ORAL ABSTRACTS

May 28, 2014 Morning
Session 1: Columbia River Basin/Estuary Issues

Fast prediction of river influences on the Columbia River estuary and plume, and implications for policy, adaptive management and operation

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We have long known that the Columbia River estuary and plume are strongly responsive to river discharges, and particularly to the hydrograph at Bonneville Dam. For two decades, we have developed long-term observations and detailed numerical circulation models that—together—enable understanding and simulation of contemporary variability, past conditions, and future scenarios of estuarine and plume circulation, in response to the Bonneville hydrograph and other local and global forcing. We have also learned how to translate circulation conditions and changes into metrics of relevance to ecosystems and fisheries. However, only recently—while addressing the needs of the 1964 Columbia Review Treaty Review—have we began to use decade$^+$ legacy simulations to train _fast predictors_ of the behavior of ecologically relevant estuarine and plume metrics. With this step, we are—within limits—no longer constrained by computationally expensive numerical simulations, for first-order assessments of impacts in the estuary and plume from changes in select forcing types. The fast predictors are particularly effective in addressing changes in the Bonneville hydrograph, which opens substantive opportunities for science-based adaptive management and operation of the Federal Columbia River Power System. With this presentation, we set the foundation for a broad regional conversation on these opportunities.

Preventing non-indigenous species transport to the lower Columbia River and an approaching paradigm shift in ballast water management practices

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Shipping activities are a vital engine of our economic system but represent an important pathway for aquatic invasive species to threaten the ecological health and services of the Columbia River. The transport and release of non-indigenous species via ballast discharge and biofouling are unintentional, yet preventable, by-products of global and regional shipping operations. Over the past two decades state and federal authorities have implemented oceanic ballast water exchange requirements as the primary risk-reduction strategy to decrease threats associated with discharged ballast. Although results of these regulatory actions are promising (when implemented with vessel inspection and compliance verification efforts), recent federal and international regulatory developments aim to replace oceanic ballast exchange as the predominant strategy by the end of the decade - primarily via deployment of shipboard ballast water treatment system technologies (BWTS). BWTS development has progressed dramatically in recent years and promises to drastically reduce the density of viable organisms in discharged ballast water. However, research suggests that the regulatory shift will produce risk-reduction gains primarily for high-salinity port ecosystems and not estuarine or freshwater ports. Specific concerns for the protection of the Columbia River are 1) the efficacy of the BWTS when operating under high turbidity-low salinity conditions and 2) the prospect that organisms surviving BWTS processes may be high-risk species sourced from foreign locations with similar environmental characteristics to our receiving environment (i.e. environmental match) rather than the low-risk species that are currently discharged following mid-ocean exchange management practices (i.e. environmental mis-match). The Oregon Task Force on Shipping Transport of Aquatic Invasive Species and the Department of Environmental Quality have evaluated ballast management policy options that aspire to be compatible with the new federal policies, practicable for vessel operators, and tailored to address the local conditions and habitat protection needs for Oregon waters. Potential management strategies - including a proposal to maintain oceanic exchange requirements for high-risk vessel arrivals – will be discussed, as will the Task Force recommendations to the 2015 Oregon Legislature.

Habitat Status and Trends: Lower Columbia Pilot Integrating Stormwater with Habitat Monitoring

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This project represents the second stage in a larger project to develop and implement an Integrated Habitat Status and Trends Monitoring (HSTM) Program for the Lower Columbia Region. Focusing on Lower Columbia tributaries, the Program is intended to support monitoring needs for resource management, salmon recovery, watershed health, and future municipal stormwater permits in Southwest Washington. The goal of integrating monitoring for municipal stormwater permits with other existing monitoring efforts in the Lower Columbia Evolutionarily Significant Unit (ESU) is to gain fiscal efficiencies and more robust, meaningful regional assessments. Habitat status and trends monitoring is an important element in the Lower Columbia Research, Monitoring and Evaluation Program (LCFRB, 2010). The first stage of the project, funded in 2013 by the Department of Ecology, produced a monitoring strategy that addressed multi-scale questions about status and trends of physical, chemical and biological attributes, including those influenced by stormwater. Specifically, the first stage of the project developed a preliminary monitoring strategy that defined a pseudo-random master sample for the Lower Columbia Region, the strata used to analyze the data, a rotating panel sample schedule, and the metrics for which data would be collected. The second stage of this project is also funded by Department of Ecology through January 2015. This stage has 3 primary objectives (listed below in the order of the Objectives in the task list):

1) finalize the monitoring design for the entire Lower Columbia ESU including the Oregon portion;
2) create a pilot study design and implementation plan to test the monitoring strategy; and
3) implement an outreach program to get feedback and share ideas among stakeholders and interested parties.

The first objective will allow us to address gaps and refine the draft strategy developed last year in the first stage of the project. The second objective does the leg work necessary to conduct an "on the ground" pilot study of the monitoring design. This includes developing a Quality Assurance Project Plan (QAPP), conducting a master sample draw, sourcing supplies, coordinating with analytical labs and land owners, and verifying field sites through both desktop and field reconnaissance. The third objective is to implement an outreach program to ensure buy-in from monitoring agencies and stakeholders, receive feedback, and to educate interested parties about the goals and objectives of monitoring program being developed. Implementing the pilot study will be the future stage three of this project. Results will describe the technical, logistical, and administrative aspects involved with the actual collection and analysis of data necessary to evaluate status and trends of habitat and water quality/quantity in the Lower Columbia ESU. Information collected during the pilot study would be used to adaptively manage (revise and refine) the monitoring design, implementation plan, analytical methods, and administration of the Lower Columbia HSTM Program.

Exploring the interaction between contaminants of emerging and legacy concern and biological effects in Columbia River foodwebs

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The Columbia River Contaminants and Habitat Characterization (ConHab) Project investigated transport pathways, chemical fates and effects of polybrominated diphenyl ether (PBDE) flame retardants and other endocrine disrupting chemicals (EDCs) in water, sediments, and the foodweb in the lower Columbia River. Aquatic biota using or residing in the lower Columbia River are exposed to a variety of environmental contaminants from numerous sources, including municipal and industrial permitted discharges, atmospheric deposition, urban and industrial nonpoint source pollution, accidental spills of hydrocarbons and hazardous materials, and runoff from agricultural and forested areas as well as upstream sources. Environmental and foodweb sampling comprised (1) passive water sampling with semipermeable membrane devices (SPMD) and polar organic chemical integrative samplers (POCIS) analyzed for contaminant concentration patterns, (2) bed sediment analysis for contaminant concentration patterns and hydrodynamic sediment transport modeling, (3) benthic invertebrate biomass analysis for contaminant concentration patterns, (4) resident largescale sucker (*Catostomus macrochelius*) analysis for contaminant concentration patterns, biomagnification, and biomarker tool development and application, and (5) osprey (*Pandion haliaetus*) egg assessment for contaminant concentration patterns, biomagnification, and nest productivity assessments. Chemical concentrations of many of the contaminants of concern analyzed in this study increased in water, sediments, fish tissues, and osprey eggs in a downstream direction from Skamania to the more urbanized Columbia City and Longview. Biomarker results indicated that fish at the downstream sites experienced greater stress relative to the upstream site, and reproductive parameters reflected negative impacts at the downstream site(s) relative to the upstream site. The cDNA microarray developed identified 69 genes with expression patterns that correlated with tissue levels of contaminants, and these genes were involved in a range of biological processes previously shown to respond to contaminant exposure. Taken together, our contaminant and biomarker results support the hypothesis that contaminants in the environment both correlate to bioaccumulation and cause genetic and reproductive impacts within the foodweb. Hydrodynamic models were developed in order to predict sedimentation characteristics of the river channel, and these predictions were used to inform the design of sediment contaminant surveys. This demonstrated that contaminant concentrations and detections vary with the hydrological processes of the Columbia River, forming the basis for further studies. Additionally, contaminants of concern could be assessed and monitored as part of current and future river restoration programs to strengthen those efforts in the Columbia River and other large aquatic ecosystems.

Yakama Nation's Columbia River Remediation and Restoration Project

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The Confederated Tribes and Bands of the Yakama Nation (Yakama Nation) is a federally recognized Tribe pursuant to the Treaty of 1855 (12 Stat. 951) and has reserved lands and rights throughout the Pacific Northwest. The goal of the Yakama Nation is clear: cleanup and restore the Columbia River so as to sustain the cultural practices of Yakama members and improve life for our neighbors and future generations. The Columbia River Remediation and Restoration project includes a component to systematically inventory, evaluate and rank contaminated sites (within a 1/2 mile of the river banks) that may be impacting aquatic resources in the Columbia River, especially ESA listed salmonids. The remediation and restoration of contaminated sites is critical for healthy, self-sustaining, natural populations of salmon. The Columbia River Remediation and Restoration project has several components, including the hazardous site prioritization process. The site prioritization component's goal is to inventory, evaluate and rank hazardous waste sites impacting the aquatic resources along the Columbia River and its tributaries. The component was further divided into two tasks. Task 1, "Site Identification Master List and Map" created a master database of sites from U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), Oregon Department of Environmental Quality (ODEQ), and the Yakama Nation databases. Task 2, "Screening", compared sites from the master database to Yakama Nation-derived criteria for such things as contaminants of concern, habitat evaluation, proximity to environmentally sensitive areas, former and current site uses, and other agency ranking or scores. Using these criteria, a subset of sites on the Oregon State- and Washington State-sides of the Lower Columbia River was extracted from the master database. These sites were chosen for further prioritization and in-depth research. Information associated with the site prioritization component can be utilized when planning restoration projects in the Lower Columbia River (LCR).

Time to Reevaluate the Ecology of the Columbia River Estuary: We Need CREDDP II!

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A lot of time has passed since Haertel and Osterberg published the ground breaking report "Ecology of zooplankton, benthos and fishes in the Columbia River estuary" in 1967, and the Columbia River Estuary Data Development Program (CREDDP) that was initiated in 1980 to investigate of the ecology of the Columbia River estuary. CREDDP research programs included: physical properties (circulation, morphometry, etc.), primary production (upland, marsh, and phytoplankton, etc.), secondary production (zooplankton, benthic invertebrates, etc.), and top predators (fishes, birds, mammals, etc). While it only lasted three years, the results of this Program have persisted. The CREDDP data and papers from this program are the most frequently cited/referenced collection of ecological information on the Columbia River estuary. While there have been some studies in the Columbia River estuary since CREDDP, notably CRETM in the1990's and CMOP at present, no study has been so comprehensive or broad in scope or area. Meanwhile, the estuary has had undergone large changes since the CREDDP, many of which are undocumented or unknown. For example, estuary bird and marine mammal populations have increased significantly, many introduced species now flourish, and physical conditions (flow, channel depth) have been altered, and little is known about the present day ecological interactions, energy pathways, and trends among terrestrial, intertidal, benthic, and pelagic habitats. We suggest that a CREDDP II is warranted. While CREDDP I still represents a comprehensive data for the estuary, it is now out of date. CREDDP II would revisit and expand the baseline information from CREDDP I and other studies to identify the evolution of the system over the past 30 years. It is time to revisit that original effort and update what we know about the Columbia River with current technologies, techniques and expertise. CREDDP II would generate strong interactive educational and outreach opportunities. CREDDP II would identify: the status of conditions/resources in the estuary, estuarine changes, and establish benchmarks to evaluate past and future environmental change.

May 28, 2014 Afternoon
Session 2: Endangered Species Act Listed Species Recovery

Restoring the Lower Columbia River Ecosystem – Where do we go from here?

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The region established the goal of restoring and protecting the biological integrity of the lower Columbia River in 1999. We use the US Environmental Protection Agency definition of biological integrity (Karr and Dudley 1981; Frey 1977), and the EPA tool, Biological Condition Gradient (Davies and Jackson 2006), as a framework to assess whether we are meeting this goal. Under this framework, in April 2012 the region identified four key ecosystem attributes as important for biological integrity that should be restored and protected in perpetuity: 1) natural habitat diversity, 2) focal species, 3) water quality and 4) ecosystem processes as well as a suite of indicators for each ecosystem attribute. Subsequently, we have been focusing on developing geographic and quantitative conservation targets for the first two ecosystem attributes. We have completed a historic habitat change analysis comparing late 1800s land cover with 2009 land cover, and identified priority habitats for restoration and protection, based on what has been lost over that time period (the more severe the loss, the higher the priority). Those locations where the priority habitats still exist are priority for protection actions, whereas areas in low impact land use (called "recoverable" areas) are locations that can be restored to a suitable priority habitat if the respective landowners are willing. Maps of habitat changes, intact priority habitats and recoverable areas by River Reach are on our website. For the second ecosystem attribute, we have worked with partners to identify priority locations within the mainstem and tidal tributaries based on suitable conditions for juvenile "ocean-type" salmonids, and within the floodplain and terrestrial areas for Columbia White-tailed Deer, a subset of the focal species ecosystem attribute. This presentation will provide results from this effort, an overview of datasets and tools available for use in identifying, designing and evaluating protection and restoration actions in the lower Columbia River as well as important data gaps still remaining.

