SUMMARY OF KEY SCIENTIFIC FINDINGS RELATED TO PROTECTION OF FISH AND WILDLIFE HABITAT CONSERVATION AREAS

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August 5, 2009

Note: This summary of scientific findings does not include the September 2008 Biological Opinion issued by the National Marine Fisheries Service as corrected on May 14, 2009 (NMFS Tracking No. 2006-00472). That document provides additional guidance and requirements associated with the protection of endangered salmon and Southern Resident Orca.

References on Stormwater Management, Vegetated Buffers and Land Use Impacts

Stormwater Management Manual for Western Washington, 2005, WA Dept. of Ecology, Publication Numbers 05-10-029 through 05-10-33.

- Stormwater BMPs alone are not adequate to preserve predevelopment water quality.

- Section 1 of the Western Washington Manual discusses its objectives and applicability. The objectives include "provide guidance on the measures necessary to control the quantity and quality of stormwater produced by new development and redevelopment such that they comply with the water quality standards *and contribute to the protection of beneficial uses of the receiving waters*" (paragraph 1 on page 1-1). This same paragraph goes on to say that *"application of appropriate minimum requirements and Best Management Practices identified in this manual are necessary but sometimes insufficient measures to achieve the objective"*.

- The BMPs in the Manual do not cover physical stabilization of stream banks (and presumably banks along shorelines) which is an important function of riparian vegetation (see page 1-5, section 1.5.4, first paragraph).

- Section 1.7 has a good description of the effects of urbanization.

- On page 1-25, Section 1.7.5 has a good discussion on land use decisions and lifestyles. This includes the following:

  "The engineered stormwater conveyance, treatment and detention systems advocated by this and other stormwater manuals can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions. Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue".

A Current Assessment of Urban Best Management Practices, Metropolitan Council of Governments, March 1992.

- *This document outlines the capabilities and limitations of stormwater management practices and includes a comparative assessment of eleven different options.*
- *Major conclusions of the report are:*
  - *Not all Best Management Practices (BMPs) can reliably provide high levels of removal for both particulate and soluble pollutants, and treatment efficiencies vary widely. Effective BMPs include wet ponds, stormwater wetlands, multiple pond systems and sand filters. Infiltration BMPs are presumed to be effective in removing pollutants, but are not reliable given their poor longevity. Other BMPs, such as grassed swales, filter strips and water quality inlets, cannot provide reliable levels of pollutant removal until their basic design is significantly enhanced.*
  - *The longevity of some BMPs is limited to such a degree that their widespread use is currently not encouraged. Of particular concern are infiltration practices such as basins, trenches and porous pavement. The poor longevity of these BMPs is attributable to a number of factors: lack of pretreatment, poor construction practices, application to infeasible sites, and lack of regular maintenance. Often the life spans of these BMPs can be increased to acceptable lengths if communities adopt enhanced designs and commit to strong maintenance and inspection programs.*
  - *No single BMP option can be applied to all development situations and all BMP options require careful site assessment prior to design. Pond options are applicable to the widest range of development situations, but typically require a minimum drainage area. Infiltration practices have very limited application, requiring field verification of soils, water tables, slope and other factors.*
  - *Several BMPs can have significant negative environmental impacts. Pond systems, which offer reliable pollutant removal and longevity, tend to be associated with the greatest number and strongest degree of impacts. Careful site assessment and design are required to prevent stream warming, destruction of natural wetlands and modification of riparian habitat.*

Results of the Nationwide Urban Runoff Program (NURP), Volume 1, Final Report, U.S. Environmental Protection Agency, NTIS Accession Number PB84-185552, Washington D.C., 1983.

- *Over a period of five years, this study evaluated runoff from 2,300 storm events at 81 sites in 28 cities across the nation. Study sites had a broad range of hydrologic, land use, and population characteristics. The study found that pollutant loads from developed areas are most influenced by the amount of rainfall and impervious area, and thus the quantity of runoff.*

Controlling Urban Runoff: A Practical Manual for Planning & Designing Urban BMPs, T.R. Schueler, Metropolitan Council of Governments, Washington D.C., 1987.

