	*Size*	*Owners*	*Comments*
Rose Ranch Nemah	***93 acres***	***Rose***	
North Nemah	***173 acres***	***Sailor, Wiss, Ziesmer, Carter,Lugibihl***	***Partially impounded***

Bear River Estuarine Unit Projects

The Bear River Unit presents a limited number of opportunities for saltwater wetlands restoration projects. Although there are 1360 acres of fully impounded wetlands, most are owned by the federal government and managed for migratory bird habitat. Other impounded wetlands are part of residential parcels. There are also 375 acres of partially impounded wetlands, The following table presents the restoration projects starting with the highest ranked.

Bear River Estuarine Unit: Fully & Partially Impounded Parcels

Location	*Size*	*Owners*	*Comments*
South Long Beach Honkers	***167 acres***	***Kaino, Honkers, Sparks,***	
Tarlatt Slough	***116 acres***	***USA,***	

Albers to Giles Slough	*67 acres*	*Enyar, Markham, Schoner*	
Northeast of Tarlatt	*45 acres*	*State of WA*	
North of Tarlatt	*45 acres*	*Oman*	
South of Albers	*15 acres*	*Hardisty*	
East of the Bear	*319 acres*	*USA, Pacific West Timber, Bacon,*	

Other Nearshore/Estuarine Limiting Factors

Fish Passage Barriers along the Shoreline

ONRC GIS integrated the most current information available from the Department of Transportation on the status and location of culverts into each estuarine unit GIS system. The locations of the culverts did not always match up with the locations of streams and creeks that they were installed in, suggesting that the baseline hydrology data may also have flaws. In addition, no field survey has been done to assess the status of the culverts as passage barriers to fish. We have been told that the Department of Transportation is in the process of conducting such a survey.

☆ **Restoration Recommendation: Shoreline Barrier Survey and Repair**

WRIA 24 Strategic Plan should strongly advocate completion of the DOT culvert survey and integration of improved information in the state datasets. Once more accurate information is available, WRIA 24 should evaluate and rank the shoreline culverts that pose passage barriers and integrate that ranking into the Strategic Plan.

Information Gaps

The resulting compilation presented in this section should be seen as an effort to present the information sets available at this time, cite their sources; and acknowledge whatever inadequacies and flaws there might be. It is obvious that much less is known about the role of saltwater habitat in the life cycle of salmon species than is known about their use of freshwater habitat. In Puget Sound, a multi-million dollar effort is underway to build a better understanding of the role of nearshore habitat and assess what can be done to restore it. Far less money is likely to be available to study similar issues in Willapa Bay. We have been told that information generated by research in Puget Sound and elsewhere should not be assumed to be applicable to the Willapa Bay ecosystem. Research and monitoring must be done in this system to understand how salmon use this system. The productivity and quality of Willapa's habitat and the relative health of its salmon stocks should not deter major initiatives. In fact, there has always been a compelling counter argument to the current emphasis on spending the lions share of the money in seriously degraded ecosystems. Preserving functioning systems is more certain and less costly than trying to restore ecosystems that are no longer functional.

We also recognize that some important official datasets contain errors. They can only be *officially* modified by the agencies responsible for those datasets. Through assessment projects such as this one, local volunteers could go out into the field and verify or repair incorrect data. Locally modified data, even if known to be more accurate, does not carry the authority of official datasets. This is *not* a problem unique to Willapa Bay data. Looking ahead, the data correction process will likely involve local initiative and volunteer efforts to ground truth information and agency cooperation.

In the course of their analysis of estuarine habitat conditions, the FWCRU team developed a list of important data gaps. Other collaborators have added items to this list. The following is a compilation of the information needs identified through development of this project. It is not exhaustive.

The FWCRU team posed the following as the overall key question for nearshore recovery in Willapa Bay: ***What is the distribution of nearshore habitats in Willapa Bay both in time and space and how do salmonids use these habitats?***

Data gaps were then categorized and spelled out in more detail.

Historical and Present Habitat Conditions

- What are the nearshore habitats in Willapa Bay and how are they connected (i.e., arranged on the landscape)?
- What habitats have been lost?
- Are there changes in geomorphology, hydrology and/or bathymetry and are they important to salmonids?

Habitat Use by Salmonids

- What are the life history and habitat requirements in Willapa Bay?
- What is the residence time of salmonids in different nearshore habitats (e.g., tidal flats, estuarine wetlands, eelgrass meadows)?
- What is the overall residence time of salmonids in Willapa Bay?
- What is the food web ecology in different nearshore habitats?
- What if anything limits growth and survival of juvenile salmonids in Willapa Bay? (e.g., food limited or predation limited?).

Other more specific information needs were noted in various sections of the FWCRU report. In relation to *Spartina* eradication, data is needed on how an area is used by salmon after the *Spartina* has been removed. Another key gap concerns the interactions between native and exotic eelgrasses and their comparative value to salmon.