Columbian White-tailed Deer History, Status, and Habitat Requirements

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The Columbian White-tailed Deer was one of the first populations to be listed as Endangered under the Endangered Species Act. Numerous habitat changes and overharvest reduced the original range to two remnant populations. Since listing, habitat improvements and translocation efforts have expanded the range and lowered overall extinction risk. While prospects for recovery are good, significant challenges remain, such as potential threats from climate change and the proliferation of certain invasive species. This presentation will chronicle recovery efforts, discuss current conservation issues, and outline how we, as conservation managers, can look for opportunities to improve deer habitat in unrelated habitat projects.

Columbia White-tailed Deer Habitat Suitability Model and Methodology

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The Columbian White-tailed Deer Habitat Suitability Model identifies favorable habitat for this sub-species of common white-tailed deer throughout its historic range, which extends from the western slopes of the Cascades to the Pacific Ocean and from Puget Sound in Washington southward to the Umpqua River Basin in southern Oregon. The Columbian White-tailed deer (CWTD) was federally listed as endangered in 1968, as a result of habitat modification by human activity. Currently, two separate populations exist: a Douglas County population in southern Oregon which was delisted in 2003 as a result of recovery, and a Lower Columbia River population which was recommended for down-listing from endangered to threatened in 2013. The model is an additive geospatial model which incorporates regional scale data sets (NOAA Coastal Change Analysis Program land cover, USGS digital elevation models, and National Land Cover Dataset Canopy Density) that are categorized into binary habitat variables thought to be both beneficial to and detrimental to CWTD survival, as determined by United States Fish & Wildlife biologists. Overall model scores are based on a combination of distances from and densities of these habitat variables, which include urban areas, browse and cover habitats, and forest types. Model masks, including elevation and canopy densities, are applied as a final step in order to eliminate areas outside of the CWTD's preferred range. The model predicts large numbers of potential high-quality habitat areas above the estimated 1000-acre population-sustaining size. Field verification and model refinement (based on early model results) happened simultaneously and were informed by survey data of known CWTD locations. Model variables were adjusted to obtain best fit with field verified data. In this presentation, we discuss the model methodology, show a conceptual framework and model workflow, and present results. Suitable habitat areas as identified by this model may help to inform future reintroduction efforts, protect existing populations, and help estimate unintended migration potential.

Recovery of Columbian white-tailed deer: Proposing reclassification after 46 years

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Forty six years have passed since Columbian white-tailed deer (CWTD) were federally listed as endangered. During this time the US Fish and Wildlife Service (Service) has worked diligently on CWTD recovery including the establishment of the Julia Butler Hansen Refuge for the Columbian White-tailed Deer (JBH), multiple translocations of the species to higher quality and more secure habitat, and enhancement of existing habitat. The Service's approach has also integrated the cooperative effort of several outside partners including the Bonneville Power Administration (BPA), US Corps of Engineers (USACE), Natural Resource Conservation Service, Cowlitz Tribe, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and Columbia Land Trust. Working together with the Service, these partners are developing integrated ecologically-based landscape-scale conservation projects for the benefit of multiple species including CWTD. For example, the BPA is funding the geospatial conservation design work for future secure CWTD habitat sites, and the USACE has worked with JBH to repair a failing dike on the refuge for the benefit of CWTD and restoration of salmon habitat. Collectively, partner contributions total several million dollars. On November 5, 2013 the Service completed a 5-year status review of the Columbia River Distinct Population Segment of CWTD (DPS). The review recommended that the DPS be downlisted from endangered to threatened based on the following: the status of the DPS has improved; the downlisting criteria described in the 1983 CWTD Revised Recovery Plan have been met; and threats have decreased since listing to a point where no threat puts the DPS at risk of extinction and, therefore, the DPS no longer meets the definition of endangered under the Endangered Species Act. The Service is currently drafting a proposal to downlist the DPS from endangered to threatened and expects to publish the proposed rule in mid-2014. The Columbia River DPS has a high overall recovery potential due to the following: the establishment of a new subpopulation in higher quality upland habitat at Ridgefield National Wildlife Refuge, the likely recovery of the JBH Mainland Unit subpopulation after the completion of the set-back dike in summer of 2014, and the long-term stability exhibited by the Westport/Wallace Island subpopulation.

The Streaked Horned Lark: Conservation of a Threatened Species in an Industrial Landscape

Cat Brown

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In October 2013, the US Fish and Wildlife Service finalized the listing of the streaked horned lark (*Eremophila alpestris strigata*) as a threatened species under the Endangered Species Act. The streaked horned lark occurs only in the Pacific Northwest, and its natural habitats have virtually disappeared as the natural processes that created early successional prairies and scoured floodplains no longer operate. The lark's range has contracted, and it now occurs mainly in places where its habitat is created inadvertently on working landscapes – on airports in Washington and Oregon, in agricultural lands in the Willamette Valley and on dredge spoil islands in the lower Columbia River. Recovery of the species will require restoration of "natural" habitats where feasible, but will also involve a novel conservation challenge – maintaining the species on lands actively used for other purposes, where it finds nearly all of its habitat. On the lower Columbia River, this involves working with the US Army Corps of Engineers to manage dredge material deposition in a way that continues to create suitable habitat for the lark on a network of islands used for deposition of sand dredged from the navigation channel.

Streaked Horned Larks and Dredged Material Placement in the Lower Columbia River: Habitat Analysis and Recommendations

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The streaked horned lark *(Eremophila alpestris strigata),* an ESA-Threatened species uses islands and mainland sites along the lower Columbia River for breeding and wintering. The US Army Corps of Engineers maintains the depth of the navigation channel with dredging. It is the deposition of the resulting dredged material in the upland that maintains vegetation in early successional stages preferred by streaked horned larks. The timing, location, and amount of deposited dredged material can have dramatic positive or negative effects on streaked horned larks and their habitat. Keeping an adequate amount of habitat in appropriate successional stages and managing deposition sites is critical to maintain Columbia River Lark populations. We examined vegetation conditions and dredged material deposition history through time to determine how long it takes newly deposited dredged material to become suitable streaked horned lark habitat and how long it remains suitable. On sites near the mouth of the river lark habitat conditions were achieved more slowly (2-3 years post-deposition), while at sites further upstream conditions were achieved within one growing season post-deposition. The modeled vegetation remained in conditions suitable for larks for up to 9 years post-deposition, depending on the site location. In addition to understanding the duration of lark habitat conditions, we modeled the distribution of suitable lark habitat. We used lark occurrence data and Normalized Difference Vegetation Index layers derived from near-infrared NAIP 1m resolution orthophotographs to model the distribution of suitable lark habitat along the network of deposition sites. We used the results of these spatial analyses and worked directly with the Corps and other partners to generate recommendations for the location and timing of dredged material deposition that achieve the ecological objectives for the lark and maintain the Corps' ability to effectively dredge the navigation channel. The presentation will include a brief overview of lark natural history in the region, the habitat analyses methods and results, and touch on the recommendations generated.

A Rising Tide? Shorebird Conservation and the Lower Columbia River System

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Shorebirds are a 'Trust Resource,' protected by laws and policies, but are also a bellwether of ecosystem health, charismatic, and of great interest to the public across international boundaries; many partners share a deep commitment to bird conservation. Climate change could pose significant challenges to shorebirds staging and overwintering in the Lower Columbia River system, an internationally recognized site of conservation by the Western Hemisphere Shorebird Reserve Network. A wintering coastal shorebird survey from Mexico to Alaska was initiated in 2012 to identify key centers of abundance, track trends, and to inform management and conservation into the future. Planning for sea-level rise in the tidal portions of the Columbia River, as in other major estuaries of the world, must accommodate foraging and roosting needs of shorebirds if we are to retain these species over the long-term.

Development of Diets for the Intensive Culture of Pacific Lamprey (*Entosphenus tridentatus*)

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The Pacific lamprey (*Entosphenus tridentatus*) is an ancestral species, of critical importance to the ecosystem and to indigenous cultures in the Pacific Northwest. Conservation aquaculture has been proposed as a potential technique to restore Pacific lamprey populations; however, intensive culture methods and diets for this species have not been developed. We conducted a sixteen week feeding trial to test the effects of seven diet treatments on the survival, growth, fatty acid profile and whole body lipid of 51 days post hatch (DPH) Pacific lamprey ammocoetes. Each diet was offered to 5 replicate tanks holding 20 lamprey. The diets included active dry yeast (AY), active dry yeast with fish oil emulsion (AYF), micro-algae blend (MA), micro-algae blend with fish oil emulsion (MAF), yeast with micro-algae blend (AYMA), yeast with micro-algae blend and fish oil emulsion (AYMAF), and active dry yeast with Otohime (AYO). Survival during the trial was not significantly affected by diet. The greatest length and weight increases were in fish from the AYO treatment, followed by AY and AYF, then AYMAF, next AYMA, and finally MA and MAF. The addition of fish oil emulsion to the diet only increased growth in the AYMAF diet treatment. Whole body lipid was not affected by diet, though lipid retention was significantly higher in fish fed AYO relative to all other treatments. Feed conversion ratio was lowest in fish fed diets that contained yeast. Tissue fatty acid profiles tended to reflect the profile of the diet. Concentrations of 20:5n-3 and 22:6n-3 in the ammocoetes were significantly higher when fish oil emulsion was added to the diet. The findings of this study will be critical to the development of protocols for intensive ammocoete rearing.

May 29, 2014 Morning
Session 2: Endangered Species Act Listed Species Recovery (cont)

Estuary-Ocean Coupling: Characterizing Ocean Conditions for Juvenile Salmonids at the Time of Ocean Entry for Spring Outmigrants (April-May)

******Bill Peterson*[1], Cheryl Morgan[2], Jay Peterson[2] and Jennifer Fisher[2]

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Our previous research has shown that "ocean conditions" averaged over the upwelling period (May-Sep) during a salmond's first summer at sea are significantly correlated with returns of adults to the Columbia River. "Ocean conditions" are characterized through examination of the Pacific Decadal Oscillation, Oceanic Nino Index, sea surface temperature and several indicators of food chain structure including zooplankton species and abundance of fish larvae. This information is used to provide outlooks on adult returns and is posted on our Center's website (http://www.nwfsc.noaa.gov/oceanconditions). We have recently begun to evaluate the potential impacts of ocean conditions during late-winter and spring, coinciding with the months prior to Columbia and Snake River juvenile salmonids entering the ocean (Feb-Apr). The existing hypothesis is that survival and growth of salmonids is higher in years when coastal upwelling is initiated early. Given that the climatological start to the upwelling 'season' off Oregon is early April, an earlier start to the season suggests that there will be additional time for accumulation of primary and secondary production and thus better feeding conditions for salmon when they enter the sea in late-April and May. The date when coastal upwelling is initiated is referred to as the "spring transition". In this talk we will evaluate several indicators based on data that are readily available (coastal sea level, coastal winds, sea surface temperature, the Bakun upwelling index) and we will present several new indicators of the spring transition that are based on data collected during our biweekly oceanographic cruises that have sampled continental shelf and slope waters off Oregon since 1996. From this 18-year time series we compare "indicators of the spring transition" estimated as the date when upwelled water first appears on the continental shelf based on temperature and salinity characteristics, and the date when the zooplankton have transitioned from a "winter" community to a "summer community". The various estimates will be compared to each other and a correlation matrix will be developed that will illustrate the degree to which each indictor is correlated with adult salmon returns.

Stock-specific distributions of juvenile Chinook salmon along the Oregon and Washington coasts

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Delineation of salmon marine distributions is important for understanding how regional ocean conditions influence the growth and survival of specific stocks and life-history types. In this study, we sampled habitats along the Oregon and Washington coasts and describe the stock-specific distributions of juvenile Chinook salmon during their first summer at sea. We used genetic stock identification methods to estimate the origins of yearlings and subyearlings collected during 15 years of trawling at a series of fixed sites along the coast. Spatial distributions were characterized by calculating the mean latitude and distance from shore of each stock. In late spring, yearlings from interior Columbia River Basin populations, including those from the Snake River, were distributed farther offshore and not as far north as fish from the lower basin (Willamette River and West Cascade spring stocks). By summer, the more rapidly migrating interior basin spring run fish were significantly farther north than yearlings from the lower basin and from summer/fall run populations. Moreover, the summer/fall and lower basin yearlings were more spread out in latitude. We also observed differing distributions among stocks of Columbia River subyearlings. In early summer, Snake River fall and Upper Columbia River summer/fall subyearlings were primarily dispersed along the Washington coast. By autumn, these fish were broadly distributed across the entire latitudinal range of the study area, including areas south of the Columbia River. In contrast to the seasonal shift observed in these interior basin stocks, the distribution of the lower Columbia River's Spring Creek tule fall stock was relatively stable throughout the summer. We found for both subyearling and yearling life-histories, that the differences among stocks occurred consistently each outmigration year. In this presentation, we discuss these differing patterns in relation to the timing of hatchery releases, length of downstream migrations and timing of ocean entry.