- *This document includes a method of estimating stormwater pollutants based on the results of the Nationwide Urban Runoff Program (Schueler's Simple Method). Thomas Schueler used linear regression analysis of NURP data to develop an equation relating imperviousness to runoff and to estimate the quantity of pollutants exported from a site. This procedure is appropriate for stable watersheds, less than one square mile in area, with no active construction and no significant soil erosion.*

Method to Determine Optimal Riparian Buffer Widths for Atlantic Salmon Habitat Protection, Kleinschmidt Associates, Pittsfield, Maine, 1999.

- *The objective of this effort was to provide a scientifically based method of establishing riparian buffers next to streams. Appropriate buffer widths were determined by reviewing the scientific literature describing the relationship between buffer characteristics and buffer effectiveness.*

- *Recommended buffers are broken into two zones:*
  - *Zone 1 is located closest to the stream and is a fixed width of 35 feet in which there should be no disturbance to the soils or vegetation. The primary function of this portion of the buffer is to provide shade, temperature regulation, bank stabilization, and inputs of organic debris, and to act as a final barrier to potential water quality degradation.*
  - *Zone 2 is a variable width extending from 35 feet to the landward edge of the buffer. The primary function of the Zone 2 portion of the buffer is to filter sediment, provide water quality functions, and to protect Zone 1 from higher than natural rates of wind throw. Additional functions of Zone 2 include attenuation of peak stream flows and maintenance of base flows. Activities that can occur within Zone 2 include light recreational use and light tree harvesting that does not jeopardize water quality or wind-firm conditions (guidance is provided on how to accomplish this). Activities that cannot occur within this zone include the creation of impervious surfaces, removal of the organic soil horizon, use of fertilizer or chemicals, significant alteration of the infiltration capacity of the soil, and tree removal sufficient to jeopardize-wind firm conditions. Uses that would compromise the function of Zone 2 include residential and commercial development, septic disposal systems, roads, and agricultural uses.*

- *Tables are provided illustrating appropriate buffer widths based on slope, soil type, and amount of tree canopy, with additional adjustments for other important buffer variables such as surface roughness and the presence of wetlands, surface water features, springs, significant sand and gravel aquifers, and very steep slopes (>25%). The minimum buffer is 70 feet and the maximum is more than 300 feet.*

A Review of the Scientific Lieterature on Riparian Buffer Width, Extent and Vegetation, Seth Wenger, March, Office of Public Service and Outreach, University of Georgia Institute of Ecology, 1999.

- Over 140 articles and books were reviewed to establish a legally defensible basis for determining riparian buffer width, extent and vegetation. Several options are presented including fixed width buffers of 100 feet and buffers with a base width of 50-100 feet plus 2 feet for each 1% slope.

Rutgers, 1989. *Buffer Strips to Protect Water Supply Reservoirs and Surface Water Intakes: A Model and Recommendations.* Cook College, Dept. of Environmental Resources, New Jersey Agricultural Experiment Station, Rutgers – The State University of New Jersey, New Brunswick, NJ. 143 pp.

- This is a comprehensive study of filter strips intended to remove sediment and pollutants that resulted in a slope/ width/ time of travel model for sizing water quality buffers. 650 references were reviewed and 49 of these were used in developing the model. Recommended widths of filter strips ranged from 50 feet (1% slope in forest with heavy ground cover and hay meadow) to 775 feet (15% slope in areas with little vegetation and untilled alluvial fans). Filter strip widths were calculated for overland, sheet flow with additional stormwater treatment practices provided upslope.

Stream-Riparian Ecosystems in the Puget Sound Lowland Eco-region, Christopher W. May, 2003.

- The recommended 30 meter (98 feet) sediment and pollutant removal "riparian management zone" is in addition to implementation of upland stormwater BMPs and the recommendations include, in some cases, an additional buffer to protect the riparian management zone (e.g. in areas with steep slopes or higher intensity land development).

- This report was written for the Puget Sound and includes an extensive review of the science related to riparian areas. While the focus is on stream riparian areas, much of the discussion can be applied to shoreline areas.