Eelgrass, Oyster Culture, & Salmon

The WRAC Study identified the following key information needs:

- What are the parameters of eelgrass in "healthy" beds?
- How do eelgrass beds respond after ghost shrimp removal?
- How are eelgrass density and growth rate related?
- How do eelgrass distribution and abundance change over time?
- How do eelgrass change through a crop cycle?
- How do eelgrass and oysters compete for space?
- Does eelgrass recovery consistently occur in the Spring?

☆ Restoration Recommendation: Identify Strategic Information Needs

We recommend that the Pacific County Lead entity acknowledge the need to be strategic in addressing data problems. If feasible, a list of the flaws in the information most important to salmon habitat restoration should be developed as part of the strategic plan. In relation to the estuarine habitat ranking process, we recommend efforts to improve the following information: the status of shoreline culverts as barriers to fish passage; actual presence or absence of fish species in creeks and streams through the watershed; and the distribution of native and non-native eelgrass.

Bibliography

Aitkin, J. K. 1998. The Importance of Estuarine Habitats to Anadromous Salmonids of the Pacific Northwest: A Literature Review. Western Washington Office, US Fish and Wildlife Service, Aquatic Resources Division. Lacey, WA.

Alcock, T. Z. and K. Bennett. 2005. Willapa Bay estuarine ranking – Preliminary geospatial data inventory. University of Washington, Olympic Natural Resources Center, Forks, WA. 31 pp.

Banas, NS, B.M. Hickey, P. Maccready, J.A. Newton. 2004. Dynamics of Willapa Bay, Washington: A Highly Unsteady, Partially Mixed Estuary, American Meteorological Society.

Banas, N.S., B.M. Hickey, J.A. Newton, J.L. Ruesink. 2005. Tidal exchange, bivalve grazing, and patterns of primary production in Willapa Bay Washington, USA. Submitted to Mar. Ecol. Prog. Ser.

Beamer, E.M., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larson, C. Rice, and K. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Skagit River System Cooperative. LaConner, WA.

Borde, A. , R. Thom, S. Rummill, and L. Miller. 2003. Geospatial Habitat Change Analysis in Pacific Northwest Coastal Estuaries. Estuaries Vol. 26, No. 4B, p. 1104–1116.

Brennan, J. S., K. F. Higgins, J. R. Cordell, and V. A. Stamatiou. 2004. Juvenile salmon composition, timing, distribution, and diet in marine nearshore waters of Central Puget Sound in 2001-2002. King County Department of Natural Resources and Parks, Seattle, WA. 164 pp

Clifton, H. E., R. L. Phillips, and R. J. Anima. 1989. Sedimentary facies of Willapa Bay, Washington. Canadian Society of Petroleum Geologists' field guide. Second International Research Symposium on Clastic Tidal Deposits, Calgary, Alberta, Canada. 62 pp.

Dumbauld, B.R., K.M. Brooks, and M.H.Posey. 2001. Response of an estuarine benthic community to application of the pesticide carbaryl and cultivation of Pacific oysters (Crassostrea gigas) in Willapa Bay, Washington. Mar. Poll. Bull. 42:826-844.

Dumbauld, B. R. and S. W. Echeverria. 2003. The influence of burrowing thalasiinid shrimp on the distribution of intertidal seagrasses in Willapa Bay, Washington. Aquat. Bot. 77:27-42.

Dumbauld, B.. J. Ruesink, K. Holsman, G. Hosack, B. Semmens, H. Tallis, H. Li, D. Armstrong, S. Rumrill, V. Poulton, D. Cheney, S. Harbell, and B. Dewey. 2004. The ecological role and potential impacts of molluscan shellfish culture in the estuarine environment. Termination Report to the Western Regional Aquaculture Center (WRAC). Reporting period: April 1st 2003-March 31st 2004. 31 pp.

Dumbauld, B. 2006. Summary of WRAC Study Findings. Personal Communication.

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 23:141-176.

Ferraro, S. and F. Cole. 2006. Benthic macrofaunae habitat associations in Willapa Bay, Washington, USA, Estuarine, Coastal and Shelf Science in press

Gray, A., C. A. Simenstad, D. L. Bottom, and T. J. Cornwell. 2002. Contrasting functional performance of juvenile salmon habitat in recovering wetlands of the Salmon River estuary, Oregon, USA. Restoration Ecology 10: 514-526.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, Vancouver, B. C., Canada. 564 pp.

Grue, C. 2006. Shrimp, Salmon, and Sevin. The big picture. Presentation to the Burrowing Shrimp Conference. February 1, 2006.

Harrison, B.G., Bigley, and R.E., 1982. The recent introduction of the seagrass *Zostera japonica* Aschers. and Oraebn. to the Pacific coast of North America. Canadian Journal of Fisheries and Aquatic Sciences 39: 1642–1648.