Evidence for selective mortality in marine environments: the role of fish migration size, timing, and production type

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The underlying causes of mortality during the critical life stages of fish are not well-understood, nor is it clear if these causes are similar for naturally and artificially propagated individuals. To assess the importance of selective mortality related to production type (hatchery vs. natural), size, and timing of marine entry during the early marine phase, we compared attributes of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from the upper Columbia River summer- and fall-run genetic stock group captured in the Columbia River estuary with back-calculated attributes of survivors captured several months later in marine waters in 2010 and 2011. We used genetic stock identification, otolith chemistry and structure, and physical tags to determine stock of origin, size and timing of marine entry, and production type. Overall, fish emigrated from fresh water in May-September and the majority of fish collected in the estuary (83%) had arrived within 3 days of capture. In one of two years timing of marine entry for both production types significantly differed between the estuary and ocean such that fish emigrating in late July were more represented in the ocean than estuary. There was no evidence of selective mortality of smaller juveniles during early marine residence in hatchery or natural juveniles, but the mean percentage of natural fish in ocean collections was 16% (± 5.8 SE) greater than in the estuary, which could indicate enhanced survival of natural fish. Results from this study highlight the need to understand the effects of hatchery rearing and how hatchery-propagation may influence survival during later critical life-history transitions.

Marine Perspectives on Hatchery Chinook Salmon Production in the Columbia River Basin

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No matter what Columbia River sub-basin, tributary or hatchery a smolt emigrates from, all successful smolts congregate in the coastal ocean off Oregon and Washington. There is increasingly clear evidence that variable ocean conditions are directly responsible for large-scale variation in the return of adult Chinook salmon to the Columbia River. There is also accumulating evidence that marine mortality occurs soon after smolts enter the ocean. However, not all smolts are equivalent. Different hatchery rearing regimes generate smolts of differing size, that are released at different times and from different locations in the Columbia River Basin. So, ocean conditions vary from year to year and smolt characters from different hatchery programs vary. In this talk we will examine the interactions among varying ocean conditions and varying smolt characters with two questions: 1). From a given hatchery program, how does size at release relate to smolt survival across varying ocean conditions? and 2). Are there differences in smolt performance in the ocean among different stocks of Chinook salmon and how do these differences relate to size at release and ocean entry timing? Together, the data provided will provide insights into potential ecological interactions between smolts from different stocks in the ocean and may lead to some insights on ocean carrying capacity.

Prey availability and feeding ecology of juvenile salmon in coastal waters based on stomach content and stable isotope analyses

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Extensive work has been done to quantify the diet of juvenile Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in marine waters via stomach content analyses, the results of which can provide very detailed but only short-term view of an organism's feeding history. In contrast, stable isotope analysis of carbon and nitrogen can provide a longer-term integration of their diet in terms of relative trophic position and source production. The combined results from SIA and conventional diet analyses of predators and their prey can thus provide a more comprehensive view of the feeding ecology of juvenile Chinook and coho salmon. In this study we conducted an intensive field study within a relatively small area in the Columbia River Plume with repeated sampling of the salmon prey field community. We utilized herring and Nordic sampling nets and compared these catches to the composition of salmon diets caught at the same time. We found that the herring trawl caught more biomass than the Nordic trawl, with much of the biomass attributed to pelagic juvenile rockfishes. In addition, we found that the herring and Nordic trawls sampled different communities. Chinook and coho salmon yearlings had similar diet compositions and consumed somewhat different prey items compared to both net communities. To test whether stable isotopes are a good predictor of diet, we measured the $\delta^{13}C$ and $\delta^{15}N$ of juvenile Chinook and coho salmon tissue and their prey from the northern California Current ecosystem and used these stable isotope values in a Bayesian mixing model to estimate relative dietary contributions to individual salmon. We found that marine prey (marine fishes and invertebrates) constituted the largest proportional prey contribution to both Chinook and coho salmon diets. Despite the fact that juvenile rockfish were the most important component of their diets, other marine fishes contributed the largest proportion to both salmon diets based on model results. Although the juvenile salmon were collected in coastal marine waters, they still retained a freshwater and hatchery food signature in their carbon isotopic composition. Our results show that stable isotope analysis can provide additional information to quantify the feeding ecology of juvenile Chinook and coho salmon as they transition from freshwater to estuary to the plume.

Assessing the Relative Importance of Local and Regional Processes on the Survival of an Endangered Salmon Population

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Research on regulatory mechanisms in biological populations often focuses on environmental covariates. An integrated approach that combines environmental indices with organismal-level information can provide additional insight on regulatory mechanisms. Survival of spring/summer Snake River Chinook salmon (*Oncorhynchus tshawytscha*) is consistently low whereas some adjacent populations with similar life histories experience greater survival. It is not known if populations with different survival rates respond similarly during early marine residence, a critical period in the life history. Ocean collections, genetic stock identification, and otolith analyses were combined to evaluate the growth-mortality and match-mismatch hypotheses during early marine residence of spring/summer Snake River Chinook salmon. Interannual variation in juvenile attributes, including size at marine entry and marine growth rate, was compared with estimates of survival and physical and biological metrics. Multiple linear regression and multi-model inference were used to evaluate the relative importance of biological and physical indices in explaining interannual variation in survival. There was weak support for the match-mismatch hypothesis and strong evidence for the growth-mortality hypothesis. Marine growth and mean size at capture were strongly, positively related with survival, a finding similar to spring Chinook salmon from the Mid-Upper Columbia River, which highlights the importance of early marine growth to the survival of interior spring Chinook salmon stocks. In hindcast models, basin-scale indices (Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO)) and biological indices (juvenile salmon catch-per-unit-effort (CPUE) and a copepod community index (CCI)) accounted for substantial and similar portions of variation in survival for juvenile emigration years 1998-2008 (R2 > 0.70). However, in forecast models for emigration years 2009-2011, there was an increasing discrepancy between predictions based on the PDO (50-448% of observed value) compared with those based on the NPGO (68-212%) or local biological indices (CPUE and CCI: 83-172%). Overall, the PDO index remains remarkably informative but other basin-scale and local biological indices provided more accurate indications of survival in recent years and warrant further examination.

Conceptual framework for food web links between seabirds and fish in the estuary, plume, and nearshore ocean of the Columbia River

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Estuary and ocean research over the past decade demonstrates that hundreds of thousands of fish-eating birds aggregate in the Columbia estuary, plume, and nearshore ocean during April through September. Piscivorous species include loons, gulls and terns, cormorants, pelicans, alcids, and shearwaters. In this environment, large tidal exchanges of freshwater and saltwater among the Columbia River Estuary, plume, and nearshore ocean are accompanied by large but poorly understood changes in the biomass of marine schooling fishes such as anchovy, smelt, and herring. Seaward-migrating juvenile Columbia River salmon of similar size to the marine fishes also occupy the same estuarine and marine habitat as the avian predators. Our presentation provides a basic overview and conceptual framework of fish/bird interactions in the estuary and plume, including their role as indicators of trophic "hot spots" and ecosystem change over time. We highlight trends in seabird composition and abundance, data gaps that presently exist, and several management and conservation issues involving fish-bird interactions.

Matching bird diets with fish data: New insight into avian predation in the Columbia River estuary

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Two avian predators in the Columbia River estuary, Caspian Terns (*Hydroprogne caspia*) and Double-crested Cormorants (*Phalacrocorax auritus*), are known to consume millions of juvenile salmon (*Oncorhynchus* spp.) each spring. However, smolt consumption levels can be highly variable within and across years and the factors that influence these predator-prey relationships are poorly understood. Diet differences at bird colonies located in different parts of the estuary in the late 1990s illustrated the importance of alternate prey to salmon consumption. To formally explore this idea, we have begun to match diet information from these avian predators with fish community data collected using a purse seine in open waters of the lower estuary over six years (2006-2012) for which we have common data. Initial analyses show that both bird diets and purse seine catches are highly variable at short temporal scales (2 week periods). However, both bird species are consuming most of the fish species we catch, suggesting the seine data at least partially capture the prey field used by the birds. Furthermore, initial analyses suggest that Caspian Terns and Double-crested Cormorants select salmon in very different ways: tern consumption is highest when salmon abundance is highest, while cormorant consumption is highest when the relative – not absolute – abundance of salmon is highest. This suggests that while terns are actively selecting for salmon (regardless of other fish abundances), cormorants are not and the presence of other fish may decrease cormorant consumption of salmon. We provide additional examples of how abundances of particular fish species may be positively or negatively related to their consumption by birds. Our ability to match bird diets with fish community data provides new insight into potential factors that influence avian predation on juvenile salmon and allows us to begin to untangle these complex interactions.

Juvenile steelhead distribution, migration, growth, and feeding in the Columbia River estuary, plume and coastal waters

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Steelhead (*Oncorhynchus mykiss*) smolts migrate to the ocean in late-spring and early summer, and unlike other salmon species, they do not spend much time in the estuary and nearshore areas. Instead, they move quickly offshore to oceanic feeding grounds, bypassing the normal coastal migration route used by other salmon species. Steelhead are the third most abundant salmonid caught in May in our annual surveys off the coasts of Oregon and Washington, yet little is known about how they utilize early marine habitats and food resources, and how this might relate to survival. We analyzed diet, distribution, and growth data collected between 2000 and 2011 to address these unknowns, and to look for any differences between hatchery and wild fish and estuary and ocean fish. Steelhead catches in the Columbia River estuary correlate well with catches in the ocean. Estuary fish showed little interannual differences in size but quickly had high variability in the ocean. Estuary fish also ate very little relative to ocean fish. In the ocean, juvenile steelhead were caught mostly north of the Columbia River and were consistently caught at the westernmost stations, indicating that we were not sampling at the western edge of their distribution. Tagging data indicated that Steelhead generally move westward upon ocean entry, but there were some exceptions to the pattern (N and S movement). In general, fork length, condition and stomach fullness increased with distance offshore. Hatchery fish were significantly longer than unmarked fish in most years, yet the unmarked fish had better body condition. Overall feeding intensity has been above the 10-year mean during 2007-2011 and unmarked fish had more food in their stomachs relative to body weight than hatchery fish and fewer empty stomachs. Steelhead ate a wide variety of mostly neustonic prey. The main components of the diet were fish, euphausiids, and crab megalopae, accounting for more than 85% of the diet across all years. Unmarked and marked fish both had strong interannual variations in their growth hormone IGF-1 levels, and lastly, using otolith chemistry data, about half the fish had been in ocean waters an average of 10 days (±11) while the other half were newly arrived.

May 29, 2014 Afternoon
Session 2: Endangered Species Act Listed Species Recovery (cont)

Life History Strategies of Selected Chinook Salmon Spawning Populations in the Columbia River, as Inferred From Otolith Microchemistry

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Growing evidence in the Columbia River estuary suggests juvenile Chinook salmon (*Oncorhynchus tshawytscha)*, utilize portions of both the freshwater and salt water components of the estuary before out migration. However a clear link between these estuarine using juvenile life history strategies and returning adult populations has not been made. To test the hypothesis that estuary rearing juveniles contribute to adult populations, we recovered adult otolith samples on the spawning grounds of upper, middle and lower Columbia River tributaries. Laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) was used to analyze chemical patterns in otoliths. Otolith microchemistry was used to estimate the size and timing of juvenile outmigration for selected adult populations. Furthermore residency within the freshwater portion of the estuary was estimated based on recoveries of SrCl marked adult otoliths from the Coweeman River.

Migration patterns of juvenile chum salmon in the lower Columbia River and estuary

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Of the eleven threatened or endangered salmonid stocks in the Columbia River Basin, restoration of chum salmon (*Oncorhynchus keta*) has received the least attention, until recently. This is surprising considering chum salmon historically comprised one of the largest spawning biomass of any salmonid in the region (over one million adult returns annually), with wide ecological and economic implications. Chum salmon populations in the Columbia River have been dramatically reduced from historical levels. Most lower Columbia River chum spawning populations in Oregon are thought to be extirpated, and viable chum salmon populations are found only in the Chinook and Grays rivers in Washington and in the main stem river below Bonneville Dam, although scattered adult returns have been recorded elsewhere. Conversely, chum salmon is aggressively cultivated at numerous hatcheries around the north Pacific Rim for its roe, and thus has a significant unrealized economic potential in the Columbia River. As a step towards recovery of the species, we have been monitoring juvenile chum salmon abundance and size at selected habitats in the lower Columbia River and estuary from 2002 through the present. We have also been studying chum salmon habitat use in restoration sites within the Grays River, and have made limited studies tracking marked juvenile chum salmon to investigate migration rates. This talk will report research on contemporary juvenile chum salmon migration patterns that can aid implementing habitat restoration activities.

