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Where the wild fish are: Natural isotope indicators of juvenile Chinook life histories in the Columbia River estuary

With the listing of many Columbia River salmon (*Oncorhynchus* spp.) populations under the Endangered Species Act, major recovery efforts have been enacted to restore diminishing wild stocks. In addition to declines in salmon abundance, biological and physical changes in the river system have led to the simplification of life history diversity among wild populations. Preserving diversity among remaining life histories is vital to the resilience and productivity of wild populations. Use of natural stable isotope ratios to identify origins and life history patterns of fishes presents a promising approach to answering vital questions concerning the life history structure of salmon populations. The goals of this study are to reconstruct life histories and identify origins (hatchery vs. wild) of juvenile Chinook (*O. tshawytscha*) in the Columbia River estuary. We are examining the habitats of origin, movement, residency times, and food-web linkages of fish through the use of stable isotopes ratios of carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$), and sulfur ($\delta^{34}\text{S}$) in liver and muscle tissues. Our analysis shows that there are temporal, spatial, and size-specific differences in the life history strategies expressed by populations utilizing the estuary. Ultimately, this work will be used in conjunction with a larger study concerning the role of the Columbia River estuary in the decline and recovery of salmon.

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The Boundaries Project: Mapping Washington’s shoreline for public accessibility and public ownership

The Boundaries Project is a GIS project to identify the location and length of publicly accessible marine shoreline in the state of Washington. Currently, it is unknown how much of Washington’s approximately 3000 miles of shoreline is accessible and owned by the public. This information is scattered amongst various government agencies and the quality is variable. The Boundaries Project, scheduled to be completed in 2006, will combine this scattered data and create one GIS layer that answers many of these questions about ownership and public accessibility. The data will also combine information from the ShoreZone classification project (Nearshore Habitat Group, WADNR, 1994-2000), a geospatial dataset summarizing the physical and biological characteristics of the shoreline. With this data combination, we can answer big picture spatial questions about the distribution of biological communities, geological features, and anthropogenic development amongst public shoreline in Washington. This presentation will exhibit the many potential uses for this dataset ranging from identifying public beaches for playing, to mapping spill response routes. How many miles of publicly accessible shoreline are in each County? How many miles of public shoreline have aquatic vegetation and are armored? These questions and more can be answered using the Boundaries dataset.

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Using historical data to explore trends in floating kelp along the Strait of Juan de Fuca and outer coast of Washington State

Floating kelp beds (*Nereocystis luetkeana* and *Macrocystis integrifolia*) are important nearshore habitats that support commercial and sport fish, invertebrates, marine mammals and marine birds. Information on the historical and current distribution of kelp is needed in order to monitor this protected resource. To investigate long-term temporal trends in floating kelp in Puget Sound, we compared historical maps delineated in 1911 and 1912 to aerial photography collected between 1989 and 2004 along the Strait of Juan de Fuca and the Outer Coast of Washington State. Results show apparent changes in kelp distribution over two time periods -- over the last century and during the last 15 years. However, apparent changes must be interpreted cautiously due to limitations associated with available data. Therefore, we also examine the limitations of our change detection capability and how this affects the interpretation of our results.

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Plankton dynamics of the lower Columbia River estuary

In January, 2005 we initiated a multi-year field study to investigate several aspects of the plankton dynamics in the lower Columbia River estuary, with particular emphasis on non-indigenous species and freshwater flow effects. Our sampling design consisted of three types of surveys: i) monthly sampling at 5 locations ranging from 180 km upstream to the mouth of the estuary, ii) four broad-scale surveys near the mouth of the estuary (two each in June and August, corresponding to high and low river flow periods, respectively), and iii) sampling every 3 hours over a full tidal cycle in August. We sampled hydrography, chlorophyll, nanoplankton, microplankton, and mesozooplankton at each station. The dominant microplankton groups were diatoms (*Asterionella formosa*, *Fragllaria crotonensis*, and *Synedra* spp), dinoflagellates (*Gonyaulax* sp.) and aloricate ciliates (*Mesodinium* sp.). Dominant mesozooplankton taxa included the copepods *Eurytemora affinis* and *Coullana canadensis*. Two species of non-native copepods were also observed: *Pseudodiaptomus forbesi* and *Sinocalanus doerri*. Results suggest a strong seasonal cycle, with spring blooms of diatoms and copepods, followed by compositional shifts in summer toward flagellates, ciliates and other copepods. With respect to freshwater flow, both biomass and abundance of microplankton were higher in June (high flow) than in August (low flow).

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Evaluating factors contributing to tidal wetland community distribution in the Columbia River estuary

Tidal wetland communities are affected by numerous physical controlling factors. These factors include elevation, hydrology, salinity, sediment type, light, and exposure to waves. Information on how these factors affect the distribution of tidal vegetation communities is not available for many parts of the Lower Columbia River (LCR). In 2005, field data on vegetation and controlling factors were collected at 11 sites in three regions of the LCR as part of a long-term habitat monitoring study and as baseline data for assessing the cumulative effects of restoration in the LCR. As LIDAR data (Light Detection and Ranging; large scale elevation data collection method) and remote sensing products become more widely available, elevation and vegetation data can be used to extrapolate vegetation community distribution throughout the LCR. Correlating vegetation communities with elevation data can also aid in planning and designing restoration projects by providing a tool for predicting vegetation colonization after a restoration action. We hope to develop a comprehensive database on wetland vegetation communities and their associated controlling factors throughout the LCR.

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A comparison of coastal wetland inventories of British Columbia

There are several coast-wide wetland inventories for the British Columbia coast and a few more localized wetland inventories. We compared these inventories in terms of (a) number of coastal wetlands identified (i.e. point features), (b) wetland shoreline lengths associated with each inventory and (c) estimated wetland areas. Three areas were compared: the Gulf Island National Park shoreline (332 km), Clayoquot Sound shoreline (1,300 km) and Haida Gwaii (Queen Charlotte Islands (5,000 km). The Pacific Estuarine Conservation Program (PECP) inventory and ShoreZone inventories exist for all three locations and show substantial differences in number, length and area. For example, in the 1,600 km of Clayoquot Sound, ShoreZone identified 73 wetlands spanning 143.8 km (9.0%) of shoreline; no areal estimates are included in this ShoreZone dataset. PECP, which focused on larger estuaries only, mapped 16 estuaries, 3 of which mapped with wetlands that span 7.3 km of shoreline and encompass 36.1 Ha. The analysis demonstrates that, for the time being, linear extent is the primary metric for “measuring” wetland occurrence, and that no single system provides an accurate areal extent of wetlands in the province.

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Water quality properties of south Puget Sound basin: Spatial and annual observations 1997-2004

The southern basin of Puget Sound (south of the Tacoma Narrows) is characterized by slow residual circulation with a shallow entrance sill and deeper water landward. Human population in the adjoining watershed is projected to continue to increase steadily, bringing increased development, deforestation, and shoreline impacts. Climate impacts can have a more intensive effect on this basin compared to the main basin of Puget Sound because it is shallower. Thus, there is a need to monitor and assess the water quality conditions of South Puget Sound inlets and passages more frequently than current monthly surveys allow. The Washington State Dept. of Ecology is addressing this issue through South Puget Sound Marine Environmental Modeling (SPSMEM) project. As part of this effort, we collected synoptic measurements of basic water quality properties during several cruises from 1997-2004. Sections of temperature, density, nutrients, dissolved oxygen, and chlorophyll levels were created using MATLAB. The data reveal sporadically patchy areas of high chlorophyll levels, low surface nutrients and episodically low dissolved oxygen levels. We present spatial and annual plan views of variation in these properties with identification of the areas with continued sensitivity to eutrophication, drought and climate impacts.

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Assessment of seed collection as a method of *Zostera marina* restoration in small costal embayments in San Juan County

In recent years a decline of *Zostera marina* occurred in several small embayments in San Juan County. These costal embayments suffered losses between 1995 and 2004. Because of the decline of *Z. marina* we felt it was important to initiate a pilot study on possible reseeding methods of *Z. marina*. We sampled of three bays; Shallow bay (Sucia Island), False Bay (San Juan Island), and Picnic Cove (Shaw Island.) We haphazardly collected 400 flowering shoots during the low tides of September, 2005. The seeds were left to mature in a culture system. After twenty days we sieved the bottom material and found 2,025 seeds. A sub-sample of seeds was then tested with tetrazolium chloride for viability. There are several reasons we wanted to conduct this study. This type of study is common place for East Coast students but we are the first high school in the Puget Sound to perform such a study. The pilot study presented here is a base line for future studies.