- From page 44: "Watershed urbanization, which includes rural, suburban, and urban development, can also have significant negative impacts on the ecological integrity of the stream-riparian ecosystem (May et al., 1997; Leavitt, 1998; May and Horner, 2000; Booth et al., 2001). Little is known about the effectiveness of riparian buffers in mitigating for the cumulative impacts of urbanization, but research indicates that a combination of riparian buffers, land use controls and an aggressive SWM (Stormwater Management??) program may be the best strategy (Horner and May, 1999; May and Horner, 2000; Horner et al. 2002)".

- Page 46 includes the following statement: "In order to balance conservation of our valuable natural resources with the need for continued development, we need a comprehensive management strategy. The use of riparian buffers is only one component in an effective watershed management approach. In addition to buffers along the stream-riparian corridor, we need to improve the effectiveness of our stormwater management best management practices, reduce watershed imperviousness, and retain/enhance natural forest cover throughout our watersheds (May et al., 1997). Ecologically based land use and development practices appear to be our best hope for conservation of our aquatic resources. In managing our watersheds, we should establish conservation and restoration goals that support a properly functioning, natural stream-riparian ecosystem".

- The second paragraph on page 53 includes a discussion on protective actions needed adjacent to riparian management zones. Construction erosion control, stormwater biofiltration BMPs, and in some cases additional buffers are all needed in addition to a designated riparian management zone.

- Page 55 of this report contains a table with recommendations on riparian management zones for streams. While some of the stream riparian functions are not applicable to shoreline riparian areas (e.g. large woody debris recruitment), sediment removal, erosion control and non-point source pollutant removal processes should be the same for streams and shoreline areas. This report recommends a minimum 30 meter (98 ft) riparian management zone, and if I understand the recommendations correctly, an additional buffer to protect this area. The recommendations also specify that a larger riparian management zone and buffer may be required in some cases (e.g. steep slopes and areas where surrounding land use activity is potentially harmful).

- From the summary on page 58: "Due to the pervasive effects of human activities in the watershed, riparian area protection and restoration is not sufficient in itself to maintain healthy stream-riparian function. Management of stormwater runoff and protection of upland forest areas is essential to protect and restore the natural hydrologic regime and the ecological health of stream-riparian ecosystems. Wider riparian corridors (and buffers) may be needed in urban areas with higher intensity land uses than compared to a rural landscape".

K. Lea Knutson and Virginia L. Naef, December 1997. *Management Recommendations for Washington's Priority Habitats – Riparian,* Washington Dept. of Fish and Wildlife.

- This document was also developed in Washington State and includes a comprehensive review of the science related to riparian areas.

- The first paragraph on page 83 includes the following statement: "It is important to recognize that the retention of riparian habitat alone will not mitigate all impacts of upland activities on riparian and aquatic ecosystems. Nor will riparian habitat alone meet the needs of upland species that seek refuge in intact riparian areas when upland habitat is lost (McGarigal and McComb 1992). An integration of riparian habitat protection with watershed management is essential in maintaining diverse fish and wildlife in perpetuity".

- Appendix C on Page 164 lists from several studies, the buffers needed to remove sediment and pollutants from runoff. The buffers from these studies range from 100 – 300 feet (and up to 600 feet for herbaceous or cropland riparian areas –though this generally would not apply to our shoreline property).

Envirovision, Herrera Environmental, and Aquatic Habitat Guidelines Working Group (made up of Washington State agencies involved in habitat protection and Growth Management Act compliance), 2007. *Protecting Nearshore Habitat and Functions in Puget Sound,* Olympia, WA.

- This document presents a summary of what Washington State considers to be the Best Available Science related to nearshore areas.

Levings, Colin and Glen Jamieson, 2001. *Marine and Estuarine Riparian Habitats and Their Role in Coastal Ecosystems,* Fisheries and Oceans Canada, Pg. 8.