Oceanographic and Ecological Indicators for Salmon Returns in the northern California Current

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Estimates of the number of salmonids returning to spawn in the Columbia River basin are needed by managers to set harvest quotas, to determine the efficacy of improvements to fish passage through the hydropower system and to determine if there are measurable improvements in returns due to freshwater habitat restoration efforts. However, missing from many existing harvest models (with a few notable exceptions) is any consideration of environmental variability during the time that fish reside in the ocean. We suggest here that these models fail to consistently and accurately forecast returns because the prediction problem is inherently multivariate, that is, no single factor controls growth or sets survival. Moreover, we do not yet understand the mechanisms that link physical forcing (upwelling and the PDO) with a biological response (salmon returns). With these ideas in mind, we have developed a number of physical and ecological indicators, set in the context of an ecosystem approach to management, that have proven useful for providing both management advice as well as forecasts of salmon returns. All data and indicators are publically available on our Center's website: http://www.nwfsc.noaa.gov/oceanconditions. Some of the indicators are from web-based sources and others are from two long-term at-sea monitoring programs. The indicators capture basin-scale physical forcing (e.g., the Pacific Decadal Oscillation, or PDO) as well as local-scale physical attributes (e.g., sea surface temperature). In addition, biological data used in the forecasting include biomass of northern and southern copepods, abundance of the fish larvae in winter (using only those larvae that salmon will consume as juveniles in spring), and catches of Chinook salmon. Data from 1998 to present are analyzed using multiple modeling approaches, including principal component regression (PCR) and maximum covariance analysis (Burke et al. 2013). Results from multiple models are presented to provide a range of expected returns. We have learned that changes in the sign of the PDO are followed closely by changes in copepod community structure: during negative ("cool" phase of the PDO), a "cold water community" dominates whereas during positive ("warm") phase, a "warm water community" dominates. The copepods which are key players during cool phase are large lipid-rich species whereas the key players during warm phase are small lipid-poor species. Thus, we suggest that the mechanism that links the PDO with salmon growth and survival is as follows: when the PDO is persistently negative, source waters from the north bring the cold-water copepod community to the NCC, which results in a food chain anchored by large sub-arctic lipid-rich copepods. When the PDO is positive, a subtropical water type dominates coastal waters in the Pacific Northwest, which brings sub-tropical lipid-deplete copepods to the NCC. Our results suggest that these lower trophic level characteristics (including food quantity and quality) affect early ocean salmon growth, which in turn affects overall survival. We intend to continue evaluating the utility of various ecosystem indicators, as well as techniques for analysis and forecasting.

Migration Timing and Survival of Adult Salmonids from the Columbia River Estuary to Upstream Dams using Passive Integrated Transponder Tag Technology

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We have developed an autonomous PIT-tag detection system for deployment along a pile dike in the Columbia River estuary (rkm 70). The purpose of this study was to detect returning adult PIT-tagged salmonids and compile survival estimates to Bonneville and Willamette Falls Dam. These estimates provide perspective of mortality due to the cumulative effects of pinniped predation and anthropogenic removal through the nearly 180km tidal freshwater zone. We also determined estuary migration timing and compiled travel rates to these dams where data was sufficient. In 2013, we replaced the FS1001M with the new IS1001 multiplex transceiver system that drove a single antenna coil encompassing an area previously covered (in 2012) by a matrix of 4-antenna coils (2.4 × 6.1 m). Initially, we installed three of these new antennas encased in 10-cm diameter, rigid PVC housing. DIDSON acoustic camera observations proved that fish passed more readily through the new antennas than those used in prior years. However, after stress fractures developed in two of the rigid antennas, replacements constructed from 1.9-cm diameter flexible PVC tubing were installed. We also expanded the system with two additional flexible antennas placed further inshore along the pile dike (5 antennas total); 55m and 91m from the transceiver and power source. Except for interruptions to replace the two rigid antennas and some brief solar-power shortages in late season, the detection system remained in operation from March through October. In 2013, the pile dike system at rkm 70 (PTAGIS site code PD7) detected 375 adult and jack salmonids including 96 (22 adults) spring Chinook, 104 (68 adults) summer Chinook, 106 (101 adults) fall Chinook, 54 adult steelhead, 12 adult sockeye, and 3 coho salmon (2 adults). These detections represent 2.1, 3.4, 1.2, 0.9, 3.1 and 0.4% of upstream migrants detected at Bonneville Dam, and we estimated survival to Bonneville Dam at 90.5 ±15%, 88.2 ±7%, 92.1 ±5%, and 90.7 ±8%, respectively for spring, summer, and fall Chinook salmon and steelhead. Median travel times from detection at PD7 to Bonneville Dam for the same fish groups were 4.0, 3.7, 3.2 and 4.6 d. PIT-tagged adult and jack detections at PD7 represented nearly 2% of all PIT-tagged passing Bonneville Dam in 2013. We also detected 612 juvenile salmonids, 10 sturgeon and 1 northern pikeminnow. The successful performance of the large, flexible PIT-tag antennas at PD7 indicates expansive stationary or towed arrays to monitor juvenile salmonid migration in a large riverine environment are feasible. Additionally, peripheral pile dike sites would strengthen adult salmonid survival estimates in the tidal freshwater region of the estuary.

Session 3: New Understanding of the Lower Columbia River Ecosystem

Habitat Quality, Toxics, and Salmon in the Lower Columbia Estuary: Updated Results from the Ecosystem Monitoring Program

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Since 2007, NOAA Fisheries, the Pacific Northwest National Laboratory, and USGS have been collecting coordinated salmon, salmon prey, habitat and water quality data in collaboration with the Lower Columbia River Estuary Partnership as part of their Ecosystem Monitoring Program. To date, sampling has been conducted at 21 sites in seven of the eight hydrogeomorphic reaches of the Lower Columbia River, including multi-year monitoring at six sites: Ilwaco Slough in Reach A; Secret River and Welch Island in Reach B; Whites Island in Reach C; Campbell Slough in Reach F; and Franz Lake in Reach H. A synthesis of the data collected from 2007 to 2013 reveals distinctive seasonal and spatial patterns in fish community composition, salmon habitat occurrence, genetic stock composition, contaminant exposure, and other parameters. In general, moving upriver from Reaches A-C to Reach H, we have observed increased species diversity, richness, and abundance of non-native species; a shift in available prey from Diptera and Hemiptera to Copepods and Cladocerans; increased proportions of marked hatchery fish; and increased proportions of Chinook salmon from Interior Columbia River stocks. Chemical contaminant concentrations are generally higher in salmon from sites near or below the near urbanized areas of the estuary such as Portland and Vancouver, with surprisingly high levels in some samples from Reach C. Expanded seasonal sampling has shown that unmarked subyearling fall Chinook salmon are present in the tidal freshwater emergent marsh habitats we sample by February and continued to be found through July or August. In November and December, the sites are used by spring stocks, including Willamette River spring and West Cascades spring Chinook. Seasonal patterns were also observed for other factors. Species diversity, richness, and proportions of non-native species were highest during the summer months. The proportions of Chinook salmon from Interior Columbia Basin stocks also tended to be higher in June, July, and August than in February through May. At the multi-year sampling sites, to date we see year-to-year variability in the parameters we measure, but little evidence of increasing or decreasing trends. Our findings overall confirm the importance of freshwater tidal habits to juvenile salmon, as well as the widespread impact of human activities even in many of the least disturbed areas of the Lower Columbia Estuary.

Juvenile Salmon Food Webs, Primary Production, and Water Quality in Tidal Emergent Wetlands in the Lower Columbia River and Estuary

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Estuary use by outmigrating juvenile salmon and the food web dynamics supporting them in the lower Columbia River and estuary are not well understood and are key unknowns for regional salmon recovery. It has been hypothesized that the loss of historical wetlands and floodplain connection has shifted the base of estuarine food webs from wetland detritus to microdetrital sources, including phytoplankton, potentially favoring pelagic-feeding fish over epibenthic feeders, such as juvenile salmon. Subyearling salmon, particularly Chinook, rear extensively in tidal freshwater emergent wetland channels in the lower river and estuary. We examined food-web characteristics, instream primary production, and water quality conditions at four minimally disturbed shallow wetland sites in the tidally influenced reaches of the Columbia River during spring-summer 2011-2013. Our findings can help clarify the role of these habitats in supporting juvenile salmon and inform restoration planning from the context of ecological dynamics rather than physical habitat alone.

Role of Phytoplankton Parasites in Food Webs of the Columbia River Estuary

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The Columbia River has been dramatically altered from its natural state due to extensive regulation of river flow for hydropower, irrigation, and shipping. The associated decrease in turbidity and increase in water clarity due to the input of dams have led to an ecosystem conducive to pelagic phytoplankton growth. From 2009-2013, *in situ* biogeochemical sensors at Beaver Army Terminal (river mile 53) have captured annual chlorophyll blooms in the spring and summer in the lower Columbia River. Adaptive sampling has allowed for species composition analysis of bloom events and revealed a dominance of large diatoms in the phytoplankton community. Additionally, fungal parasites of phytoplankton ('chytrids') have been observed annually during spring blooms. Although often overlooked, parasitism in aquatic systems may play an important role in food web dynamics and biogeochemical cycling. Chytrids efficiently re-package organic material from the large, often inedible, colonial diatoms they infect into fungal zoospores, which are easier for zooplankton to consume. In this study, we evaluated both prevalence of infection of the phytoplankton community and developed a specific quantitative PCR assay to quantify zoospores. Field samples were collected from 2010-2013 and size fractionated to separate host-attached and free-swimming parasite life stages. The dominant diatom in spring blooms, *Asterionella formosa*, was infected consistently between 30-40% each year. Free-swimming zoospore concentrations were low in the summer, fall, and winter. However, in spring, when host diatoms bloom, zoospores were detected at levels up to 1600 per mL, accounting for 17.1 $\mu g\ L^{-1}$ of particulate organic carbon. The data indicate that up to 15% of the carbon biomass tied up in the dominant spring bloom diatom may be released into the environment and available for filter feeding grazers. Parasites of microalgae may actively shape the Columbia River food web by increasing the availability of large diatom carbon to higher trophic levels, in addition to influencing species composition and the density of primary producers.

Monitoring biogeochemical cycles in the Columbia River Estuary using in situ sensors

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The Columbia River displays a seasonal cycle in pelagic primary production, driven by diatoms and other phytoplankton that bloom during spring and summer periods when light and nutrient limitation are overcome. It is important to quantify and describe this source of primary production to better understand food web dynamics, water quality, and biogeochemical fluxes to the coastal zone. To this end, we have conducted continuous in situ biogeochemical monitoring of the mainstem at two locations in the lower river that are representative of the upsteam and downstream portions relative to the Willamette River confluence. Here we describe seasonal and interannual variability of water quality parameters including nitrate, phosphate, dissolved organic matter, turbidity, chlorophyll, and dissolved oxygen. Variability in concentration related to river discharge, episodic storm events, snowmelt, and hydroelectric management activities are resolved by this high resolution data set and allow us to differentiate fluxes associated with the mainstem versus the Willamette and other tributaries. In addition, estimates of Net Ecosystem Metabolism based on dissolved oxygen allow us to quantify the seasonal growth of the pelagic phytoplankton community. During spring and summer, increases in chlorophyll and primary production demonstrate that pelagic productivity is a significant contribution to the nutrient and organic carbon flux to the estuary and coastal zone.

Remote sensing of turbidity and water temperature in the Columbia River Estuary

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This study investigates the potential of using satellite data to monitor estuarine circulation and transport processes in the Columbia River Estuary (CRE). Surface reflectance measurements gathered by the Moderate Imaging Spectrometer (MODIS) are compared to in situ observations of turbidity and water temperature (T_w) to develop empirical models for remotely derived water quality parameters. Remote estimates of turbidity and T_w are then used to explore the physical processes that drive their spatial distribution. Results indicate that MODIS data significantly correlate with in situ measurements of turbidity and T_w throughout the CRE (R^2 = 0.91 & 0.86, respectively). The spatial variability of these parameters also demonstrates a realistic response to the full range of hydrodynamic conditions in the system (e.g. neap/spring transitions and fluctuations in freshwater discharge). As hypothesized in previous studies, topographically trapped turbidity maxima are observed in both the North and South Channels. Initial, process-based models illustrate the relationship of these observations to salinity intrusion and estuarine hydrodynamics.

Development of a 1-Dimensional Unsteady State Model of the Lower Columbia River and Application in Determining a 50% Annual Exceedance Stage Profile

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The US Army Corps of Engineers has completed an unsteady-flow hydrologic model of the Lower Columbia River System from the outflow of Bonneville Dam to the Pacific Ocean (River Miles 146.1 to 0.0). The model also includes a portion of the major tributaries that flow into the Columbia River below Bonneville Dam. The modeled tributaries are: Willamette, Cowlitz, Lewis, Multnomah Channel, Columbia Slough, Youngs, Westport, West-Kerry, Will-Ross, Wallooskee, Skipanon, Lewis and Clark, Klatskanine, Johnson, John Day, Grays, Deer, and Coal Rivers. The purpose of this hydrologic model is to predict water levels that will occur under low probability exceedance events, from the zero-damage event up to the 0.2% annual exceedance event. The model uses outflow from Bonneville dam as its main upstream boundary condition, as well as flow hydrographs computed for each of the major tributaries modeled. The downstream boundary condition is a tidal stage hydrograph. HEC-RAS (River Analysis System) in conjunction with RAS Mapper produces water surface profiles, hydrographs, stage-discharge curves, and inundation grids. Portland District subsequently calibrated the model to observed annual peaks and simulated conditions downstream of Bonneville from Water Year (WY) 1973 through WY 2010 using period of record tide and flow data. Modeled annual peak stages were extracted and a statistical analysis was performed to determine the expected 50% annual exceedance stage. This “2-year” profile is applicable as the upper bound of the Expert Regional Technical Group range for calculating Survival Benefits Units.