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The interactive effects of propagule pressure and disturbance regulate invasion by the Japanese seaweed *Sargassum muticum*

Ecologists have identified several factors that exert strong controlling influences on the invasion process. However, understanding how these processes interact to control invasions remains a major challenge in ecology. I used a factorial field experiment to investigate how the number of propagules released (i.e. propagule pressure) and disturbance influenced invasion by the Japanese seaweed *Sargassum muticum* in subtidal marine communities of the San Juan Islands. *Sargassum* recruitment was propagule and space limited. Disturbance enhanced survivorship of new recruits, probably because competition with native algae was reduced. Although most plots had at least some *Sargassum* recruitment initially, *Sargassum* was absent from many plots one year after initial invasion. I calculated the probability of successful invasion (defined as the presence of one or more *Sargassum* in a plot 1 year after invasion) in each of the treatment combinations and found that disturbance decreased the level of propagule pressure necessary to ensure invasion success. However even undisturbed plots had a high probability of invasion once the level of propagule pressure exceeded that produced by an average sized *Sargassum* adult. These results suggest that anthropogenic activities that both disturb habitats and disperse propagules will greatly increase the risk of invasion in natural systems.

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Prioritizing tidal wetland conservation and restoration in midsized estuaries of Oregon, U.S.A.

About 70% of Oregon's tidal wetlands have been lost or converted to other habitat types since the 1850s. We developed a prioritization protocol to help local Watershed Councils plan for non-regulatory tidal wetland conservation and restoration, and applied the protocol in five Oregon estuaries: Nehalem, Yaquina, Alsea, Siuslaw, and Umpqua. Goals included: 1) Provide a tool for strategic planning rather than "opportunistic" restoration; 2) Use an ecosystem approach rather than a project-based approach; 3) Provide education on the suite of historic habitat types; 4) Strive for a high-visibility project; actively seek input from local residents and resource experts to increase accuracy and raise public awareness of estuarine resources. Prioritizations were conducted within each individual estuary and were comprehensive, including emergent, scrub-shrub and forested wetlands from ocean to head of tide. Prioritization criteria emphasized habitat connectivity and diversity, historic landscape change, and alteration intensity. Supplementary analyses (land ownership, site vulnerability) were applied as filters after prioritization. Site characterization used existing GIS data and new data generated through aerial photograph interpretation, field reconnaissance, and local knowledge. Products included detailed tables allowing users to "drill down" to individual site characteristics, re-rank sites for different purposes, add new criteria or data, and track projects.

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Distribution of eelgrasses and macroalgae in Padilla Bay, Washington in 1989, 2000, and 2004

Eelgrasses (*Zostera marina* and *Z. japonica*), macroalgal beds (primarily *Ulva* spp. and *Enteromorpha* spp.), and intertidal flats without macro-vegetation were mapped in Padilla Bay, Washington in 1989, 2000, and 2004. True color aerial photographs were taken during an extreme summer low tide event each year. Photointerpretation and ground truth investigations (at 100, 250 and 1360 sites respectively) were combined each year with different methods of digitizing and georectification to produce distribution maps of vegetation in Padilla Bay. For 1989, photointerpretation and mapping were conducted with a zoom transfer scope onto enlarged USGS quads. For 2000, the aerial photos were scanned, georectified and mosaicked using ArcView 3. Delineation was done on-screen using the Habitat Digitizer extension. For 2004, the aerial photos were orthorectified and mosaicked by an outside contractor. Delineation was done on-screen in ArcGIS 9. Comparisons were made among years in the total area covered by vegetation, in the distribution of individual species, and in the gains and losses in local sub-areas of Padilla Bay. Eelgrasses consistently covered 3-4000 hectares of intertidal and subtidal flats in Padilla Bay, with inter-annual variation most pronounced on the intertidal flats above mean water.

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Restoration of seagrass communities using seeds: Conservation issues

Several studies document a global decline of seagrass populations over the last 40 years. Because these marine flowering plants directly contribute to nearshore productivity and biodiversity, there is cause for concern. A trait common to all flowering plants is the production of seeds to inoculate available habitat and, in some cases, re-populate areas previously inhabited. Recognizing this fact and based on early experimental work (Massachusetts [1947] and Long Island [1978]) several projects are underway to restore areas in the Chesapeake Bay, Narragansett Bay, RI, Long Island, NY and, more recently, San Francisco Bay using an array of techniques including hand broadcasting, mechanical insertion and seed buoys. While programs to restore damaged populations of *Z. marina* using seeds are increasing, attention has focused primarily on environmental factors that influence successful recruitment leaving issues related to collection, processing, storage, and restoration success less fully researched. Moreover the ecosystem impact of removing and relocating large quantities of seed either on the extant seagrass population or secondary consumers has not been evaluated. Our objective is to discuss conservation issues associated with seagrass seeding programs from collection to recruitment monitoring, thereby providing a framework for all seagrass seeding programs.

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How mud shrimp *Upogebia pugettensis* (Dana, 1852) got big new bumps

The bopyrid isopod parasite *Orthione griffenis* Markham, 2004 was introduced to North America from Asia with ballast water within the last 25 years. *Orthione* infests over 50% of the reproductive sized mud shrimp in Oregon and Washington estuaries that have been examined. An extreme mud shrimp population decline in Willapa Bay, WA after 2001 is closely associated with increasing *Orthione* abundances that began after 1997. The near absence of egg production by mud shrimp infested with *Orthione* indicates that this blood parasite effectively castrates hosts. Energetic costs of *Orthione* on mud shrimp were estimated from relative parasite and host weights. Severe effects of *Orthione* presence on hosts weight are poorly correlated with relative parasite weight *Orthione* thus appear to produce negative costs to hosts beyond blood losses and castration. *Orthione* appear to be a major new source of *Upogebia* reproductive losses and mortality and therefore a major new introduced species altering northeast Pacific soft-bottom estuary ecosystem dynamics. This first record of an introduced parasitic isopod "jumping" to a new native host is unlikely to be the only case in the world.

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Invasive tunicates in Puget Sound: An early warning system

Two invasive species of tunicates (sea squirts) have been introduced into Puget Sound recently. Both tunicates, *Didemnum* sp. and *Styela clava*, show a preference for hard surfaces of natural and anthropogenic origin. Each has the potential to wreak havoc in the environment and the economy, smothering native organisms, disrupting shellfish operations, and degrading recreational opportunities. Experience with these organisms from other regions, as well as observations in the Northwest indicate that populations of these tunicates can increase dramatically and are easily spread by water currents, recreational boating, and other human activities. At the request of the State of Washington, Washington Sea Grant Program undertook an effort to train recreational divers to identify and report sightings of the tunicates. The on-line reporting mechanism feeds into a GIS layer maintained by Puget Sound Action Team and new sightings are reported to Washington Department of Fish and Wildlife for action. WSGP organized a demonstration project to assess the potential for eradication of *Styela clava* from an infested marina using volunteer divers.

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How does geoduck aquaculture affect eelgrass in south Puget Sound?

Geoduck (*Panopea abrupta*) aquaculture happens on a large scale in south Puget Sound in some of the same areas that harbor eelgrass (*Zostera marina*), a protected species in Washington. It is crucial to understand the impacts of geoduck aquaculture on eelgrass to make informed management decisions. In long-term surveys, eelgrass showed strong seasonal patterns in the following variables: prolific branching of the rhizome in spring; high density, individual plant biomass, and internode length in summer; and high growth rates in summer, except during periods of heat stress. We experimentally tested how eelgrass responded to nutrients, disturbance, and geoducks by manipulating each of these factors. The presence of geoducks reduced eelgrass densities by 50%, but only in summer. Recovery of small (1 m²) removals of eelgrass occurred slowly (>17 mo) and exclusively by vegetative growth. There was no detectable effect of any treatment on eelgrass growth, although the presence of geoducks increased porewater ammonium by 20%. The overall porewater nutrients were high and possibly not limiting for eelgrass. Our small-scale results were mirrored in samples from aquaculture beds, which had higher porewater nutrients than with eelgrass. Our results suggest limited impacts on eelgrass of geoducks themselves, but lingering effects of aquaculture practices that involve substantial disturbance of eelgrass.

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An ethnobotanical study of the Kwakwaka'wakw traditional harvesting of eelgrass, *Zostera marina* L.; Zosteraceae

The Kwakwaka'wakw First Nation of the Pacific Northwest once gathered *Z. marina* rhizomes (ts'ats'ayem) for food, and recognized extant eelgrass meadows as an important component of nearshore productivity and biodiversity. Contemporary elders recall harvesting considerable quantities of the plants with 'twisting sticks' every spring, and have suggested that the *Z. marina* rhizomes grow thicker and the meadows more productive when sites are routinely harvested. As rhizome growth is the foundation for *Z. marina's in situ* clonal expansion, and because it is well recognized in terrestrial systems that injury to the clonal plants can promote 'compensatory growth' (a positive growth response to damage), an analysis of Kwakwaka'wakw ts'ats'ayem harvesting as a method of promoting meadow development was undertaken. The study consists of two parts: 1) interviews and harvesting expeditions with elders to inform the mimicking of harvesting procedures and techniques; and 2) a controlled experiment within an extant *Z. marina* meadow to examine the potential growth response after rhizome removal and fragmentation due to harvesting. This interdisciplinary approach, drawing from the fields of ethnobotany and ecology, integrates western science and traditional knowledge to provide insights for a holistic framework for ecosystem management.

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Assessing the ecological connectivity of eelgrass habitats and protected areas: A tail of the population genetic structure of the bay pipefish, *Syngnathus leptorhynchus*.