- Sediment control is important to fish incubation habitat at all tidal levels.
- All invertebrates are susceptible to smothering or buying be sedimentation rates in excess of natural conditions (including clams and other bi-valves).
- Important values of marine riparian areas include bank stabilization; shading; and filtration/ mineralization of upland runoff and septic system effluent to remove sediment and pollutants, food production, temperature regulation, and wave energy aborption.
- This report includes a discussion of the insects and invertebrates which live in or near marine riparian vegetation, and which serve as food for salmon and other fish.
- The abundance of insects varies depending on the type of vegetation.
- There is a statistically significant difference beween insects caught in areas where shoreline vegetation has been removed, and those where it has been retained.
- All marine riparian vegetation has an intrinsic value of providing stability and ecosystem integrity through direct or indirect means.
- Riparian vegetation on stable beaches maintains a soft shoreline by absorbing and reflecting wave energy in root systems and exposed woody structures. If the shoreline is hardened,

more wave energy is reflected which results in steepening of the shore and winnowing of finer sediment. A changes ecosystem results.
- Setback distances to shoreline vegetation need to be wide enough to prevent trees from blowing down and/or uprooting during storms
- Table 7 in this reference identifies the sensitivity of various intertidal habitats to different types of sediment.

Levings, C.D. 1994. *Feeding behavior of Juvenile Salmon and Significance of Habitat During Estuary and Early Sea Phase,* Nordic Journal of Freshwater Research, 69: 7-16
- Higher elevation beach habitats submerged at high tide, immediately below riparian vegetation, are clearly recognized as rearing and migratory habitat for juvenile salmonids in the Pacific region. There is evidence use of this habitat confers survival value by virtue of food provided and refuge functions.

Cameron, G.N. 1972. *Analysis of Insect Trophic Diversity in Two Salt Marsh Communities,*. Ecology 53: 58-73.
- Detritus from trees and shrubs is a key energy supply for invertebrates.

Levings, C.D. and A.I. Moody, 1976. *Studies of Intertidal Vascular Plants, Especially Sedge on the Disrupted Squamish River Delta, British Columbia,* Fisheries Marine Service Technical Report 606: 56 p.
- Algae and vascular plants at the base of the food web are negatively affected by excess sediment.

Richardson, J.S., 1992. *Coarse Particulate Detritus Dynamics in Small, Montane Streams of Southwestern British Columbia.*, Canada Journal of Fisheries Aquatic Science, 49:337-346.
- Discusses importance of detrital food webs.

Morgan, J.D. and C.D. Levings, 1989. *Effects of Suspended Sediment on Eggs and Larvae of lingcod, Pacific herring, and Surf smelt,* Canada Technical Report Fisheries Aquatic Science, 1729: 31 p., 1989.
- Incubating Surf smelt eggs are sensitive to suspended sediment (>.5 mg/l).

Penttila, Daniel A., 2002. *Effects of Shading Upland Vegetation on Egg Survival for Summer Spawning Surf Smelt on Upper Intertidal Beaches in Puget Sound.* Proceedings of the Puget Sound Research 2001 conference, Puget Sound Water Quality Action Team, Olympia, WA.
- Shading terrestrial vegetation (i.e. canopies of full size deciduous trees) has a positive effect on the survival of surf smelt spawn incubating in sand gravel beaches in the upper intertidal zone during the summer months in the Puget Sound basin.

Kerr, S., 1995. *Silt, Turbidity and Suspended Sediments in the Aquatic Environment*, Ontario Ministry of Natural Resources.
- This reference has detailed information on physical and chemical processes and impacts on water quality, light penetration, aquatic plants, invertebrates, and fish

Mumford, Thomas F., 2007. *Kelp and Eelgrass in Puget Sound,* Puget Sound Nearshore Partnership Technical Report 2007-05, Seattle District, U.S. Army Corps of Engineers, Seattle, WA.
- Sediment can readily smother the microscopic stages of kelp and human impacts probably consist largely of processes that increase sedimentation in shallow waters. A variety of

impacts affect eelgrass including docks, which shade the bottom; increased nutrient inputs to the nearshore, which can cause plankton blooms or excess growth of eelgrass epiphytes (?) both of which can reduce the ability of eelgrass to get enough light; and numerous aquaculture activities which compete for space. Toxics, such as metals and crude oil directly impact eelgrass and kelp. Low oxygen and the related high sulfide levels in sediments also impact eelgrass.

Kurt Fresh, 2006. *Juvenile Pacific Salmon in Puget Sound,* Puget Sound Nearshore Partnership Report No. 2006-06. U.S. Army Corps of Engineers, Seattle, WA.