May 30, 2014 Morning
Session 3: New Understanding of the Lower Columbia River Ecosystem (cont)

Sea level and extreme events in the Columbia River Estuary since 1853

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During the mid-19th century, the U.S. Coastal Survey measured tides and water temperature in Astoria, OR (1853-1876) and surveyed the entire Lower Columbia River Estuary (1868 and 1877). In this talk I will discuss our ongoing efforts to recover and digitize these analog data from the US National Archives. Results suggest that relative sea-level rise was statistically negligible in both the 19th and 20th centuries, but that tidal properties have been altered on the order of 10% by anthropogenic changes. Estimates of river flow from the tide gauge suggest that the Dec. 1861 flood was 20-30% larger than any subsequent winter flood, and that spring-freshets in 1862 and 1876 are amongst the 5 largest recorded events. Extreme water levels and long-term shifts in the 100 year storm surge and the 100 year river flood are explored. Because these data provide a snapshot of the Columbia River region before wide-spread anthropogenic development and climate change, they comprise a unique opportunity to determine the magnitude—and causes—of century-scale change.

Modeling of Historical Columbia River Flood Impacts

**Lumas Helaire*, Drew Mahedy, Dr. Stefan A. Talke

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The Lower Columbia River Estuary (LCRE) has undergone extensive modifications since the 19th century. Construction of dams, installation of jetties and dikes, dredging of the navigation channel and filling-in of tidal wetlands have all contributed significantly to alterations in tidal dynamics and the flow regime, with consequences for habitat inundation and salinity intrusion. In this talk we discuss the development and implementation of a 19th century flow model for the LCRE, using a digital elevation model based on historic bathymetry. The model has been calibrated with recently re-discovered and digitized tide data from the 19th century. In this research project we look at several river flow scenarios. We are interested in the interaction between river flow and ocean tides, how it has changed in the LCRE since the 19th century and how it affects the river physics. With the model, we focus on the following questions:

1. How has the spatial structure of salinity changed since the 1890's? Has the salinity intrusion length increased or decreased? Is there a change in residual salinity in some of the bays in the estuary? How have changes to the bathymetric structure of the river affected salinity intrusion?
2. For the same flow river flow, how have wetland inundation patterns changed? How have changes to the tidal prism ascertained from a temporal analysis of tidal records, affected the amount of land inundated in a tidal cycle and how long that land remains inundated?

Initial results suggest that salinity intrusion patterns have shifted and that wetland inundation patterns have been impacted by the up to 10% increase in the estuary tidal range since the late 19th century.

A System View of Water Level Processes in the Lower Columbia River, Pacific Ocean to Bonneville Dam: From Channel to Floodplain

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**Presenting author* (email: djay@pdx.edu)

Time and frequency domain data analyses and models have been used to provide a comprehensive view of water-level processes in the Lower Columbia River and Estuary (LCRE), with a focus on the interactions of floodplains and channels. A 50+ station-year floodplain water level data set collected 2007-2013 was combined with 1991-2013 data from main channel tide gauges to quantify the influence of astronomical tides, river flow, upwelling/downwelling, and power-peaking on the LCRE water-level regime on time scales from tidal monthly to interannual. Estuarine water levels are influenced primarily by astronomical tides and coastal processes, and secondarily by river flow. Coastal influences decrease in importance landward, and water levels are increasingly controlled by river flow. Thus, water level records are only slightly non-stationary near the ocean, but become increasingly irregular upriver. Although astronomically forced tidal constituents decrease above the estuary, tidal fortnightly and overtide variations increase for 80-200km landward, both relative to major tidal constituents and in absolute terms. Near the head of the tide at Bonneville Dam, strong diel and weekly fluctuations caused by power-peaking replace tidal daily and fortnightly variations. Water level records for wetland stations are more complex than those for channel stations, because of shallow-water effects and a truncation of low waters that varies strongly with river stage. Regression models based on tidal theory quantify the role of the above processes in determining lower low water (LLW), mean water level (MWL), and higher high water (HHW) for channel stations and floodplain wetlands. These models are also used to provide 21yr inundation hindcasts throughout the system. Water level and inundation patterns suggest that the system has four zones encompassing eight reaches. The zones are: 1) the wave and current dominated Entrance (ocean to river kilometer (rkm) 5); 2) the Estuary (rkm-5 to 87), comprised of a lower reach with salinity intrusion, the energy minimum, and an upper estuary reach without salinity intrusion; 3) the Tidal River (rkm-87 to 229), with lower, middle and upper reaches in which river flow becomes increasingly dominant over tides in determining water levels; and 4) the steep and weakly tidal Cascade (rkm-229 to 234). Water level properties for the floodplain stations show the same zonation as the channel stations but with considerable modification of tidal properties. The boundaries of five wetland vegetation zones are congruent with the above reach boundaries. A sum exceedance value (SEV) index, a measure of the total seasonal inundation over a wetland site, was used to connect wetland vegetation conditions to water levels and flows. SEV values increase by >10× from the ocean to Bonneville Dam, but SEV is most variable (between sites) in the lower and middle Tidal River. A potential SEV (or pSEV) index was developed based on channel water levels. Because channel water levels are readily predicted, pSEV can be used to estimate SEV for nearby wetland locations for any annual river flow and tidal range pattern, if the elevation of the wetland site is known. This should be useful for restoration planning and management decisions.

Modeling changes to residual circulation in the historic Lower Columbia River Estuary using Delft3D

Drew Mahedy, Lumas Helaire, and Stefan Talke

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Changes to the morphology and hydrodynamics of the Lower Columbia River Estuary (LCRE) over the past 130 years have primarily resulted from large-scale anthropogenic modifications. In the 1880's, the construction of jetties at the mouth of the river as well as navigation channel alterations initiated a new era human influence on tidal and fluvial processes in the mainstem. A succession of modifications to the river followed, including construction of hydropower dams and flood-control facilities, wetland in-fill, additional channel modifications, and installation of pile-dikes. Quantifying LCRE hydrodynamic processes as they existed prior to these modifications is important in understanding subsequent changes in estuarine ecosystems and has the potential to facilitate future prediction of sea-level rise and changing tides. To this end, a 19th century baroclinic numerical model of the Lower Columbia River was developed using the Delft3D modeling suite. U.S. Coast Survey hydrographic soundings sheets (1877-1901) that were georeferenced and digitized by the University of Washington's Wetland Ecosystems Team formed the basis of the model. Tide gauge data for Astoria, OR (1853-1877) and other shoreline gauges within the river (1868-1877) that have recently been rediscovered and digitized were used for calibration. Using the historic model, we endeavor to determine how vertical and horizontal residual velocities in the north and south channels have changed with respect to: a) spring and neap tide, and b) variable flow conditions. Preliminary results indicate a reduction in salinity intrusion length and strong differences in horizontal circulation patterns, particularly near the mouth of the river on ebb tide.

Session 4: Lessons from Ecological Restoration Projects

Improving State and Federal Fish Passage Design Guidelines for Water Crossings in Tidal Environments

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Restoration of estuarine habitats is a focus of salmonid recovery efforts in the Pacific Northwest because of the significant loss of historic intertidal habitats and the importance of these habitats to the recovery of federally listed salmonids (Bottom et al 2005; Gregory and Bisson 1997; Fresh et al 2003; Simenstad et al, 1982). Two common elements of juvenile salmonid habitat restoration are culvert / tide gate removal and replacement of undersized culverts that do not meet fish passage criteria. Restoring these “links” between the river and disconnected wetlands and tidal floodplains is fundamental to ecosystem health in the estuary. Replacement of these structures requires fish passage approval from state and often federal resource agencies. State of Oregon and Washington as well as federal fish passage design guidelines for bridge and culvert structures in fluvial (riverine or stream) environments are well developed (ODFW 2006; Barnard et al 2013; Hotchkiss and Frei 2007). However, specific design criteria in these documents that are applicable to tidal environments are limited. Further, geomorphological approaches and specific hydraulic criteria developed for fluvial environments are not appropriate for tidal channel systems. The purpose of this presentation is to address limitations in state and federal fish passage design guidelines. Emphasis will be on the physical processes governing tidal / estuarine environments, and how they affect fish ingress and egress. The following design considerations will be explored: applied tidal geomorphology approaches (Williams et al. 2002; Hood 2007; Diefenderfer et al. 2008; ESA PWA 2011) rather than fluvial approaches; the concept of the natural passage condition; consideration of tidal period-based criteria rather than arbitrary frequency or fluvially-based criteria; and, adopting new biological design criteria applicable to fish movements in tidal channels. Applicability of these design recommendations to several recently constructed tidal reconnection projects will be discussed. Information presented is intended to support the agencies and practitioners responsible for evaluating, permitting, designing, and implementing fish passage projects in estuarine environments.

River restoration for a changing climate

Tim Beechie[1], Mathias Collins[2], Robert Dudley[3], Faith Fitzpatrick[4], Glenn Hodgkins[3], Laura Perry[5,6], George Pess[1], Lindsay Reynolds[5,6], Phil Roni[1], Pat Shafroth[6]

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Future climate scenarios indicate that riverine habitats will be significantly altered in the next few decades, forcing managers to ask whether and how river restoration activities should be altered to accommodate climate change. Obvious questions include: (1) Will climate change alter river flow and temperature enough to reduce action effectiveness?, and (2) What types of restoration actions are more likely to remain effective in a climate altered future? To help address these questions, we reviewed literature on habitat restoration actions and river processes to determine the degree to which different restoration actions are likely to either ameliorate a climate effect or increase habitat diversity and resilience. One key finding is that restoring longitudinal and lateral connectivity to physically and thermally diverse habitats is most likely to succeed in a climate-altered future. Other restoration actions (e.g., reducing sediment supply, instream rehabilitation) are less likely to ameliorate climate change effects. In general, actions that restore watershed and ecosystem processes are most likely to be robust to climate change effects because they allow river channels and riverine ecosystems to evolve in response to shifting stream flow and temperature regimes. We offer a decision support process to illustrate how to evaluate whether a restoration plan or project design should be altered to accommodate climate change effects, and show examples of restoration actions that are likely to be resilient to a changing climate.

Cold water refuges: critical temporary habitats for migrating salmon and steelhead

**Matthew Keefer* and Chris Caudill

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The combination of regional climate warming and water management in the Columbia River basin has decreased the extent and quality of thermal environments for migrating salmon and steelhead. Earlier spring warming, later fall cooling and higher mean and maximum temperatures affect migrants at multiple scales, from individual fish behaviors to fitness effects on regional populations. We have conducted radiotelemetry and archival temperature tag studies of adult Chinook salmon, sockeye salmon, and steelhead in the Columbia and Willamette rivers and their major tributaries for many years. These studies have generated thousands of migration histories that we have used to investigate relationships among water temperatures, adult migration behaviors, and survival to spawning at several spatial scales. In the lower Columbia River migration corridor, many adults behaviorally thermoregulate during the warmest periods, using non-natal, cool-water tributaries as refugia from the warm main stem Columbia River. These small, patchily-distributed sites appear to be biologically important temporary habitats for many migrants seeking relief from stressful conditions. Threshold water temperatures of 19-21°C prompt extensive refuge use, with some fish (especially summer steelhead) holding for several weeks or more. Cool- and cold-water patches along migration corridors presumably provide a mix of physiological and energetic benefits for migrants. However, dense concentrations of fish in these small patches also increase the risks of predation, human harvest and other hazards. As evidence of thermal stress for Columbia River migrants has accumulated, interest in identifying cool-water refuge sites has also grown. Tools for identifying such sites have improved, and there are a variety of opportunities for protecting and restoring thermal diversity in the Columbia River estuary and along migration corridors.

Restoration of cold water refugia in the Columbia River Estuary

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During the past century, a combination of factors has degraded Columbia River water quality, including its thermal regime. Adult and juvenile salmonids migrate through the mainstem Columbia River (including the Columbia River estuary) during periods when temperatures average 18-22˚C and reach as high as 24˚C. The effects of these temperatures include physiological stress and higher susceptibility to predation. Data are available detailing the characteristics and use of thermal refugia by adult salmon and steelhead above Bonneville Dam; however, very limited data exist regarding use of thermal refugia in the Columbia River below Bonneville Dam. Despite this data gap, available evidence suggests that thermal refugia may provide important benefits to outmigrating juvenile salmon. This is particularly true for subyearling Chinook, whose migration timing coincides with the period of warmest mainstem Columbia River temperatures. This reliance has important implications for salmon recovery, particularly in the face of climate change (warmer air temperatures and changes in precipitation patterns), which is anticipated to increase mainstem temperatures above already stressful levels. The anticipated benefits (and potential future reliance) of thermal refugia to subyearling Chinook also presents a new habitat enhancement strategy for salmon recovery projects in the Columbia River estuary. We present a summary of the potential benefits of thermal refugia, an initial assessment of current and potential thermal refugia in reaches G and H, a summary of remaining uncertainties associated with the ability of individual sites to provide thermal refugia, and examples of habitat enhancement techniques anticipated to protect and restore thermal refugia.