Populations require a network of interconnected habitats to maintain biological processes such as reproduction. Defining the spatial scale and patterns of exchange among interbreeding groups is critical to establish breeding units and population boundaries. Investigating genetic connectivity (dispersal) of individuals among habitat patches is an effective way to measure these population parameters and assess the ability of protected areas to maintain population processes. Eelgrass habitats play a critical role for nearshore and offshore marine ecosystems as nurseries, spawning habitats, and as habitat for resident species. Locally, significant losses of eelgrass habitat have been documented and ultimately these losses will affect ecological function and species diversity. Monitoring eelgrass habitat function can be achieved by studying populations of such eelgrass specialists as the bay pipefish, *Syngnathus leptorhynchus*. My research focuses on measuring the ecological connectivity of eelgrass beds by investigating the genetic population structure of *Syngnathus leptorhynchus* in Barkley Sound, British Columbia. I will present my findings of pipefish population boundaries and breeding units. This will include an assessment of the degree of connectivity (gene flow) of the bay pipefish within and outside of a de facto marine reserve, the Broken Group Islands, Pacific Rim National Park Reserve of Canada. The influence of seascape features on gene flow will also be discussed.

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Demographic similarities and differences between *Zostera japonica* in its native (Korea) and introduced (Willapa Bay) habitats

Biological invasions of all types are understudied in marine systems, but it is understood that coastal ecosystems have been heavily influenced by invasive species. The small eelgrass species *Zostera japonica* arrived in western North America around 1957, probably with oyster imports. To understand *Z. japonica*'s invasion process, we studied its demography and morphology in Willapa Bay, WA. Sampling occurred at near monthly intervals at two tidal elevations at each of three sites in 2004-2005. We found that i) *Z. japonica* is perennial but its shoot density declines by 50-80% over winter; ii) sexual reproduction contributes at least 30% of shoots in spring; and iii) total annual production is 4.79×10^6 kg DW/yr, or 14% of native eelgrass production. A recent publication from Korea allowed us to compare *Z. japonica* in its native and introduced ranges. Some seasonal patterns were similar, in particular, peak germination in April, peak growth rate in mid-late summer, and reproduction from June to September. In contrast, the Korean population showed little seasonal variation in shoot density, and plants there tended to be larger, with lower proportions of flowering shoots. We suspect that *Z. japonica*'s successful invasion stems in part from high reproductive ability that enables it to overcome stressful overwinter conditions.

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Measuring the accuracy of seagrass maps produced from video and side scan sonar Imagery: Preliminary results for two sites in Yaquina Estuary, Oregon

Accuracy of habitat maps is often critically important, with legal and economic consequences, such as when they are used for measuring temporal changes in habitat area or condition associated with regulated discharges or restoration. However, the measurement error associated with mapping habitat patches is rarely determined, and thus the accuracy of the maps is largely unknown. This problem is exacerbated in estuaries where visibility is often limited because of turbidity, and underwater remote sensing methods are used to image seafloor habitat features. In this study, we conducted triplicate underwater video and side scan sonar surveys of several seagrass beds (*Zostera marina*) in Yaquina estuary, produced seafloor habitat maps for each survey, classified the imagery for seagrass presence, and measured seagrass %cover and area from each map. Imagery, maps, and results from two sites are presented. Within sites, coefficient of variation (CV) for seagrass area and %cover was similar for sonar- and video-derived data. However, between sites the CV ranged from 2-13%. Possible causes for between-site differences in CV include study-site size, seagrass patchiness, or sea-state during surveys. Data from additional sites will help resolve this question. These preliminary results suggest a 15% detection limit for measuring temporal changes in seagrass beds using side scan sonar or underwater video in turbid estuaries.

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Evaluating cumulative ecosystem response to restoration projects in the Columbia River estuary: 2005 field studies

Baseline data were collected in 2005 on two restoration sites and two associated reference sites in the Columbia River estuary. The sites represent two habitat types of the estuary – brackish marsh and freshwater swamp – that have sustained substantial losses in area and that may play important roles for salmonids. Baseline data collected included vegetation and elevation surveys, above and below-ground biomass, water depth and temperature, nutrient flux, fish species composition, and channel geometry. Following baseline data collection, three kinds of restoration actions for hydrological reconnection were implemented in several locations on the sites: tidegate replacements (2) at Vera Slough, near the city of Astoria in Oregon State, and culvert replacements (2) and dike breaches (3) at Kandoll Farm in the Grays River watershed in Washington State. Limited post-restoration data were collected: photo points, nutrient flux, water

depth and temperature, and channel cross-sections. In subsequent work, this and additional post-restoration data will be used in conjunction with data from other sites to estimate net effects of hydrological reconnection restoration projects throughout the estuary. This project is establishing methods for evaluating the effectiveness of individual projects and a framework for assessing estuary-wide cumulative effects including a protocol manual for monitoring restoration and reference sites.

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Recent results from annual monitoring of eelgrass (*Zostera marina*) area in greater Puget Sound

In greater Puget Sound in Washington State, *Zostera marina* is the dominant seagrass. It provides important nearshore habitat for forage fish, juvenile salmon and marine birds. In 2000, the Washington State Department of Natural Resources initiated a monitoring project to assess the total cover of *Z. marina* in the study area on an annual basis. The study design provides estimates of total *Z. marina* area and uncertainty over greater Puget Sound as a whole, over five sub-basins and at randomly selected sites. Sampling of *Z. marina* within sites is accomplished with underwater video recorded along random transects generally perpendicular to the shore. Data from the first six years show no evidence of declines in the total cover over the study area as a whole, but the results from the Hood Canal sub-basin show three years of consistent declines. The results from 2005 suggest that a number of sites in southern Hood Canal are experiencing declines in *Z. marina* area. In addition a cluster of shallow embayments in the San Juan Archipelago has been identified as an area of concern because of sharp declines in *Z. marina* cover relative to levels in the mid-1990s as determined from aerial photography.

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Japanese eelgrass, *Zostera japonica*, in Oregon estuaries

Biological invasions may considerably alter community dynamics of invaded areas, potentially altering ecosystem processes including productivity, decomposition, nutrient cycling and hydrology. The Japanese eelgrass, *Zostera japonica*, was introduced to Pacific Northwest estuaries in the 1950’s with Pacific oysters. The effects of introductions are often obscured by the lack of information on distribution and abundance patterns. To assess the impact of *Z. japonica* in PNW estuaries, its current distribution and abundance was documented in Netarts, South Slough National Estuarine Research Reserve (SSNERR), and Bandon Marsh National Wildlife Refuge (BMNWR). In Netarts Bay *Z. japonica* beds intermingle with the native eelgrass *Zostera marina*.

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The interaction of oyster aquaculture and burrowing shrimp in pacific northwest coastal estuaries: Spatial and temporal scales

Two species of burrowing thalassinid shrimp cause a substantial problem for the commercial shellfish industry in Willapa Bay, Washington by softening the substrate and suffocating oysters grown on the intertidal mudflats. These shrimp have been managed using the pesticide carbaryl to treat intertidal oysterbeds in this estuary for the last 40 years. A recent challenge to the pesticide application program however, and pressure to investigate alternative control measures for shrimp resulted in a re-evaluation of both oyster culture and shrimp as estuarine ecosystem components at broader spatial and temporal scales. These shrimp are relatively long lived and have pelagic larval stages that are flushed from west coast estuaries, so their life history and annual recruitment patterns are clearly influenced by nearshore coastal and estuarine oceanography at a spatial scale that exceeds that observed for a locally managed bed. Oysters, though farmed and therefore manipulated by growers, are also influenced by estuarine hydrography and dynamics that have recently been discovered to differ from those studied elsewhere. We describe these patterns and outline studies that will help define and scale an appropriate integrated pest management plan for these shrimp regardless of the ultimate control measures chosen to remove them.

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Estimating phytoplankton advection at Lofall, Hood Canal using an interdisciplinary technique

In order to determine what concentration of the toxin-producing diatom *Pseudo-nitzschia* becomes available to nearshore suspension-feeders in Hood Canal, a first order estimate of the phytoplankton advection rate from offshore to nearshore was necessary. This estimate was obtained in Lofall, Hood Canal using an interdisciplinary approach to gather and combine data from multiple temporal and spatial scales. Data collection occurred on two separate dates: August 8, 2005 and December 13-14, 2005. Data sources include: particle velocity measurements through the water column collected using an acoustic Doppler current profiler (ADCP); conductivity-temperature-depth (CTD) and optical backscatter profiling of the water column at six stations along a transect oriented from offshore to inshore; and water samples collected from the same six stations at two depths (generally surface and chlorophyll max) for analysis of total suspended solids, nutrients, chlorophyll pigments, DNA analysis for *Pseudo-nitzschia* species, and microscope examination of fixed phytoplankton cells. To complement the data set, spectral imaging data were collected from the following sources: optical imaging casts through the water column; 1-m resolution photographs from airplane flyovers; and 1-km resolution satellite images obtained from NASA satellites. Data analysis by an interdisciplinary team will yield a better understanding of phytoplankton advection in Lofall, Hood Canal.

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The *Green Shores* Project – A voluntary assessment and ratings program to facilitate sustainable approaches to coastal development.