- During their transition to salt water, juvenile salmon occupy nearshore ecosystems in Puget Sound. This period of transition is critical to the viability, persistence and abundance of Puget Sound salmon.
- Restoring and protecting nearshore habitats must be a part of efforts to rebuild depleted salmon runs throughout this region.
- Puget Sound salmon listed as threatened under the Endangered Species Act include 22 populations of Chinook salmon that spawn east of the Elwha River, and two populations of chum that spawn in the Hood Canal and eastern Strait of Juan de Fuca.
- Much of what is known about salmon is probably based on hatchery produced fish, which may use habitat differently than wild fish.
- Our understanding of salmon habitat use has been shaped by the condition of the habitats studied and the populations of salmon using them.
- Salmon abundance in shoreline areas of the Puget Sound peaks in June and July, though some are present through October.
- Optimal conditions for smaller juvenile Chinook salmon (,70 mm) include low gradient, shallow water, fine grained substrates, low salinity and low wave energy.
- Once juvenile Chinook leave estuarine/ delta habitats they distribute widely and can probably be found along all stretches of shoreline as some point during the year.
- As with Chinook, juvenile chum salmon occupy non-natal estuaries during their migration from Puget Sound.
- Small chum fry appear to migrate primarily along the shoreline in shallow water less than 2 meter deep. Use of shallow water habitats relates to predator avoidance and prey availability.
- When present in shallow water habitats juvenile chum <60 mm consume primarily epibenthic invertebrates, which are associated with protected, fine grained substrates and often eelgrass. As they increase in size their habitat use expands to nearshore surface waters.
- Juvenile salmon feed in all habitats they occupy and use prey that originate from a wide array of sources including pelagic (open water), benthic (bottom), and terrestrial sources. These prey originate from a complex series of interactions that involve the processing and conversion of organic matter and nutrients into prey that are eaten by salmon.
- Nearshore food webs depend upon inernally derived sources of organic matter (e.g. eelgrass).
- A variety of factors affect feeding and growth including habitat characteristics, fish size, temperature, turbidity, tidal convergence zones, time of year and climate.
- Salmon are preyed on by a wide variety of fish, birds and mammals during their nearshore residence.
- High levels of turbidity and shallow water may help reduce predation on juvenile salmon.
- Other factors affecting nearshore habitat include water temperature, salinity, dissolved oxygen, connectivity of habitat, vegetation composition, vegetation height, prey abundance and composition, and predator abundance.

- The integrity of nearshore habitats as a whole have a profound effect on the ability of salmon to journey to and from ocean feeding areas.
- The distribution and configuration of eelgrass may be important to chum salmon fry.
- In general use of nearshore areas by Chinook salmon is not well understood.
- Table 4 summarizes functional responses of salmon to actions in nearshore ecosystems.
- Stormwater and wastewater can reduce dissolved oxygen levels, increase contaminant levels, cause scouring from increased runoff, alter beach hydrodynamics, change plant/ animal assemblages (e.g. cause macroalgae blooms) and harm eelgrass beds. These changes can result in reduced prey and habitat for salmon, and cause tumors and lesions.
- Loss of shoreline vegetation results in reduced input of nutrients to support the food web, increases in erosion and sedimentation, loss of shade and large woody debris, and increases in water temperature. These changes can result in reduced prey and increased predation.

Wylie-Echeverria, Tina. Best Available Science for Salmon and Salmon Habitat in San Juan County, Nov. 2008.

- Adult and juvenile salmon are present in the San Juans and different nearshore habitats are used differently by each salmon species.
- Predation around over water structures does not appear to be greater than open areas.
- Over water structures do not impede fish migration but may change the pathway of some fish (juvenile salmon avoid swimming under docks).
- Juvenile salmon tend to follow prey, and to use the middle of the upper kelp habitat more than unvegetated habitats.
- Overwater structures that affect eelgrass do affect salmon because of reduced availability of prey and cover.
- For docks less than 10 ft. above eelgrass beds there are some effective light enhancement technologies (e.g. Sun Tunnel and grating).