May 30, 2014 Afternoon
Session 4: Lessons from Ecological Restoration Projects (cont)

Trajectories of Ecosystem Recovery in oligohaline Tidal Wetland Reconnection Restoration Projects

**Sarah Kidd* and Alan Yeakley

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The purpose of this study is to identify the rates of ecosystem service recovery in tidally reconnected oligohaline (salinity 0.5-5 ppt) wetlands on historically diked agricultural lands in the Lower Columbia River Estuary. A 54-year chronosequence of tidal wetland restoration sites is being used to identify restoration trajectories and rates of ecosystem service recovery. In the first phase of this study, initiated summer of 2013, restoration projects monitored included sites breached in 1959, 1988, 2006, 2007, and 2012, a reference wetland and two diked pastures (pre-restoration). Data collection focused on plant community composition, biomass, biodiversity, soil bulk density and organic matter content, sediment accretion, erosion, and hydrology. Although the existence of restoration trajectories is highly debated, preliminary results from this study indicate that trajectories toward reference conditions were present within the study's 54 yr chronosequence. We found native species richness levels equivalent to or greater than reference compositions (3±2SD, mean native species per $1m^2$) and non-native species richness levels equivalent to or less than reference compositions (1.3±4) in the 2007, 2006, 1988, and 1959 sites. Mean soil bulk density also showed clear signs of decreasing over the chronosequence with the 1988 and 1959 sites having levels (both 0.38±0.1 g/cm^2) comparable to reference conditions of 0.42±0.1 g/cm^2. These results suggest that native plant species compositions may form in under 6 years while soil development may take over a decade to develop in tidally reconnected oligohaline wetlands. Given this rapid rate of wetland vegetation recovery frequent (annual or biannual) monitoring during this time could inform critical adaptive management strategies and improve restoration outcomes. The inclusion of more restoration and reference sites and further monitoring are planned for 2014-2015. Understanding the development and delivery of tidal wetland ecosystem services during the restoration process is essential to successful restoration management.

Tidal Channel Allometry: Developing a Tool for Restoration Planning, Design, and Monitoring

W. Gregory Hood

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Effective tidal marsh restoration requires the ability to predict the outcomes of proposed restoration actions. Tidal channels are central elements of marsh hydrodynamics, sediment dynamics, and habitat, so GIS was used to digitize tidal channels from aerial photographs of Puget Sound river delta marshes and develop allometric models of channel geometry that predict the number and size of tidal channels that could develop following marsh restoration through dike breaching or removal. Tidal marsh area was the independent variable for all dependent channel planform metrics. Tidal channel allometry showed similar scaling exponents for channel planform metrics throughout Puget Sound, which simplified comparisons of Y-intercepts between locations. Multiple-regression indicated Y-intercepts of allometric relationships were positively related to tide range and negatively related to storm-significant wave height. Closer examination of four case studies, each with paired regions of similar tide range and contrasting wave environments, further indicated wave environment affected channel geometry. Wave-mediated sediment delivery may be the mechanism involved, with wave-sheltered areas experiencing relative sediment deficits such that some tidal marshes in Puget Sound are already suffering sea level rise impacts that are reflected in their channel network geometry. Analysis of Columbia River tidal marshes shows channel count allometry similar to that of Puget Sound systems. Likewise, there is evidence of a similar influence of tide range. Comparison of lower Columbia River Estuary dike breach restoration projects to reference marshes indicates project planners and designers underestimate the number of tidal channels or dike breaches their restoration sites should have, with likely impacts to site accessibility by juvenile salmon.

Exploring the Ecosystem and Salmon Habitat Functions of Large-River Floodplain Marshes with Altered Disturbance Regimes

Heida L. Diefenderfer[1], Amy B. Borde[1], Valerie I. Cullinan[1], Lyndal L. Johnson[2], G. Curtis Roegner[3]

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The Columbia River is emblematic of familiar river management trade-offs between floodplain energy, food and water resource developments with the potential to stress ecological processes through various pathways. The estuary and tidal river are subject to a dynamic mesh of natural disturbances, from intersections of fluvial and oceanic hydrologic processes to legacies of volcanism and earthquakes. An understanding of the effects of anthropogenic alterations to the disturbance regime on still-extant endangered species has the potential to inform future choices for energy development, ecosystem restoration and species recovery. It has practical applications in informing us whether alternative treatments (e.g., habitat creation and restoration methods) will produce different physical or biological outcomes in the future. In this study, we endeavored to determine whether differences observed in wetland physical environment and biota could be detected based on disturbance history. We reconstructed the histories of anthropogenic and natural disturbance at 50 floodplain wetland sites from the late 1800s forward, where we also collected ecological data. Anthropogenic disturbances included dredged material placement; the accidental or intentional breaching of dikes; and other local and landscape scale factors. Our historical analysis and the development and discrimination of six "disturbance categories" were used to characterize tidal wetlands in the lower Columbia River and estuary. For 24 wetland sites, both environmental data and juvenile salmon were collected. Metrics include fish community composition, species diversity and richness; sediment grain size, total organic carbon and accretion rate; channel width:depth ratio, inundation frequency and bank elevation; the cover and richness of native and non-native plant species; and water temperature. We compared the magnitude of effects from disturbance history to those from landscape position, and will present specific site examples including the Chinook River estuary and other marshes in Baker Bay. Implications of our findings for tidal wetland habitat creation, restoration and adaptive management in this complex regulated river system are discussed.

Improving Wetland Capacity through Integration of Science and Restoration in the Lower Columbia River and Estuary

Amy B. Borde[1], Heida L. Diefenderfer[1], Valerie I. Cullinan[1], Ronald M. Thom[1], Shon A. Zimmerman[1], Jina Sagar[2], Catherine Corbett[2], and Matthew Schwartz[2]

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One goal of the Columbia Estuary Ecosystem Restoration Program (CEERP) is to improve tidal wetland *capacity* for juvenile salmonids. The science-based tools for successful implementation of this goal are being developed in part from results gained from research and monitoring conducted at 58 reference wetlands over the past nine years. Emergent marsh habitat was evaluated at 51 of these wetlands with a focus on structural and hydrologic attributes. Seven of these sites have been monitored for multiple years to evaluate trends. In recent years, six sites have been areas of focus for food web studies. The results of this research are beginning to be integrated into tools to better inform restoration design, monitoring, evaluation and management. This talk will discuss the development of these tools and provide examples of recent applications such as using data on the elevation and inundation period where reed canarygrass thrives to design restoration projects with less likelihood of reed canarygrass invasion. We will also present recent findings regarding primary productivity and the relationship to food web dynamics, and discuss implications for management and future research.

An Evidence-Based Evaluation of the Cumulative Effects of Tidal Freshwater and Estuarine Ecosystem Restoration on Endangered Juvenile Salmon in the Columbia River

Heida Diefenderfer[1], **Gary Johnson*[1], Ron Thom[1], Amy Borde[1], Christa Woodley[1], Laurie Weitkamp[2], Kate Buenau[1], Roy Kropp[1]

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The purpose of this research was to evaluate the effect on listed salmon of the restoration effort currently being conducted under the auspices of the federal Columbia Estuary Ecosystem Restoration Program (CEERP). We designed an evidence-based approach to develop, synthesize, and evaluate information to determine early-stage (~10 years) outcomes of the CEERP. The primary hypothesis was that habitat restoration activities in the LCRE have a cumulative beneficial effect on juvenile salmon. There were two necessary conditions of the hypothesis: 1) habitat-based indicators of ecosystem controlling factors, processes, and structures show positive effects from restoration actions, and 2) fish-based indicators of ecosystem processes and functions show positive effects from restoration actions and habitats undergoing restoration. We identified a set of 12 ancillary hypotheses regarding habitat and salmon response. Each ancillary hypothesis states that the response metric will trend toward conditions at relatively undisturbed reference sites. Our evidence-based approach to evaluate the primary hypothesis incorporated seven lines of evidence, most of which are drawn from the LCRE, and included: spatial and temporal synergies, cumulative net ecosystem improvement, estuary-wide meta-analysis, offsite benefits to juvenile salmon, landscape condition evaluation, and evidence-based scoring of global literature. We synthesized the evidence for and against the two necessary conditions by using eleven causal criteria: strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, analogy, complete exposure pathway, and predictive performance. Our final evaluation included cumulative effects assessment because restoration is occurring at multiple sites and the collective effect is important to salmon recovery. We concluded that all five lines of evidence from the LCRE indicated positive habitat-based and fish-based responses to the restoration performed under the CEERP, although tide-gate replacements on small sloughs were an exception. Our analyses suggested that hydrologic reconnections restore access for fish to move into a site to find prey produced there. Reconnections also restore the potential for the flux of prey from the site to the main-stem river, where our data show that they are consumed by salmon. In general, this evidence-based evaluation indicates that tidal wetlands in the LCRE support juvenile salmon, including interior basin salmon. The beneficial effect of restoring tidal wetlands is expected to increase over time as existing restoration projects mature and new ones are implemented.

Particulate Organic Matter Export from a Restored Tidal Freshwater Wetland in the Columbia River Estuary

Ronald Thom[1], Stephen Breithaupt[1], Curtis Roegner[2], Dana Woodruff[1], and Gary Johnson[1]

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We investigated the hypothesis that by reconnecting the floodplain wetland, organic matter produced in the wetlands would reach other parts of the systems and ultimately provide a source of organic matter for the mainstem estuarine food web. To accomplish this, we utilized a numerical hydrodynamic model to estimate the mass of particulate organic matter (POM) exported from a restoring tidal emergent marsh in the Grays River, a tributary to the Columbia River estuary. Restoring hydrological connections to former tidal wetlands in the estuary to enhance juvenile salmonid rearing habitat has been the focus of a growing effort to recover endangered and threatened salmonid species in the Columbia River basin. Land use changes including diking and filling has resulted in the loss of 48,145ha of tidal wetlands since the late 1800's. Besides severely limiting direct access by salmon to wetlands, these actions have interrupted the flow of organic matter from the wetlands to the broader estuary by 82%, which has shifted the trophic structure from an benthic-epibenthic food web supported by estuarine marsh macrodetritus to a planktonic food web dominated by phytoplankton and zooplankton produced in reservoirs above the dams. We showed that a restoring 65 ha emergent marsh site exported 96.2×10^3 kg of POM primarily during pulsed flooding events in later autumn and early winter. This exported mass amounted to about 19% of the summer peak above ground biomass. However, the colonization of the restoring site largely by reed canarygrass (*Phalaris arundinacea*) may have resulted in 18-28% lower POM mobilization estimates from regional studies where marshes dominated by less recalcitrant species. Of that 19%, about 48% (46.2×10^3kg) of that was deposited downstream in the Grays River and floodplain wetlands, and the remaining 52% (50.0×10^3kg) reached the confluence of the Grays River and the mainstem estuary located about 7 km from the mouth of the wetland. We conclude that restored floodplain wetlands can contribute significant amounts of organic matter to the estuarine ecosystem, and thereby contribute to the restoring of the historical trophic structure.

A High-Resolution Area-Time Inundation Model to Assess Habitat Opportunity and Quality under Existing and Alternate Conditions

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The hydrodynamics of tidal and fluvial areas in the lower Columbia River floodplain and estuary directly affect habitat opportunity and quality for aquatic and terrestrial species. Physical and biological structures and functions in the system are directly affected by patterns of inundation. The frequency, duration, and magnitude of inundation is driven by tidal cycles, meteorological events, hydropower operations, upriver water withdrawals, climate, and physical barriers such as dikes, culverts, and tide gates. Ongoing ecosystem restoration efforts have a need to evaluate the effects of inundation on existing and alternative physical designs as well as future alternative climates in order to understand potential impacts and meet habitat objectives. Addressing the need to evaluate habitat opportunity and quality, a GIS-based model, the Area-Time Inundation Index Model (ATIIM) was developed as a tool for informed rapid assessment at the site scale. The ATIIM integrates in-situ or modeled hourly water-surface elevation (WSE) data and advanced terrain processing of high-resolution elevation data coupled with a spatially based wetted-area algorithm that enforces hydrologic connectivity. Over 50 spatial, tabular and graph-based products are produced and include process metrics such as site average bankfull elevation, two- and three-dimensional inundation extent/volume, mean water depth, inundation frequency, duration, maximum area, and maximum frequency area, probability of exceedence, non-inundated area, frequency, and duration, habitat complexity and opportunity, and various morphological indices. The analysis results from ATIIM can be used to help determine trade-offs between WSE and habitat opportunity, contrast alternative restoration designs, predict impacts of altered flow or climate regimes, estimate nutrient and biomass fluxes, and more.