Communities in the coastal areas of the Pacific Northwest and elsewhere are experiencing unprecedented levels of new development that utilizes sensitive shore areas. In addition, many older community waterfronts once dominated by industrial and resource industries, are moving toward residential and commercial re-development. This presents an opportunity to re-think and influence approaches to coastal design and land use. The vision for Green Shores Project is to become a voluntary assessment/ certification process to encourage sustainable development of coastal shores, similar to the LEED certification process for Green Buildings. The four guiding principles for Green Shores certification are: 1. Preserve the integrity or connectivity of coastal processes, 2. Maintain or enhance habitat diversity and function, 3. Address methods to minimize or reduce pollutants to the marine environment, 4. Reduce cumulative impacts to the coastal environment, such as shore hardening and loss of riparian vegetation. This presentation will provide an overview of the Green Shores Project, recently funded by a diverse group of partners to assess the feasibility of a voluntary certification program for shore development. The outcome of this assessment will be applied to several case examples ranging from waterfront residential properties to a large estuarine brownfield redevelopment project.

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Ecosystem-based marine conservation planning in the San Juan Islands

In 2004, the San Juan County Marine Resources Committee (MRC), a multi-stakeholder citizen advisory body to the county government that is part of the federally-funded Northwest Straits Initiative, successfully lobbied San Juan County to declare all marine waters within its boundary as a Marine Stewardship Area, similar to a multiple-use marine protected area. Though the declaration did not set forth any management measures, it has served as the impetus for a bottom-up management planning process now underway that explicitly adopts an ecosystem approach and considers multiple resources and human uses. To develop an implementation plan, we are adapting a methodology developed by The Nature Conservancy for terrestrial site conservation planning to do science-based marine resource planning that incorporates social and cultural values. Among the key challenges we have encountered are the significant mismatch between the kinds of scientific information needed for such an ecosystem approach and the research results actually available for the region, and the difficulties in relying on best professional judgment in the absence of data.

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The effects of black brant herbivory and fecal addition on the animal community within an eelgrass bed of Humboldt Bay, CA

Seagrass beds are productive ecosystems that support a diverse assemblage of aquatic animals. Managers of seagrass systems have traditionally held a bottom-up view of how the biomass of animals in these systems is regulated, however top-down effects by grazers may substantially affect primary productivity, habitat complexity, and consequently, the associated fauna. We used an experimental approach to test the hypothesis that brant grazing and fecal deposition affects the abundance, size and diversity of the animal community in the eelgrass bed. A randomized block design was used and each block, which was surrounded by PVC to exclude brant, contained the following four treatments: ‘no brant’, fecal, clip, ‘brant control’ (fecal + clip). Either the abundance and/or size of all animals changed with time, but responses to particular treatments were highly variable among the types of animals. For example, both the abundance and size of *Heptacarpus* shrimp were greatest in the combination fecal + clip treatment. However other animals, such as juvenile black rockfish (*Sebastes melanops*) and 3-spined sticklebacks (*Gasterosteus aculeatus*), showed minimal treatment effects. The effect of brant grazing and fecal deposition on the animals in the eelgrass community of Humboldt Bay appears to vary among species, as demonstrated in previous studies that have manipulated seagrass bed structure.

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Web-based ShoreZone mapping and imagery: Gulf Islands National Park

ShoreZone imagery of 1,115 km of shoreline in the Gulf Islands was collected in July of 2004. All of the low-tide (zero tide) videography and still-photos are displayed on an interactive web site with each video frame and photograph georeferenced. ShoreZone habitats have been mapped for the 782 km of shoreline for the Gulf Islands National Park Reserve (GINPR) and for much of the proposed National Marine Conservation Area (NMCA). The web-based combination of continuous videography, still photos and summary data is unique, allowing users to see features ranging from the size of individual boulders to landscape-scale distributions of eelgrass. Web access and functionality will be demonstrated real time¹. Four examples of mapping data use for conservation planning will also be presented: (a) a sand lance spawning capability model, (b) occurrence of man-made modifications of the shoreline, (c) occurrence of wetlands (8% of the shoreline) within the GINPR/NMCA and (c) the occurrence of eelgrass (34% of the shoreline) in GINPR/NMCA. The dataset (and associated access) represent an important research and conservation planning tool.

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Assessing eelgrass transplants in the Squamish Estuary, British Columbia: A case study for community-based coastal restoration

Methods for community-based seagrass restoration on the West Coast of North America have not been well developed, and are often conducted on a project-by-project basis. This case study investigated the feasibility of transplanting *Zostera marina* (eelgrass) in highly impacted sites in the Squamish Estuary, British Columbia. The use of small-scale experimental transplant plots, low-budget monitoring techniques and volunteer personnel were assessed. Eelgrass transplant plots were planted at two sites in the estuary (Cattermole Slough and Stawamus), and were subsequently monitored for 2 years in order to assess the survivorship of eelgrass, as well as the physical/chemical variables in these two locations. Within this monitoring timeline, eelgrass survivorship and the physical/chemical variables measured were within the range reported for other transplant projects in the Pacific Northwest. It was concluded that transplant survival is possible in these two regions of the Squamish Estuary. The transplant results and methodological recommendations from this project are transferable to similar seagrass restoration projects along the coastline of the contiguous Pacific Northwest, and may help to establish more consistent guidelines for such projects. Furthermore, this project is among the first community-based projects on the West Coast of North America to demonstrate the potential for eelgrass transplantation as a means of restoring highly impacted coastal ecosystems.

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Structural complexity of native, naturalized, and invasive ecosystem engineers influence habitat use by subadult Dungeness crab (*Cancer magister*).

Autogenic ecosystem engineers often increase habitat complexity resulting in cascading impacts on their respective communities. Although facilitation of small benthic organisms is often cited as a positive impact of complexity, foraging by large transient predators may be impeded within complex habitats. In this study we explored how habitat use by Dungeness crab, *Cancer magister*, varies with changes in physical complexity associated with four littoral habitats in Willapa Bay, WA; unstructured littoral habitats (ULH), native eelgrass beds (*Zostera marina*), beds of a naturalized oysters (*Crassostrea gigas*), and patches of an invasive cordgrass (*Spartina alterniflora*). We found that *C. magister* making daily intertidal migrations most often utilized ULH over eelgrass and oyster habitats, and that energy derived from ULH sources subsidizes the large estuarine population of crab in Willapa Bay. Furthermore, significantly fewer crabs were captured in baited traps placed within *S. alterniflora* patches than those placed in ULH. Thus physical state changes associated with the culture of *C. gigas* and the expansion of the invasive macrophyte reduces *C. magister* access to prey resources. This may have profound ecological and economic impacts since populations of *C. magister* represent a substantial component of the predator guild and estuarine production of *C. magister* contributes significantly to the coastal fishery.

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A conceptual model of depositional, rather than erosional, tidal channel development in the rapidly prograding Skagit River Delta (Washington, USA).

The origin and growth of blind tidal channels is generally considered an erosional process. This poster describes a contrasting depositional model for blind tidal channel origin and development in the Skagit River delta, Washington, USA. Chronological sequences of historical maps and photos spanning the last century show that as sediments accumulated at the river mouth, vegetation colonization created marsh islands that splintered the river into distributaries. The marsh islands coalesced when intervening distributary channels gradually narrowed and finally closed at the upstream end to form a blind tidal channel, or at mid-length to form two blind tidal channels. Channel closure was likely mediated through gradient reduction associated with marsh progradation and channel lengthening, coupled with large woody debris blockages. Blind tidal channel evolution from distributaries was common in the Skagit marshes from 1889 to the present, and it can account for the origin of very small modern blind tidal channels. The smallest observed distributary-derived modern blind tidal channels have mean widths of 30 cm, at the resolution limit of the modern orthophotographs. While channel initiation and persistence are similar processes in erosional systems, they are different processes in this depositional model. Once a channel is obstructed and isolated from distributary flow, only tidal flow remains and channel persistence becomes a function of tidal prism and tidal or wind/wave erosion. In rapidly prograding systems like the Skagit, blind tidal channel networks are likely inherited from the antecedent distributary network. Examination of large-scale channel network geometry of such systems should therefore consider distributaries and blind tidal channels part of a common channel network and not entirely distinct elements of the system. Finally, managers of tidal habitat restoration projects generally assume an erosional model of tidal channel development. However, under circumstances conducive to progradation, depositional channel development may prevail instead.

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Results from the regional *Spartina* dispersal study (September 2004 – January 2006)

Only six estuaries on the west coast of North America have known populations of non-native *Spartina* species, while over thirty estuaries are considered at risk for invasion. We conducted a study that utilized monthly releases of drift cards to better understand potential seed dispersal patterns from Humboldt and San Francisco bays in California, and Willapa Bay in Washington. These estuaries are already known to have significant populations of one or more *Spartina* species and are potential sources of seeds or plant fragments. A total of 7,200 cards were released between September 2004 and August 2005 with recovery rates (by bay) ranged from 26.2% to 43.8%. Drift card recoveries occurred over a wide geographic range – Alaska, British Columbia and much of the Washington, Oregon and California coastlines – and indicate near-shore currents from each release location could serve as potential vectors to both local and distant susceptible habitats.