Feeding behavior of Juvenile Salmon and Significance of Habitat During Estuary and Early Sea Phase, C.D. Levings, 1994, Nordic Journal of Freshwater Research, 69: 7-16

- Higher elevation beach habitats submerged at high tide, immediately below riparian vegetation, are clearly recognized as rearing and migratory habitat for juvenile salmonids in the Pacific region. There is evidence use of this habitat confers survival value by virtue of food provided and refuge functions.
- Juvenile salmon find food and refuge in nearshore areas.

Nutrition and Feeding Habits of Pacific Salmon in Relation to Life History Stage. D.A. Higgs, J.S. Macdonald, C.D. Levings, B. Dosanjh, in R. Brett, W.C. Clarke, K. Groot, and L. Margolis [ed.], 1995. Physiological Ecology of Pacific Salmon, University of British Columbia Press, Vancouver, BC, p. 161-315.

- Insects from shoreline vegetation are an important part of the juvenile salmon diet.

Beamer, E., R. Henderson, A. McBride, and K.W. Wolf, 2003. *The Importance of Non-natal Pocket Estruaries in Skagit Bay to Wild Chinook Salmon: An Emerging Priority for Restoration.* Skagit River System Cooperative, Research Dept., La Connor, WA.

- Connected lagoons and small stream mouths along the shores of Puget Sound (pocket estuaries) are important habitat for migrant Chinook fry.

Dethier, M., 2006. *Native Shellfish in Nearshore Ecosystems of Puget Sound*. Puget Sound Nearshore Partnership Report No. 2006-04. Army Corps of Engineers, Seattle, WA.

- Factors affecting shellfish include water quality (particularly insecticide and heavy metals which are especially harmful to crabs), silt, turbitity, reductions in dissolved oxygen and changes in temperature and salinity. Dungeness crab prefer higher salinity waters. Changes in sediment size or supply can reduce settlement, growth or result in death. Increases in very fine sediment can smother filter feeders except crabs. Several species have larvae that cannot settle or survive on very fine sediments. Reduction in naturally occurring levels of fine sediments can also negatively affect species using mixed substrates.

References Related to Seagrass, Salmon and Overwater structures:

Mumford, Thomas, 2007. Kelp and Eelgrass in Puget Sound, Puget Sound Nearshore Partnership Technical Report 2007-05, Seattle District, U.S. Army Corps of Engineers, Seattle, WA.

- A variety of impacts affect eelgrass including docks, which shade the bottom.

Fresh, Kurt, 2006. Juvenile Pacific Salmon in Puget Sound, Puget Sound Nearshore Partnership Report No. 2006-06. U.S. Army Corps of Engineers, Seattle, WA.

- Over water structures affect salmon by changing sediment transport, altering beach sediment size and type, reduding light penetration into the water, and negatively effecting eelgrass. This results in reduced prey for salmon, loss of refuge habitat, increased predation, and altered migration behavior.

Fresh, Kurt L., Tina Wyllie-Echeverria, Sandy Wyllie-Echeverria and Brian Williams, 2006. Using Light Permeable Grating to Mitigate Impacts of Residential Floats on Eelgrass Zostera marina L. in Puget Sound, WA., Ecological Engineering 28, Pg. 354-362.

- A decline in eelgrass shoot densities was underneath three floats and adjacent to two floats (with eelgrass being eliminated under one float). There was a weak relationship between eelgrass bed quality and percent of the deck grated but no relationship when the range of grating was 12-50%. Conclusions are either there was no effect of grating up to 50% of a float deck or an effect could not be detected. The large number of site and landscape scale variables associated with a float may have influenced the effect of any one variable or the ability to detect it.

Wylie-Echeverria, Tina. Best Available Science for Salmon and Salmon Habitat in San Juan County, Nov. 2008.

- Adult and juvenile salmon are present in the San Juans and different nearshore habitats are used differently by each salmon species.
- Predation around over water structures does not appear to be greater than open areas.
- Over water structures do not impede fish migration but may change the pathway of some fish (juvenile salmon avoid swimming under docks).
- Juvenile salmon tend to follow prey, and to use the middle of the upper kelp habitat more than unvegetated habitats.
- Overwater structures that affect eelgrass do affect salmon because of reduced availability of prey and cover.
- For docks less than 10 ft. above eelgrass beds there are some effective light enhancement technologies (e.g. Sun Tunnel and grating).