Estuary Restoration Planning for Fish and Wildlife: North Unit, Sauvie Island Wildlife Area (SIWA)

Allan Whiting[1], Curt Mykut[2], Tom Josephson[3], Mark Nebeker[4], Curtis Loeb[5], Brad Bales[6], Scott Gall[7]

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The North Unit project is one of the higher value restoration projects completed to-date for the Columbia River Estuary in terms of scale, complexity, and unique partnerships. Located at the confluence of two river systems, its formative geomorphic processes have evolved to develop a gradient of habitat types that perform a diversity of wetland functions for fish and wildlife. The presentation will focus on technical and social tools used to develop restoration concepts that met both the needs of juvenile salmon while concurrently meeting the needs of SIWA wildlife objectives. Technical products developed during the project feasibility phase were used to attain support of refuge manager and its partners to ensure consistency with management objectives and funding authorities. The presentation will highlight the planning processes used to vet datasets, model results, and alternatives analysis at important decision points with all project partners.

Changes in Tidal Hydraulics at Crims Island in Response to Restoration Activities

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This presentation will demonstrate how tidal circulation has been affected at Crims Island, in response to ecosystem restoration activities. Hydraulic conditions prior to restoration will be compared to the post-restoration configuration using results from detailed hydrodynamic modeling. Restoration of Crims Island near Longview, Washington (RM 55), re-established 38.1 hectares of marsh and swamp in the tidal freshwater portion of the lower Columbia River. The goal of the restoration was to improve habitat for juveniles of Endangered Species Act (ESA)-listed salmon stocks and ESA-listed Columbian white-tailed deer. During August 2004 to September 2005, a 0.6-meter layer of soil was excavated and channels were dug in the interior of the island to remove reed canary grass and increase habitat area and tidal exchange. The excavation created 34.4 hectares of tidal emergent marsh where none previously existed and 3.7 hectares of intertidal and subtidal channels. New intertidal channels allowed for the inundation of tidal mudflats at high tide to increase rearing habitat for juvenile salmonids. The Crims Island restoration action resulted in a 95-percent increase in available juvenile salmon rearing habitat. The featured hydrodynamic results were obtained using the Adaptive-Hydraulics (AdH) model which has been calibrated and validated for the lower Columbia River. Model resolution within Crims Island extended to a 2-meter scale. The presentation will: 1) demonstrate the connectivity of water flow within the network of newly created tidal channels, 2) illustrate how newly created intertidal areas are inundated in time-sequence, 3) show how the restored area interacts with the Columbia River adjacent to Crims Island. The presentation will also compare summary hydraulic parameters between the pre- and post-restoration conditions.

Chinook River Estuary – Restoring Anadromous Fish Passage and Tidal Ecosystem Dynamics

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The Chinook Estuary Restoration provides an excellent example of transferring our research and monitoring results to management and policy decisions related to tide gate management and ecosystem restoration strategies. The project Vision is a naturally functioning Chinook River Estuary – to be achieved via reducing artificial tidal flow regulation (stressor) and restoring natural processes. The restoration approach for hydrologic processes is threefold: (1) optimize tide gate operations, (2) enhance tidal channels and (3) conduct action effectiveness monitoring and adaptive management. The primary physical controlling factors are water surface elevation, temperature and salinity. The biological and physical response will be evaluated in terms of fish passage improvements, tidal flux, estuary inundation, sediment accretion, water quality, plant community changes, and anadromous fish survival benefits. Direct salmon population enhancement is measured in terms of (1) adult salmon spawning runs (endemic stocks); and, (2) juvenile salmonid rearing and foraging conditions (endemic and out-of-basin stocks). This restoration framework is consistent with the Columbia River Estuary Conceptual Model. The operational tide gate management goal is to open tide gates year-round to the maximum extent possible while protecting adjacent landowners from flooding. We believe the strategy is being successfully implemented because the number of days that all tide gates were closed has decreased from 65% in 2011-12 to 39% in 2012-13 to only 6% in 2013-14. Conversely, the percent of time that two tide gates have been in the fully open (raised) position has increased from 21% to 45% to 93% during the same three time periods. Channel restoration actions planned for summer 2014 will increase salmon habitat access and capacity by removing tidal channel blockages via excavation at up to 14 locations to improve juvenile salmonid access to currently blocked areas, and improve capacity by improving water quality and vegetation community structure. Salmon habitat capacity will be further enhanced by restoring historical channel width in select locations; filling agricultural ditches; and planting riparian areas and controlling noxious weeds. Re-establishment of estuarine plant communities will be monitored, and evaluated via comparison with previously established reference wetlands in the Columbia River estuary. We are increasing public outreach and involvement as we move from planning to implementation – to involve local citizens, communities and governments.

POSTER ABSTRACTS

2014 Columbia River Estuary Workshop:
Forging Links in the Columbia River Estuary

Analysis of inundation for wetland features of the Columbia River Estuary Ecosystem Classification

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This overlay analysis of static water levels assesses the influence of stream-flow, tides, and isolation on the inundation of wetlands along the Columbia River estuary. The Columbia River Estuary Ecosystem Classification (Classification) is a hierarchical inventory of landforms along the estuary. The Ecosystem Complex level of the Classification represents the processes responsible for individual landforms (Geomorphic Catena level) and is the emphasis of this analysis. Most natural wetland features (including lakes) along the estuary were formed within surge plain, floodplain backswamp, or floodplain ridge and swale complexes. Wetland areas in these complexes are tidal marshes, broad floodplain basins, and narrow swales between floodplain ridges, respectively. These wetland settings are concentrated in different parts of the Classification, are at different elevations, and have different hydrologic functions. Many have been isolated from the flooding by levee systems. We assess how flow changes and isolation affect the frequency and area of wetland inundation using the Classification, an inventory of isolated areas, historical flood profiles, and statistical water levels interpolated from stations along the estuary. Water levels analyzed represent median pre- and post- regulation annual peak stream-flow, maximum historical flooding, and low stream-flow. They do not account for dynamic flow effects. Representative stream-flows were determined from measurements at The Dalles. Considering river flow and tides and their potential interaction with all wetlands (whether isolated or not), preliminary results indicate: (1) little difference in area of inundated surge plain or backswamp wetlands that is because of reduced peak flows; (2) reduced peak flows would reduce inundation of floodplain ridge and swale wetland areas by nearly 20 percent, much less for other, lower, wetland types such as those in backswamps and surge plains; (3) most surge plains and backswamp areas would be inundated less than half of the time during low stream flow, but many would still be inundated at least once during monthly tidal cycles. Isolation is the larger factor limiting inundation. Of the area inundated by the median pre-regulation flood of 16,400 m^3/s, about 60 percent of floodplain and surge plain areas are isolated from flooding by levees, including 65 percent of surge plains, 58 percent of floodplain ridge and swale wetland areas and 44 percent of backswamp wetland areas.

Estuarine Restoration at Lewis and Clark National Historical Park

Carla Cole

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In partnership with CREST, BPA, LCEP, USFWS, OWEB and others, Lewis and Clark National Historical Park has reconnected over 80 acres of tidal floodplain to the Lewis and Clark River in the Youngs Bay watershed. Beginning in 2007 with the replacement of a failing tidegate with a bridge, several sites (Colewort Creek, South Clatsop Slough, The Reference Marsh, and Otter Point) have now undergone restoration and/or monitoring actions. Work has included channel excavation, marsh plain lowering, dike breaching, invasive plant removal, and levee building. Restoring diverse, native plant communities is a crucial component of these projects. A variety of revegetation efforts are underway, from totally passive to experiments with solarization, hydroseeding, elk exclosures, and elevation-guided plantings. These methods are being intensively monitored by standardized protocols of hydrology, topography, fish abundance, and vegetation. Together, these National Park sites collectively offer excellent opportunities for collaborative long term studies and experimentation.

How much habitat is enough in the lower Columbia River?

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Native species in the lower Columbia River evolved under ecological conditions that existed for thousands of years previous to large-scale development that started in the late 1800's. As a result of conversion of native habitats to agriculture, industry and urban development, the lower Columbia has lost over 70% of vegetated tidal wetlands, 55% of forested uplands and 114,050 acres of native habitats overall since this time. Protecting remaining areas of native habitats and restoration of native habitats to recover historic habitat diversity should benefit native species, and resource management entities frequently target protecting historic native habitats as an end point for restoration actions or recovering native species. The difficult question that scientists and managers have been asking for many decades is "how much habitat is enough?" Many agencies use minimum viable population or population viability analyses to determine conservation targets for identified species (or focal species). If this information is not available, entities often have to employ an approach that targets protecting or restoring a percentage of historic habitats. Quantities range widely from 10% to over 40%. Another method is using a point in time that represents reference conditions, such as in Tampa Bay, FL where managers target 1950's habitat coverage (represents an era before air conditioning and wide-spread urban development). We are evaluating a technique employed by The Nature Conservancy for the southern Rocky Mountain ecoregion and US Fish and Wildlife Service for the National Wildlife Refuges, for protecting ecosystems (see Tear et al. 2005), which is based largely on the general species-areas curve in MacArthur and Wilson (1967) with adaptations to include additional aspects of biogeography and landscape ecology. We have established draft numeric targets and begun evaluating them for the ability to protect common species using the lower Columbia:

- No new net loss of native habitats (2009 baseline; 114,050 acres lost since 1870)
- Recover 30% of historic extent for priority habitats by 2030; 40% of historic extent by 2050 including:
    - *Representation* of priority habitats and rare, vulnerable communities
    - *Redundancy* by representing multiple examples of habitats within each region
    - *Resiliency* of communities to persist through disturbances by ensuring good quality, condition of habitats
- Other aspects, based on historic template:
    - Multiple large "reserves" and smaller patches that fill gaps, ensure corridors, increase connectivity
    - Identify minimum size criterion
    - Identify minimum number of occurrences of habitats by region

Next steps to complete these targets include: 1) identifying a minimum size criterion for larger "reserves" and smaller patches of habitats, 2) identifying a minimum number of occurrences of habitats by region, 3) identifying gaps in habitats, key corridors for species, 4) evaluating these targets to ensure they are protective of common species and 5) having them peer reviewed. Additionally, we are working on a concurrent process for rare and threatened focal species and will integrate these targets into the natural habitat diversity targets once they are ready.

Effective methods for assessing benthic macro-invertebrate response to dredge disposal off the Columbia River, Oregon

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Annually, more than three million cubic meters of material are dredged from the mouth of the Columbia River (MCR) in the Pacific Northwest to maintain shipping channels. Much of this dredge material is dumped at designated ocean dredged material disposal sites (ODMDS); a process monitored by the US Environmental Protection Agency (USEPA) and US Army Corps of Engineers (USACE). Currently with the Lower Columbia Solutions Group, a multi-agency collaboration including the USEPA, USACE, Oregon Department of Fish and Wildlife, NOAA, and Oregon State University is working towards adaptive management solutions to monitoring potential dredge disposal effects near the MCR. Monitoring studies by the USACE have included community surveys to quantify and compare benthic composition and diversity across many ODMDS. The effectiveness and efficiency of benthic survey methods at ODMDS will be assessed in this study. Past and current monitoring off the Columbia River has utilized trawling to assess benthic communities, a method that results in take (killing) of many benthic organisms, as well as crab pots to specifically assess Dungeness crabs (_Cancer magister_). Video-based surveys could be an effective alternate sampling method to trawl and crab pot surveys; often being less expensive and intensive to operate, as well as not physically removing benthic organisms from their habitat to conduct community and population assessments. Otter trawls versus video sled surveys, as well as crab pots versus stationary baited video methods will be compared in their effectiveness to gain an understanding of benthic organism distributions and behavior. Macro-invertebrates including sea stars and Dungeness crabs will be the focus of these survey analyses due to their prominence as benthic predators and an easily identifiable basis of benthic community conditions. The results will determine the best suited monitoring techniques to meet the demands of both marine resource managers and the benthic ecosystem.

Design and construction of a cost effective ocean acidification pHstat/chemostat with adaptable pH-manipulation controls

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Although ocean acidification (OA) is likely to influence nearly all regions of the surface ocean in the coming decades, there are already measurable effects in Eastern Boundary Current ecosystems due to the influence of coastal upwelling. As the largest river on the west coast of the United States, the Columbia River Estuary (CRE) has a significant impact on the biogeochemistry of the Pacific Northwest coastal region. Although substantial progress has been made in elucidating the influence of OA on the coast, the consequences for the estuary remain poorly characterized, in part due to the large natural variations in pH and water quality parameters. In order to better understand estuarine ecosystem responses to OA,we have designed and constructed a novel, cost-effective pHstat/chemostat system that will enable us to conduct laboratory experiments that study the effects of pH onenvironmental variables such as phytoplankton health, photosynthetic efficiency, oxidative stress and (for some phytoplankton species) toxin production. The design allows pH to be precisely regulated using interchangable reagent or gas manifolds, both of which feature flow regulation by solenoid valve. A LabVIEW© virtual instrument communicates with a solid state relay array, which in turn controls the manifolds. Superior control of pH has been achieved, with resolution of 0.05 pH units possible at time scales of less than one minute. This approach will provide much needed information about plankton growth in estuaries that will inform model studies and management practices for the CRE.