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Characterizing restoration trajectories through food web linkages in San Francisco Bay’s estuarine marshes

As a component of the CALFED-sponsored Integrated Regional Wetland Monitoring program, we are comparing tidal marsh food webs in northern San Francisco Bay (SFB). Current scientific literature suggests that due to reduced wetland area within the bay, the overall SFB estuary relies heavily upon bay phytoplankton production, rather than marsh-derived organic material, to drive the estuarine food web (Canuel et al. 1995). We therefore hypothesize that food webs in SFB’s newly restoring wetlands will primarily rely upon allochthonous bay phytoplankton, but that in more mature marshes, primary production from autochthonous sources will play a larger role. Using stable isotope analysis, including $\delta_{13}\text{C}$, $\delta_{15}\text{N}$, and $\delta_{34}\text{S}$ in a space-for-time substitution, we track food web linkages in restored and natural marshes to explain how food webs change over time and across space. The study consists of two components: a mussel transplant experiment and a study of estuarine-dependent organisms collected in marshes of varying age and restoration status. Preliminary results indicate that phytoplankton does not play as large of a role as previously anticipated, making up roughly 8- 10% of the base diet of any individual fish or invertebrate. For the transplant experiment, we found no strong pattern along the marsh age gradient, but did see strong differences in the isotopic signatures of mussels inhabiting different sites.

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The San Juan County Marine Stewardship Area: Developing a voluntary marine management regime that recognizes the social, economic and ecological values of county waters

In early 2004, the Board of County Commissioners designated San Juan County a Voluntary Marine Stewardship Area. Under this designation, the local Marine Resources Committee (MRC) is responsible for identifying special management areas that allow sustainable use of marine resources while protecting and restoring sensitive marine species and habitats. The County is committed to the development of voluntary management policies to increase public awareness and provide guidelines for responsible use. Special management areas will be defined through the development of a zoning scheme, which will include multiple-use, special, and restricted areas throughout county waters. The development of this zoning scheme requires consideration of scientific information on species, habitats, and the processes that sustain them as well as the human values and economic benefits that are tied to the marine environment. The MRC is incorporating these factors into the zoning scheme by compiling and analyzing the best available science concerning local marine ecosystems and by collecting information from residents, visitors, tribes and stakeholder groups. Through community meetings, the MRC hopes to bring science and communities together in a collective process to develop voluntary management strategies for the Marine Stewardship Area.

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Biological invasion threatens habitat essential for young-of-year rockfish in a large urban estuary

Non-native invasive species are known to cause negative impacts to native communities via direct interactions such as competition and predation. Here we show that indirect interactions between the invasive seaweed *Sargassum* and a suite of native kelp species (*Agarum*, *Laminaria*) threatens to reduce availability of habitat essential to young-of-year rockfish in the San Juan Archipelago, WA. Using SCUBA surveys, we determined that 93-100% of young-of-year rockfish of the genus *Sebastes* are found in association with native understory kelps. This relationship is density dependent, occurring only where kelp canopies achieve more than 60% cover. In separate studies, we determined that *Sargassum* reduces the abundance of native understory kelps through shading and other negative interactions. Consequently, reductions in kelp canopy cover associated with invasion by *Sargassum* will reduce the amount of habitat available to young-of-year rockfish. This effect may be especially strong in marine protected areas, where *Sargassum* is most abundant. Our findings have special relevance because rockfish populations throughout the Georgia Basin/Puget Sound region have declined substantially and several species now are regional conservation targets. Consequently, the efficacy of regional conservation efforts, which currently focus on adult rockfish, may be reduced by fisheries-independent processes acting on early life-history stages.

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Probabilistic survey of fish tissue contamination in west coast estuaries and coastal waters: Results from the National Coastal Assessment 1999-2003

A probabilistic survey of west coast estuarine condition was conducted in 1999-2003 by USEPA's West Coast Monitoring and Assessment Program (EMAP), a component of the National Coastal Assessment. Data are presented on the concentrations of metals, total PCBs, total DDT and other pesticides measured in fish tissue from 266 sites in estuaries from the Canadian to Mexican borders collected in 1999-2000, 50 sites in Alaska collected in 2002 and 23 sites on the continental shelf collected in 2003. EPA human health guidelines for fish consumption were exceeded at some sites for tissue mercury in Alaska, Oregon and California, tissue DDT in California and tissue PCBs in Washington, Oregon and California. Fish collected from estuaries in industrialized areas had higher tissue residues than fish from less industrialized areas. Concentrations of tissue residues of organic contaminants in fish from Alaskan and offshore sites were much lower than in fish from estuaries in the more industrialized coastal states of Washington, Oregon and California. Canadian Tissue Residue Guidelines (TRG) for the protection of wildlife consumers of aquatic biota were exceeded for DDT at many sites in small coastal estuaries, the Columbia River and Alaska. One site in the Columbia River exceeded TRG for PCBs.

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Enhancement of damaged seagrass habitat: A case study in the potential application of Buoy Deployed Seeding

Georgia-Pacific West, Inc. (GP) completed an integrated remediation and habitat restoration project in their former Whatcom waterway log pond storage area in 2001. During the second year of monitoring physical, chemical and biological responses of the project, natural colonization of *Zostera marina* (eelgrass) was observed indicating that the clean sediment cap had suitable conditions for re-colonization. In 2005, the Bellingham Bay Demonstration Pilot Project Team identified the log pond as a potential site to test targeted seeding as a restoration method. For this test we are using the Buoy Deployed Seeding (BuDS) technique. This technique, used effectively in the Peconic Bay Estuary, Long Island, NY mimics natural dispersal but controls seed release into pre-selected habitats. In order to assess the potential use of BuDS, this pilot study was initiated in fall 2005. Our primary objectives are to: 1) assess the accessibility of local seed donor populations, 2) determine the appropriate timing of seed collection for these local populations, 3) conduct field trials and 4) monitor recruitment success. While results of the seeding trial will not be assessed until later in 2006, methods and timing of local seed collection, buoy and net deployment and maintenance, and study design will be discussed.

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Energetic trade-offs among potential habitats of an invasive crab: Reconciling a model with empirical results

We developed an individual-based bioenergetics model to investigate habitat use and migration behavior of nonindigenous green crab (*Carcinus maenas*) in Willapa Bay, Washington, USA. The model was parameterized using published studies of *C. maenas*. We ran simulations describing four scenarios during a 214-day simulation period (April – October), including adult crabs occupying habitats characterized as: (1) high littoral, (2) mid-littoral, (3) sublittoral, and (4) sublittoral but undertaking intertidal migrations. We compared model results to the observed distribution of *C. maenas*. Model estimates indicate crabs in sublittoral habitats had lower metabolic demands and higher monthly growth efficiency than their migrating or littoral counterparts. Yet *C. maenas* are abundant in mid-littoral habitats, and there is no evidence of resident sublittoral populations. The discrepancy intimates the significance of agonistic interactions with native Dungeness crabs (*Cancer magister*) that are not incorporated into the model but nonetheless increase metabolic costs and decrease foraging opportunities. *C. maenas* may avoid encounters by remaining in littoral habitats neglected by native crabs, such as meadows of nonindigenous cordgrass (*Spartina alterniflora*). We suggest that *C. maenas* in Willapa Bay occupy tidal elevations that minimize encounters, and thus metabolic costs, while simultaneously maximizing submersion time and foraging opportunities.

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Invasive *Spartina patens* at Dosewallips State Park (WA, USA): An eradication success story ... ?

The Atlantic saltmeadow cordgrass *Spartina patens* was introduced to Washington State's Dosewallips River delta about 1930 and was first recognized in 1982. Eradication efforts began in 1991, when the grass occupied about 300 m² of saltmarsh. The number of newly discovered patches dropped after 1999 but has recently increased dramatically. *Spartina* has resisted eradication because of; (1) sporadic record keeping by field workers; (2) an expectation that no undiscovered patches were broad-casting seeds; (3) the cryptic appearance of this species; (4) gaps in "institutional memory;" and (5) its "back burner" status compared with other major pest (*Spartina*) species in Washington. An expanded effort revealed three major overlooked sources of seeds in late 2003. Now reduced to just two small known patches (in 2005), the invasive colony seems vulnerable to extermination. Success, if achieved, will be due to; (1) the unflagging persistence of field workers; (2) the total cooperation between agencies and private property owners; and (3) an apparent low viability of *S. patens* seeds at the site. The search should be expanded northward and conducted for 5 years after the "last" plants are found. Lessons from this case history can make eradication of newly discovered *Spartina densiflora* likely to succeed.