Thom, Ronald. A Review of Eelgrass Transplanting Projects in the Pacific Northwest.

- Eelgrass meadow establishment is difficult but not impossible.
- 11 of 17 projects evaluated were successful (eelgrass survived in at least part of the site).
- Survival and growth of transplanted eelgrass does not mean that a functionally performing eelgrass meadow has been achieved.
- Smaller projects are more successful.
- Plots protected from wave disturbance and receiving adequate light are most successful.
- Selecting a good site is important – though if there is no existing seagrass there is probably a reason.
- The technology for transplanting eelgrass is in the trial and error stage in the Northwest.
- It is premature to conclude that eelgrass transplanting can reliably mitigate for impacts on natural eelgrass meadows.
- More information is needed.

Wylie-Echeverria, Sandy. Seagrass Report to Critical Areas Citizens Review Committee, Dec. 2008.

- Construction of residential docks can result in the loss of seagrass.
- There are many factors that can effect seagrass.
- More information is needed.

Dethier, M., 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-04. Army Corps of Engineers, Seattle, WA.

- Factors affecting shellfish include shoreline armoring and changes to eelgrass beds. All shellfish described in this report have distinct types of sediment in which they recruit and grow the best, and any process that alters sediment amount, grain size, organic content etc. may negatively effect them. Dungeness crab are found abundantly in nearshore subtidal and intertidal zones, on substrates ranging from mud to clean sand or gravel. Juveniles feed on small mollusks and crustaceans; adults eat mostly clams along with crustaceans and fish. Crab larvae are eaten by coho, chinook salmon, and rockfish. Benthic juveniles are eaten by a wide variety of fish. Red rock crab occur in sandy, muddy and gravelly bays. Eelgrass beds are a particularly important habitat for both species of crab.

References Related to Bulkheads and Shoreline Stabilization Structures:

Envirovision, Herrera Environmental, and Aquatic Habitat Guidelines Working Group (made up of Washington State agencies involved in habitat protection and Growth Management Act compliance), 2007. Protecting Nearshore Habitat and Functions in Puget Sound, Olympia, WA.

- This document presents a summary of what Washington State considers to be the Best Available Science related to nearshore areas.

Kurt Fresh, 2006. Juvenile Pacific Salmon in Puget Sound, Puget Sound Nearshore Partnership Report No. 2006-06. U.S. Army Corps of Engineers, Seattle, WA.

- Shoreline armoring affects beach habitats used by salmon, reducing prey density, increasing predation, and altering migration routes.

Levings, Colin and Glen Jamieson, 2001. Marine and Estuarine Riparian Habitats and Their Role in Coastal Ecosystems, Fisheries and Oceans Canada, pg. 8.

- Riparian vegetation on stable beaches maintains a soft shoreline by absorbing and reflecting wave energy in root systems and exposed woody structures. If the shoreline is hardened, more wave energy is reflected which results in steepening of the shore and winnowing of finer sediment. A changes ecosystem results.

Rice, Casimir A., 2006. Effects of Shoreline Modification on a Northern Puget Sound Beach: Microclimate and Embryo Mortality in Surf Smelt, Estuaries and Coasts, Vol. 29, No. 1, p. 63-71.

- The proportion of smelt eggs containing live embryos on altered beaches was approximately half that of natural beaches.

Dethier, M., 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-04. Army Corps of Engineers, Seattle, WA.

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<u>General References</u>

Levin, Simon A. and Jane Lubchenco, 2008. *Resilience, Robustness and Marine Ecosystem-based Management,* BioScience, Vol. 58 No. 1.

- Marine ecosystems provide essential services to humans; yet these services have been diminished and their future sustainability endangered, by human patterns of exploitation that threaten system robustness and resilience. In marine ecosystems, small changes can be magnified through nonlinear interactions, facilitating regime shifts and collapses. Protection of the services these ecosystems provide must therefore maintain the adaptive capacities of these systems by preserving a balance among heterogeneity, modularity, and redundancy.