Hickey, B.M. and N. Banas. 2003. Oceanography of the U.S. Pacific Northwest Coastal Ocean and Estuaries with Application to Coastal Ecology, Estuaries Vol. 26, No. 4B, p. 1010–1031

Hickey, B.M., S.L Geier,., N.B. Kachel, and A. MacFadyen. In Press 2005. A bi-directional river plume: The Columbia in summer. Cont Shelf Res,.

Hosack, G. R., B.R. Dumbauld, J.L. Ruesink, and D.A. Armstrong. In Press 2006. Habitat associations of estuarine species: Comparisons of intertidal mudflat, seagrass (*Zostera marina*) anbdoyster (*Crassostrea gigas*) habitats. Estuaries and Coasts 29(6):

Hosack, G., B. Dumbauld, I. Fleming, and D. Armstrong. 2006. Juvenile chinook salmon (*Oncorhynchus tswawytscha*) utilization of low-intertidal eelgrass and oyster aquaculture beds. Abstract. Journal of Shellfish Research 25: 740-741.

Litle, Kate and J. Parrish, Eds 2003. Where the River Meets the Sea: Case Studies of Pacific Northwest Estuaries, Kate, Pacific Northwest Coastal Ecosystems Regional Study

ISSG. 2005. Invasive Species Specialist Group - Global invasive species database. *Spartina alterniflora*. http://www.issg.org/database/welcome/ [August 12th, 2005].

Kerwin, J. 2002. Salmon and steelhead habitat limiting factors for the San Juan Islands (WRIA 2). Washington Conservation Commission, Olympia, WA. 123 pp.

Patten, K. 2006. Shorebird usage of Willapa Bay following Spartina control. Poster Presentation to Senator Patty Murray. Willapa Bay, WA.

Phillips, R. C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: A community profile. FWS/OBS-84/24. Performed for the National Coastal Ecosystem Team, U.S. Fish and Wildlife Service. 85 pp.

Sayce, K. 1988. Introduced cordgrass, *Spartina alterniflora* Loisel.,in salt marshes and tidelands of Willapa Bay, WA, Report for the US Fish and Wildlife Service, Willapa National Wildlife Refuge.

Shotwell, J. A. 1977. Changes and uses in Willapa Bay - Volume II. Department of Public Works, Pacific County, WA. 74 pp.

Simenstad, C. A. and J. R. Cordell. 2000. Ecological assessment criteria for restoring anadromous salmonid habitat in Pacific Northwest estuaries. Ecological Engineering 15: 283-302.
2324

Simenstad, C. A., C. D. Tanner, R. M. Thom, and L. L. Conquest. 1991. Puget Sound Estuary Program: estuarine habitat assessment protocol. EPA 910/9-91-037. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, Washington. 201 pp.

Smith, C. J. 1999. Salmon and steelhead habitat limiting factors for the Willapa Watershed (WRIA 24). Washington Conservation Commission, Olympia, WA. 98 pp.

Suzumoto, B. K. 1992. Willapa fisheries enhancement project. Prepared for the Willapa Bay Alliance, South Bend, Washington. 73 pp.

Tallis, H.M., J.L. Ruesink, B.R. Dumbauld, S.D. Hacker, L.M. Wisehart. Differing effects of oyster aquaculture practices on eelgrass density and productivity in a Pacific Northwest estuary. In revision for Estuaries and Coasts.

Thom, R. M., A. B. Borde, S. Rumrill, D. L. Woodruff, G. D. Williams, J. A. Southard, and S. L Sargeant. 2003. Factors influencing spatial and annual variability in eelgrass (*Zostera marina* L.) meadows in Willapa Bay, Washington, and Coos Bay, Oregon, estuaries. Estuaries 26:1117-1129.

Thomas, B. 1995. Ground-water Flow and Water Quality in the Sand Aquifer of the Long Beach Peninsula Washington, by, US Geological Survey Water Resources Investigations Report 95-4026

Redman, S., D. Myers, and D. Averil. 2005. Regional Nearshore and Marine Aspects of Salmon Recovery in Puget Sound, Shared Strategy for Puget Sound, June 28, 2005

Washington State Departments of Agriculture, Ecology, Natural Resources, Fisheries, Wildlife, and Noxious Weed Control Board. 1993. Noxious Emergent Plant Management: Environmental Impact Statement. 204 pp.

The Willapa Alliance. 1998. The Willapa salmon recovery toolbox. The Willapa Alliance, South Bend, Washington.

United States Department of Commerce. 1990. A Special NOAA 20th Anniversary Report: Estuaries of the United States, Vital Statistics of a National Resource Base, NOAA, National Ocean Service.

United States Fish and Wildlife Service 1997. Control of smooth cordgrass (Spartina alterniflora) on Willapa National Wildlife Refuge, Environmental Assessment. Willapa National Wildlife Refuge, Ilwaco, WA.