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Salt marsh habitat assessment and restoration in the Gorge Waterway and Portage Inlet

Salicornia virginica (common Pickleweed) is the dominant vascular plant of the salt marshes of Southern Vancouver Island, BC. In the urbanized estuaries of the Gorge Waterway and Portage Inlet, *S. virginica*'s presence along shores is a good indicator of ecological and geomorphological stability. In this study, GPS and GIS were used to map the current spatial distribution and extent of *S. virginica* and docks to quantify the loss of natural shoreline. Historic orthophotos were digitised to evaluate the historic extent; tidal elevations and soil analysis were used to characterise *S. virginica* habitat. Tidal elevation data for *S. virginica* occurrences revealed a narrow range of 2.70- 2.79 meters above chart datum. *S. virginica* sediments from six natural urban reference sites contained 35.1% (+/- 13.9) soil moisture (at high tide) and 34.7% (+/- 12.6) soil organic matter content. Overall results indicated a significant reduction in the quantity and quality of salt marsh habitat within the study area. Finally, candidate restoration sites are identified and a restoration strategy is presented.

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The Nuu-chah-nulth root garden research project, Clayoquot Sound, Vancouver Island

Historically, the Nuu-chah-nulth and other First Nations communities of coastal British Columbia maintained gardens of plants with edible roots on their estuarine tidal flats. Diverse techniques and strategies were used to sustain and enhance the productivity of certain naturally occurring root vegetables and their associated habitats. Although the roots were formerly valued as an important food source, knowledge and use of these traditional plant foods has declined in past decades. The root garden research project was suggested by members of the Nuu-Chah-Nulth communities of Clayoquot Sound, to restore and revitalize these food traditions as a way of promoting and maintaining critically important traditional knowledge about environmental management and nutrition. The root garden research project will involve students and community members of Clayoquot Sound in the research and re-creation of a Nuu-chah-nulth root garden of iits'uqmapt (springbank clover, *Trifolium wormskjoldii*), tlitsy'upmapt (Pacific silverweed, *Potentilla anserina* ssp. *pacifica*), and kuuxwapiihmapt (northern rice root, *Fritillaria camschatcensis*). This community-based action research aims to integrate traditional ecological knowledge and traditional scientific methodologies and will involve applying an interdisciplinary approach to ecocultural restoration, drawing on the fields of ethnobotany, ethnecology, and ecology.

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Evaluating the biological condition of Puget Sound

While significant portions of Puget Sound biota continue to decline, and pressure placed on the ecosystem by society continues to increase, major gaps exist in our understanding of natural ecosystem structure and function in Puget Sound, and the biological consequences of human activity. By drawing from several distinct research projects we illustrate the importance of considering landscape, ecosystem, and human influence contexts in improving biological assessment and monitoring in Puget Sound. First, anthropogenic shoreline modification is associated with local changes in beach microclimate and increased embryo mortality in summer spawning surf smelt (*Hypomesus pretiosus*). Second, data from surface trawl sampling throughout much of Puget Sound show local and landscape – scale contrasts in estuarine habitat use by hatchery versus wild juvenile Chinook salmon (*Oncorhynchus tshawytscha*), and differences in macrofaunal (fish and gelatinous zooplankton) assemblage composition. Third, existing data from aerial surveys of marine birds and waterfowl over thirteen years are used to relate changes in bird assemblage composition to adjacent land cover and shoreline structure throughout Puget Sound. Results from these studies help document natural conditions and anthropogenic alterations of the Puget Sound ecosystem, but also suggest methods and hypotheses for future research, assessment, and monitoring.

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Comparison of two methods of rogue creosote log removal in Padilla Bay, Washington

Floating logs are deposited on beaches around the Puget Sound. Some contain toxic substances such as coal tar creosote (which contains polycyclic aromatic hydrocarbons) or chromated copper arsenate (CCA). We surveyed the shorelines of Padilla Bay in 2003 and identified two sites with large concentrations of creosote-treated logs and pressure-treated lumber: the Swinomish Spit and Sullivan Minor salt marsh. In August 2004, 118 creosote-treated logs and 115 pieces of pressure-treated lumber were removed from the Swinomish Spit site by helicopter. In April 2005, 58 logs and 44 pieces of lumber were removed from the Sullivan Minor site using manual labor, winch and pulley. Helicopter removal was not feasible at that site due to proximity of bald eagle nesting site(s). We calculated that 3,858 gallons (2,534/1,324) of creosote and 1,092 (648/444) gallons of chromated copper arsenate (or related chemicals) were removed with these projects (Swinomish Spit/Sullivan Minor). The cost per piece was \$58 (helicopter) and \$158 (labor/winch/pulley). Average cost per piece, both sites combined, was \$89.

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Development of a fish-based index of biotic integrity for eelgrass ecosystems of Pacific Rim, Gwaii Haanas and Gulf Islands National Park Reserves

We present preliminary results from year 2 of a program intended to monitor the ecological integrity of eelgrass beds (*Zostera marina*) in three regions: Gwaii Haanas National Marine Conservation Area, Pacific Rim National Park Reserve and the Southern Gulf Islands National Marine Conservation Area. Our objectives were to: 1. Characterize the present state of eelgrass beds and the fauna they support; 2. Establish empirical limits of ecosystem variations; and 3. Provide to Canadian Parks managers an early diagnosis tool of ecosystem structure. We assess the ecological integrity of eelgrass beds within the context of these objectives through three indices of health: 1. Eelgrass Disturbance Index - local land or marine disturbance 2. Water Quality Index - quality of surrounding water; 3. Fish Community Index - condition of eelgrass beds fish communities.

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Protists in a temperate estuary: Diversity, grazing and consumption by Metazoans

To assess the role of microzooplankton in the northern San Francisco Estuary (Suisun Bay) food web, we measured the abundance and composition of protist plankton between January 2004 and August 2005. In addition, we conducted microzooplankton grazing (dilution) experiments concurrent with mesozooplankton feeding incubations on the natural plankton assemblage from Suisun Bay during spring and summer of both years. We observed that heterotrophic/mixotrophic protist abundance and biomass peaked in late spring each year, coinciding with chlorophyll maxima, and was dominated by aloricate ciliates (*Strombidium*, *Strobilidium*) in 2004 and both aloricate and tintinnid ciliates (*Tintinnopsis*, *Stenosemella*) in 2005. Microzooplankton grazing rates on chlorophyll were highest during spring, although in April 2004 phytoplankton growth exceeded grazing (grazing:growth 0.7-0.8) while in April and May 2005 grazing far exceeded phytoplankton growth (grazing:growth 3-10). Ciliates dominated the diets of cladocerans (*Daphnia*) and copepods (*Limnoithona*, *Acartia*) in spring 2004 and 2005. Our results indicate that microzooplankton are the dominant grazers of phytoplankton chlorophyll and in turn the dominant prey for copepod/cladoceran consumers in Suisun Bay. Moreover, the relative abundance of aloricate ciliates vs. tintinnids may affect the grazing impact of microzooplankton and the feeding of mesozooplankton, thus confirming the need to assess both diversity and community grazing activity in studies of planktonic food webs.

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Coastal homogenization through oyster introductions: Causes and consequences

In risk assessments for modern oyster introductions, a handful of historical examples are commonly evaluated for probability of establishment and impact. However, a more thorough review of the evidence revealed at least 168 transfers of oysters from 31 source countries into 73 recipient countries. The economic impact of these introductions has been substantial, as non-native oysters are produced commercially in 26 countries tracked by the UN Food and Agriculture Organization. However, many introduced oysters have established self-sustaining populations outside of aquaculture (20%), and the outcome of other introductions remains uncertain or unreported (40%). Although 18 species have been involved, many of the introductions involve a single species, *Crassostrea gigas*, of Asian origin but now widespread in temperate latitudes. In general, oysters have caused substantial population, community, and habitat changes, but impacts on flow, nutrient dynamics, and other ecosystem properties are not well studied. This summary leaves an open question of whether such impacts are desirable in terms of restoration of coastal ecosystems, especially if native oysters have declined.

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Depth profiles of *Zostera marina* throughout the greater Puget Sound: Results From 2002-2004 monitoring data

Recognizing regional variation in *Zostera marina* depth distribution is critical to determining the stability of *Z. marina* beds and to implementing successful local conservation efforts. However, little detailed information exists describing patterns in depth distribution. This study explored spatial differences in depth distribution throughout Greater Puget Sound through analysis of monitoring data from DNR's Submerged Vegetation Monitoring Program. Study objectives were to provide depth profiles by region and habitat type, to test for significant differences, and to display spatial patterns in maximum depth. Depth profiles varied greatly between regions, geomorphic categories, and individual sites. Sound-wide, most *Z. marina* habitat occurred shallower than -5 ft (MLLW). Fringe sites displayed deeper absolute maximum depths than flats sites. San Juan Island region fringe sites displayed the deepest absolute maximum depths, with a distribution peak at approximately -18 ft (MLLW). An ANOVA found visual differences in absolute maximum depth to be significant for region, but not significantly different for geomorphic categories. Gradients at multiple scales were apparent sound-wide, on maps created using a kriging analysis. Differences may be associated to greater tidal range, major freshwater inputs, habitat availability, or more likely a combination of these factors.

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Science and management of the introduced seagrass *Zostera japonica* in the Pacific Northwest

The introduction and spread of non-native species represents a constant threat to native ecosystem diversity and function. Marine and estuarine ecosystems, in particular, have high rates of new introductions due to trans-oceanic commerce. Faced with continual shortages of labor and funds, resource managers must make decisions regarding which introduced species merit immediate attention and which deserve attention when funds and time permit. These decisions require information regarding mechanisms of establishment and spread, as well as potential impacts to native ecosystem structure and function. In the Pacific Northwest, management responses to the introduced seagrass *Zostera japonica* vary widely. In some cases these plants are thought to be harmful invaders, while in others information suggests that plants provide positive habitat benefits. However, predicted changes linked to climate shifts suggest that this species may spread both north and south of its current range. Given differences in management responses, there is a need to utilize a science-based approach to develop and implement more consistent management strategies.

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Effects of temperature on growth of the introduced seagrass *Zostera japonica* from two Pacific Northwest Estuaries

Temperature is known to exert a profound effect on rates of photosynthesis and growth in seagrasses (Marsh et al. 1986; Bulthuis 1987). Large-scale climatic changes such as those associated with global warming or El Niño/La Niña events could affect patterns of distribution and abundance of seagrass species. However, individual populations in different parts of the species' range may respond differently to temperature change; populations near the limits of their range may be particularly susceptible to climate change. Since temperature is likely to be an important factor affecting distribution of the introduced seagrass *Zostera japonica*, growth rates were measured in an experimental setting across a range of temperatures typical of those experienced by the plants in the field during the growing season. Plants were collected from two different locations, Padilla Bay, Washington, and Yaquina Bay, Oregon, in order to compare temperature-mediated growth rates between populations located near the northern and southern limits of species distribution. The results of this study will provide a basis for predicting further range expansions of this species along the Pacific Coast of North America.

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The use of high resolution remotely sensed imagery in conjunction with field surveys to determine vegetation communities in the tidal freshwater reach of the Columbia River

High resolution remotely sensed imagery is becoming an increasingly accessible and affordable tool for ecological applications. As part of a pilot study for designing a long-term habitat monitoring program in the Lower Columbia River, we evaluated the use of two sensors for collecting imagery at a pilot field site: 2.4-m pixel QuickBird satellite imagery and 0.25-m pixel GeoVantage's Precision Navigated Imagery (airborne). Each source had four multispectral bands, though the collection platforms and resolutions were different. We found QuickBird to be most appropriate for this scale and application area, though our ability to discern certain mixed vegetation patches varied. Our field surveys showed high species diversity, mixed communities, and patchiness, often with patches less than 5m². Though the vegetation types of interest are spectrally diverse, they most often occur in varying abundance and distribution, which has necessitated the use of advanced processing techniques. QuickBird was highly successful at discerning several important tidal wetland vegetation species (such as wapato, *Sagittaria latifolia*, and creeping spikerush, *Eleocharis palustris*) with high accuracy (sometimes >90%). With additional field data on mixed communities and broader classes, QuickBird imagery may aid in scaling up from site based field surveys to determination of vegetation cover at broader scales.

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Sawmills, sulfides, and seagrasses: The environmental legacy of historic Tacoma lumber mills and its implications for seagrass restoration

More than 30 lumber mills operated on the Tacoma waterfront between 1869-1977, and we have found that there is a significant amount of wood waste buried in the sediments at some former mill sites. The decomposition of this wood waste leads to high levels of hydrogen sulfide in the sediments, which is detrimental to the seagrass *Zostera marina*. However, high sediment sulfide conditions support mats of the sulfide-oxidizing bacterium *Beggiatoa* spp. The objective of this study was to determine the distribution and abundance of *Z. marina* in relation to the distribution of *Beggiatoa* spp., and levels of sulfide and organic material in the sediment. Underwater videography and beach surveys were used to map the distribution and abundance of these organisms. *Z. marina* was found at high density in areas with low sulfide levels (< 50 μM) and organic material (< 5 % total volatile solids), low density at intermediate sulfide levels (200 μM – 1000 μM), and was typically absent at high sulfide levels (> 1000 μM). In contrast, the bacterium *Beggiatoa* was only found in areas with sulfide levels > 1000 μM . Our data suggests that areas with *Beggiatoa* spp. could require sediment remediation before effective seagrass restoration can be achieved.

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The effect of nutrient limitation on eelgrass (*Zostera marina* L.) shoot density in Humboldt Bay, California

Humboldt Bay, California contains two populations of eelgrass (*Zostera marina* L.). The population in South Bay is significantly denser than the population in North Bay. Shoot density is an important factor in the ability of eelgrass to serve as a nursery for juvenile fish and invertebrates. The objectives of this study were to determine whether Humboldt Bay eelgrass is either nutrient limited or suffering from nutrient toxicity and if any difference in nutrient concentrations between North and South Bay could be the reason for the difference in eelgrass shoot density between bays. A manipulative study which added fertilizer to both the water column and the substrate showed that neither bay is nutrient limited nor nutrient overloaded at ambient nutrient levels. Measurements of ambient water column and sediment nutrient concentrations show that North Bay has lower levels of nutrients than South Bay, but also retains nutrients longer. This implies that North Bay is more vulnerable to eutrophication than South Bay and requires more protection from nutrient loading via anthropogenic sources.

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Climate-related factors of temperature and sea level affect eelgrass in the Pacific Northwest

Our work since 1982 illustrates that eelgrass abundance can vary dramatically between years. Between 1991 and 2004, annual variation in summer growth rate and abundance was correlated with variations in water temperature. In addition, annual variations in growth rate measured in summer correlated with metrics commonly used to characterize climate variability, including the El Nino Southern Oscillation index and the Pacific Decadal Oscillation index. There was a correlation between average monthly mean sea level and eelgrass growth rate. Modeling of bottom current velocities has shown that changes in mean sea level also dramatically affect bottom circulation rates on a scale that could affect eelgrass survival. We present a conceptual model illustrating how variations in temperature and water depth control the interannual variation in abundance and productivity of eelgrass in Puget Sound and coastal estuaries in the Northwest. A shift in weather and mean sea level under a global climate change scenario in the region would predictably affect eelgrass production and distribution.

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Documenting Pacific sand lance (*Ammodytes hexapterus*) spawning habitat in Baynes Sound, East Vancouver Island, British Columbia, and the potential interactions with intertidal shellfish aquaculture

Intertidal beach spawning finfish, such as Pacific sand lance (*Ammodytes hexapterus*), are vulnerable to potential impacts to upper intertidal habitats from various foreshore activities, including intertidal shellfish aquaculture. This short-lived species is an important forage fish in the Pacific Northwest that relies on ecologically functioning beaches to sustain their populations. This research documented characteristics of some of the beach spawning habitat in Baynes Sound and interactions between clam tenure operations and beach spawning activity, and evaluated potential approaches to managing these interactions. Pooled data (n = 5) indicates that *A. hexapterus* tend to spawn on medium (50%, 0.25 – 0.5mm grain size) to coarse sand (30%, 0.5 – 2mm) substrate with <3% finer material (silt/fine sand <0.25mm). The greatest potential for interactions between predator netting and sand lance beach spawning activity is in the lower limit of spawning range and the upper limit of net placement (tidal elevation +2.7m to +3.0m relative to Canadian tidal datum or 1.5m above MLLW, CHS Chart #3527). This elevation range is consistent with spawning elevations reported in Washington State. An adaptive management approach that is results focused and builds in a monitoring program (assessing performance and enabling review and revision) to address identified interactions is suggested.

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Factors preventing the recovery of *Ostreola conchaphila* in Washington

The native oyster along the Pacific coast of North America, *Ostreola conchaphila*, experienced overexploitation throughout its range in the late 1800's, resulting in commercial extinction before 1930. Marine reserves were established by 1897, and harvest pressure has been negligible for 80+ years. Nevertheless, *O. conchaphila* remains locally rare. This study summarizes multiple experiments and significant historical data analysis, with a broad focus on factors preventing recovery. In this case, reproductive limitation appears unlikely, because historical (1947-1983) and modern (2002-2005) records reveal five-fold higher annual spatfall for *O. conchaphila* than introduced Pacific oysters (*Crassostrea gigas*.) Spatfall of *O. conchaphila* was found to be significantly higher on the shell strings placed in the *C. gigas* reefs versus open tideflat and eelgrass beds. In a separate experiment, spatfall was found to be best at low elevations and on shell, with the greatest abundance on Olympia oyster shell, followed by live Olympia oysters, whole Pacific shell, crushed Pacific shell, gravel, and bare tideflat. Short emersion times (8% greater exposure) reduced survival of outplanted juveniles to less than half that of subtidal treatments, but did not affect growth rates of survivors. Finally, naturally-setting competitors, mostly nonindigenous, depressed survival by 50% and growth by 20%.

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The effects of the invasive seagrass *Zostera japonica* on ecosystem processes

Zostera japonica, dwarf eelgrass, is an invasive seagrass present in the mid-intertidal zone of many estuaries on the Pacific Coast. A project addressing the effects of *Z. japonica* on nutrient and carbon cycling and sediment accretion in the South Slough National Estuarine Research Reserve near Coos Bay, OR is in its early stages. A portion of this project consists of examining the effects of *Z. japonica* on nutrient and carbon cycling, productivity, redox state, and sedimentation through a *Z. japonica* removal and addition experiment. A second part of this project involves measuring the effects of *Z. japonica*, in addition to other spatial controls, on sediment-water nutrient fluxes in the South Slough. Locations within the estuary selected for sampling maximize variability in physical factors and include paired plots that are vegetated with *Z. japonica* and unvegetated. The investigation of the physical, biological, and chemical controls of net sediment-water nutrient fluxes will allow results to be transferable to other estuaries. Preliminary results from the project investigating the effects of *Z. japonica* on sediment-water nutrient fluxes will be presented.

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Assessment of eelgrass (*Zostera marina*) loss in the San Juan Archipelago

We can now verify that between 1995 and 2003/04 more than 30 ha of the seagrass *Zostera marina* (eelgrass) disappeared within small embayments in the San Juan Archipelago. A program to assess putative causes of this loss began in 2004; however, because no obvious cause(s) was identified we initiated an interdisciplinary program to investigate several possibilities. As such, our effort involves collaboration of scientists from state and federal agencies, universities and NGO's. The first phase included development of an appropriate sampling design, selection of field sites and evaluation of suitable assessment techniques. At a variety of embayment and open water sites we initiated a survey program to (1) assess environmental variability that includes water column properties (temperature, salinity, turbidity, chlorophyll concentration, dissolved oxygen, submarine PAR) and sedimentation rates, sediment grain size, redox and sedimentary contaminants and (2) monitor changes in *Z. marina* shoot density, flowering occurrence, internode spacing and disease presence. In addition, we are reviewing Puget Sound Assessment and Monitoring Program archives such as long-term sediment monitoring; submerged aquatic vegetation monitoring; and water quality measurements. We describe the geographic distribution of our research sites, explain our ongoing monitoring program and discuss implications of this work to guide restoration planning.

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Factors influencing the germination of eelgrass (*Zostera marina* L.): Salinity, temperature, location, seed color and sulfide concentrations

While rhizomal growth facilitates the expansion of *Zostera marina* (eelgrass) in extant locations, the seed rain associated with these flowering plants contributes to genetic recombination and short and long distant dispersal strategies to safe sites. Moreover, previous studies demonstrate that plant phenology, including germination timing and success, can vary with environment and location. Because there is an increasing demand in Puget Sound to restore *Z. marina* populations with seed and there is little understanding regarding issues of seed biology, we initiated a study to evaluate the effect of changes in temperature, salinity and sediment chemistry, in this case hydrogen sulfide, on germination success. Our objectives were to (1) increase our understanding of the relationship between seed color and germination; (2) verify that seed size variation exists between geographically distinct sites and (3) identify an optimal environment for germination success. In initial trials, we found that darker seeds were larger and had higher germination success than lighter seeds; seeds in lower salinities and higher temperatures germinated more quickly and at higher frequencies and higher germination success occurred under high sulfide

conditions. This information will contribute to field experiments designed to develop seed-based restoration methods that can be implemented in Puget Sound.

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Assessing the importance of early life history stages of eelgrass (*Zostera marina* L.) in response to aquaculture disturbance

The interactions between oyster aquaculture and eelgrass need to be explored to assist shellfish growers in the development of sustainable farms while ensuring ecological integrity in aquaculture areas. Past studies have identified negative effects on eelgrass density and cover but the interactions between aquaculture and eelgrass recruitment have not been addressed. We conducted surveys in Willapa Bay, WA and found higher seedling densities in dredged beds than in longlines or reference areas. To test the hypothesis that dredging positively influences germination we added seeds to each aquaculture type in paired control and eelgrass removal plots. March germination was highest in dredged beds and removal of adults had a positive effect, although by April there was no difference between dredged beds and reference areas and no removal effect. In August we found a negative relationship between seedling biomass and adult density. We also estimated seed density by counting the number of seeds produced per shoot in each habitat type and found this to be highest in dredged beds and lowest in longlines. Our data suggest that although eelgrass in a dredged bed may be reduced following harvest, rapid recovery may be possible due to enhanced recruitment resulting from the lack of competition with adult plants.

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Communities connecting to place: A strategy for eelgrass restoration in British Columbia

Coastal community stewardship groups in B.C. are prime “movers and shakers” in the eelgrass (*Zostera marina*) world. The BC Eelgrass Community Network has been mapping and monitoring eelgrass in their locales for the last three years. Rather than “just” monitoring eelgrass losses, restoration of sites formerly supporting eelgrass is becoming part of the focus of this network. This poster will give examples of such community based restoration projects.

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The sounds of data: A technique to detect variation

It is clear that the study of ecosystem processes is predicated by our ability to interpret forces that drive variation. That said small changes are often difficult to detect given conventional measurement techniques unless costly instrumentation is used. Based on work that was pioneered by Dr. Kim Bridges, Botany Department, University of Hawaii, and his colleague John Dunn, more than 20 years ago, we converted field sampling and environmental data (archived by remote sensors) to sound; thereby involving the use of the human ear rather than the eye to identify variation in data streams. We demonstrate the application of our technique through the creation of computer generated “compositions” from source data collected at different temporal and spatial scales and illustrate universal application of this technique by “analyzing” species counts, changes in plant traits over time and daily and seasonal variation in water temperature and submarine light. We will also conduct trial experiments during the poster display to isolate and classify data analysis by individual investigators to test the efficacy of our method by a broad spectrum of researchers. Within a reasonable time following the Pacific Estuarine Research Society meeting we will circulate a report detailing our findings to interested parties.

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Educational outreach for young boaters

Many boaters visit the San Juan Islands every year. We are concerned that the lack of awareness these boaters possess could potentially harm the San Juan County Marine Stewardship Area. Our study focuses on a portion of these boaters that are under the age of 12. We propose to design an educational coloring book for young boaters illustrating the importance of the connection between marine life and boating activities in San Juan County. The focus will be local stewardship and safety issues such as: non-harassment of marine mammals, sensitive areas, no-wake zones, fishing regulations and dangerous reefs. Our hope is that by educating the children they will become more responsible and spread this vital knowledge to others, especially their parents and peers. We anticipate that as this knowledge extends in the boater community people will be more conscious of the ecosystem and the vital role they play in it.

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An ecological analysis of the surfgrass *Phyllospadix scouleri* in the San Juan Archipelago

Phyllospadix scouleri grows in lower intertidal and shallow subtidal zones along rocky coasts from southeast Alaska to Baja California, Mexico. These plants were first identified more than 100 yrs. ago, however few studies describe shoot density or growth rate variation between sites. In the summer of 2005, we sampled two locations on the west side of San Juan Island to determine (1) shoot density and internode spacing variation and (2) natural rate of recovery. Transects were randomly located at the same elevation, and GPS coordinates were taken at each end of transect and at each sampling station. Stations were also permanently marked with a non-toxic putty and a walking video recording was taken of the transect line before sampling. Three randomly selected stations were sampled by removing all *P. scouleri* within a 0.25 m² frame. Shoot density and internode lengths were recorded for each station. Sites were revisited twice more, and densities counted to determine re-colonization status. On the last sampling date (December 2005), a few of the plots were again cleared of all vegetation and shoots were counted, internode spacing measured and biomass calculated. This is an ongoing study and sites will again be sampled in the summer 2006.

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Will the European green crab persist in Pacific Northwest estuaries?

Following the last El Niño of 1997-98, a strong cohort of young green crabs, *Carcinus maenas*, appeared in estuaries along the coasts of Oregon, Washington, and on the west coast of Vancouver Island. Unusually strong northward-moving coastal currents (up to 50 km/day from September 1997 to April 1998) must have transported green crab larvae from more established source populations in California to the Northwest. Coastal transport events and recruitment of young green crabs have been much weaker in recent years. It was hoped that green crabs would go extinct in the Pacific Northwest estuaries once the original colonists reached the end of their life span of 6 years and no new larvae arrived from California. This has not happened. Local recruitment has occurred in Pacific Northwest estuaries since 1998. Recruitment following the warm winters of 2002/2003 and 2004/2004 was especially good in Oregon and Coastal Washington estuaries. Evidence of successful settlement in 2003 was also found at three sites on the west coast of Vancouver Island. Even though the 2003-year class was an order of magnitude less abundant than the 1998 one, it produced sufficient recruits in 2005 to maintain the Oregon and Washington satellite population of green crabs.

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Dissolved sulfides stress on eelgrass *Zostera marina* in Yaquina Bay estuary, Oregon

The major seagrass in the numerous small coastal estuaries of the Pacific Northwest is the eelgrass, *Zostera marina* L. Field surveys conducted in Yaquina Bay estuary on the central Oregon Coast have revealed substantial concentrations of dissolved sulfides in the pore water of surficial sediments. Although highly variable in space and time, during mid-summer concentrations exceeding 2000 μM were measured within one eelgrass meadow in the estuary. Thus, we initiated a series of laboratory studies to test the effects of prolonged exposure of the eelgrass root/rhizome system to hydroponic concentrations of dissolved sulfides. The flow-through system and sulfide monitoring procedures for the experiments are described, along with preliminary results on leaf elongation rates, carbohydrate concentrations, and P/I ratios during the course of 3-week exposures at several sulfide concentrations. This research is directed toward providing information on the ecological significance of elevated nutrient loadings to PNW estuaries.