Oncor: A Geospatial Database for the Columbia Estuary Ecosystem Restoration Program

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We developed a geospatial database, called *Oncor*, for research, monitoring, and related data relevant to the Columbia Estuary Ecosystem Restoration Program (CEERP). This estuary-wide data discovery/retrieval system has an intuitive user environment and the necessary resources to standardize, upload, and download data. The intent is to enable synthesis and evaluation of data generated by multiple entities, the results of which can then be applied in CEERP adaptive management and decision-making processes. To support *Oncor*, a *Handbook of Data Reduction Procedures, Workbooks, and Exchange Templates* was released in December 2013. The handbook and associated data categories in the *Oncor* database are comprehensive, including: water surface elevation, water temperature, elevation, sediment accretion, channel cross-section, landscape features, plant communities, Chinook salmon genetics, and fish catch, size, density, diet, and prey. Example data have been loaded and are accessible for most categories. Future work could entail continued population of *Oncor* with newly collected as well as previously collected data. *Oncor's* web address is http://oncor.pnnl.gov.

Estimation of Juvenile Salmon Density at a Landscape Scale

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This study was the first to estimate juvenile salmon density at a landscape scale, in this case a ~30-km stretch of tidal freshwater in the lower Columbia River between St. Helens, Oregon and Longview, Washington. The sampling universe was comprised of 167 500-m segments of shallow water considered amenable to beach seining. We developed a random-stratified sampling design and a statistically-robust density estimation procedure. For seasonal sampling episodes, 15 sites were randomly sampled seasonally across three habitat strata (main channel, off channel, and wetland channel) within a rotational panel sampling design. The methodology was implemented between summer 2011 and fall 2012, inclusive. Landscape densities for unmarked Chinook salmon were greatest (0.16 fish/m^2) during the winter and spring of 2012 in off-channel and wetland habitat strata. Lowest densities occurred during fall 2011 and 2012 (<0.01 fish/m^2) in all habitat strata. Except during winter 2012, densities for unmarked Chinook salmon were lower in the wetland habitat than main channel and off-channel habitats. Landscape density estimates have potential to be applied in action effectiveness studies where it is difficult to find suitable reference sites. Moreover, such estimates provide a landscape-level assessment of fish density that could have implications for restoration program management.

Application of Two-Dimensional Hydraulic Model for the Evaluation of Design Criteria for a Large Scale Tidal Wetland Restoration Project

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Recently, the Columbia River Estuary Study Taskforce (CREST) completed the planning and design of a tidal wetland restoration project for a 320 acre portion of Karlson Island, in the Columbia River with the assistance of Tetra Tech. Karlson Island is an alluvial floodplain island located at river mile 25 within the Lower Columbia River Estuary in Cathlamet Bay. Karlson Island is one of the 18 named islands encompassed in the United States Fish and Wildlife Service managed Lewis and Clark National Wildlife Refuge. The Lewis and Clark National Wildlife Refuge was established in 1972 to preserve habitats within the Lower Columbia River Estuary that are critical for fish and wildlife. Tidal and riverine flows create bi-directional and complex flow patterns around and within the interior slough and channels. A publicly available two-dimensional hydraulic model was used to evaluate the performance of proposed alternative restoration designs with a developed list of biological and physical criteria. The two-dimensional model approach used was able to better represent the flow patterns than one-dimensional model approaches used for restoration project sites with less complex flow directions. In the late 1800s, a levee was constructed around 320 acres of the north central portion of Karlson Island to allow cattle grazing. A portion of the levee was naturally breached in the 1970s, restoring tidal exchange and causing much of the levee protected area to revert to tidal marsh. The remaining portions of the levee provide no flood protection or associated land use benefits, and instead still limit fish passage, food web connectivity and nutrient exchange, and tidal channel development, and allow growth of invasive plant species.

A first year overview of a remote PIT-tag detection system installed within the Interstate-84 culverts at the confluence of Horsetail/Oneonta Creeks and the implications for its use in monitoring restoration effectiveness at the site

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A 'next-generation' PIT (passive integrated transponder) tag detection system was installed in the culvert system at the confluence of Horsetail and Oneonta Creeks on May 9, 2013. This system consists of a Biomark FishTRACKER IS1001-MTS distributed Multiplexing Transceiver System (MTS), which powers 10 antennas mounted (5 on each end) of the 5-barrel culvert system running beneath Interstate-84 at the confluence of Horsetail and Oneonta Creeks (Columbia River, OR). The MTS unit (one of the first delivered and installed) receives, records and stores tag signals from the antennas (each measuring approximately 6' by 6') and is powered by an 840 watt (W) solar panel array and supported by a 24-volt, 800 amp-hour battery bank backup. The system is connected to a fiber optic wireless modem that allows for daily downloads of tag data and system voltage monitoring updates. This MTS system was installed to help evaluate the effectiveness of restoration actions that were planned and conducted to the culverts during the Summer 2013, specifically a retrofit to the constructed 'swim-through' diversion riffle in the western-most barrel to improve fish passage. With our installation of antennas at each end, we are able to assess the success rate of individual fish passing though specific barrels of the culvert system. In total, the system was operable and collecting tag data for nearly 7 months and recorded 591 detections, which corresponded to 72 unique tags. Nearly all of the fish detected from May though the end of July were juvenile salmonids that had been released earlier in the year. Most of the juvenile fish were hatchery Chinook salmon, comprising both spring and fall stocks, but we also detected hatchery coho and hatchery summer Steelhead. Retuning adult Chinook and coho salmon, captured and tagged in the lower river as part of an upstream migration study, were detected beginning in late September though late November. Of the 21 juvenile salmon and steelhead that were detected at the site in the spring and early summer, most were encountered for only a day or two and only 2 individuals (hatchery coho, hatchery spring Chinook) were able to successfully navigate all the way through the culvert. In comparison to the spring/summer juveniles, twice as many adult salmon were encountered at the site in autumn, and many were present for long periods of time. These adults were also far more successful in transiting through the culvert system, with at least 14 individuals detected by upstream antennas. In most instances, these fish passed through the retrofitted western-most barrel. In addition to providing information on fish passage through the culvert, this PIT-tag array will also allow us to quantify the duration and timing of habitat use by various species of tagged transient fish.

A Method to Assess Availability of Cold Water Refugia for Juvenile Salmonids in the Columbia River Gorge

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The importance of cold water refugia to adult salmon migrating through the Columbia River has been well documented in recent years. Data are available detailing the use of thermal refugia by adult salmon and steelhead in Columbia River reaches upstream of Bonneville Dam. However, very limited data currently exist regarding locations of these habitats and their use by out-migrating and rearing juvenile salmonids in the lower Columbia River (below Bonneville Dam). At the same time a number of habitat restoration projects aimed at improving cold water access to juveniles in the Columbia River Gorge are currently being considered. In order to help address this data gap we present an approach aimed at characterizing the quality and extent of currently existing cold water refugia in this river reach, through a combination of temperature monitoring data and modeling efforts.

We will use a two/three dimensional hydrodynamic model and accompanying advection dispersion module to predict water temperature distributions at tributary confluences in the lower Columbia River Gorge. Model calibration and verification will be accomplished through comparison of model simulation results to field observations of water temperature and dye concentrations. Once calibrated, the model will be used to evaluate potential effects of various restoration activities on the extent of cold water refugia at specific tributary confluences which are being targeted for restoration. In addition to modeling efforts, we propose a comprehensive monitoring effort to map shallow water, cold water inputs throughout the lower Columbia Gorge, using towed temperature loggers at multiple depths. Results of the survey will be used to produce a map of all cold water inputs to the lower Columbia Gorge, including tributary confluences as well as sources such as groundwater inputs located away from tributary mouths.

The Physics of Dredged Material Placement within Nearshore Waters: as Observed by a Crab

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The presentation will describe the physics affecting dredged sediment as it is released from a hopper dredge during nearshore placement along the Pacific coast of Oregon, at the mouth of the Columbia River (MCR), USA. Sand dredged from the MCR navigation channel is being placed in water depth of 12-16 m, to address a coastal sediment deficit while minimizing impacts to benthic ecology. The focus of this work is to observe the physics of dredged material plumes encountering the seabed, and associated effects on bottom dwellers such as Dungeness crab (*Metacarcinus magister*). The physics governing dredged material placement within open water are analogous to a negatively buoyant plume. The downward velocity of the dredged material plumes can attain speeds of 3-5 m/sec. When a dredge material plume encounters the seabed, it spreads radially from the point of impact as the plume's kinetic energy is expended through friction and turbulent dissipation. Metrics of interest include the plume's velocity along the seabed and level of dredged material deposition on the seabed. Reported results will feature in-situ video, instrumentation, and numerical model analysis.

Evolution of passive integrated transponder detection systems for a surface trawl and pile dike in the Columbia River estuary

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Since the 1980s, PIT tags have been used to mark Pacific salmon (*Oncorhynchus* spp.) in the Columbia River basin. In 1995, we began a multi-year study to evaluate migration timing and survival of migrating PIT-tagged juvenile salmonids in the Columbia River estuary. Sampling was conducted between river kilometers (rkm) 61 and 83 using a surface pair trawl fitted with a pass-through PIT-tag detection antenna in lieu of a cod end. Annual detection totals have ranged from 226 fish in 1995 to over 31,000 in 2010. As PIT tag technology has evolved to allow longer tag-reading range, our antenna designs have also changed to allow larger fish-passage openings and fewer encumbrances to fish exiting the trawl. A variety of antenna designs have been developed for the trawl system, and several of these are illustrated here. Beginning in 2009, we deployed a "matrix" antenna system featuring two three-coil components placed at the front and rear of the fish-passage opening (2.5 × 3.0 m). In 2011, we used a similar 4-coil matrix design to cover a 2.4- by 6.1-m area along a pile dike (rkm 70) to detected returning adult salmon. Larger fish passage openings proved especially important with adults, since they initially rejected passing through the pile dike antenna due to an obstruction formed where the 4 individual coils joined in the center. In 2013, we used a single antenna coil design that covered the same area (2.4 × 6.1 m) made possible by the new IS1001 multiplex transceiver. Adult detections were substantially improved, and antenna was avoidance reduced. Initially, the antennas were housed in 10.2-cm-diameter, rigid PVC pipe. We briefly tested this new antenna with short mesh wings similar to our trawl system. These tests showed significant stress on the PVC frame, and the large, rigid frame was difficult to deploy and retrieve. Using an experimental antenna housed in 1.9-cm diameter flexible PVC tubing, we replaced most rigid antennas on the pile dike and eventually expanded the pile dike system to 5 total coils, some as far as 91 m from the transceivers. Except for interruptions to replace rigid antennas and some brief solar-power shortages in late season, the detection system proved reliable and remained in operation from March through October. We continued testing the flexible antenna design with a rope frame for towing as a mobile application. Results are promising, though further testing will be needed to reduce vibration, as we plan to design a larger mobile antenna system with multiple coils.

Geological Mapping of the Columbia River Corridor; Status and Plans

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The U.S. Geological Survey in conjunction with the Oregon Department of Geology and Mineral Industries, Washington Division of Geology & Earth Resources, and the National Park Service is embarking on a concerted effort to conduct and compile digital geological mapping at scale 1:24,000 for the Columbia River corridor, eventually spanning 500 km from Astoria to the Tri Cities, Washington. Federal and state interest in Columbia River ecosystems, natural resources, and hazards are the primary motivation for better understanding of Columbia River geology, groundwater, habitat, neotectonics, and recent history. An early phase will be focused on completing this work for the estuary through the Portland Basin and the Columbia River Gorge. The mapping incorporates components of the Columbia River Estuary Ecosystem Classification mapping now being completed. This poster will present mapping status and plans. Mapping objectives include:

1) Documentation of the Quaternary history of the Columbia River and evolution of its landscape.
2) A stratigraphic framework for neotectonics and the Columbia River Basalt aquifer system.
3) Improved understanding of the Columbia Basin and Yakima Fold belt and their relation to convergent margin tectonics.
4) A quantitative framework for regional analysis of seismic hazards.
5) Documenting the geologic and tectonic history of the Columbia River Gorge National Scenic Area.

Influence of hydrogeomorphology on phytoplankton and zooplankton abundance and species composition in the lower Columbia River

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Historically, the Columbia River was characterized by high particle loads and low pelagic primary production, with ecosystem energy being derived from allochthonous sources of organic matter in the form of detrital vegetation (macrodetritus). With the installation of several dams on the mainstem and tributaries, pelagic primary production has increased and evidence strongly suggests that pelagic primary producers (phytoplankton) play an important role in the food web supporting salmonids and other fish species, particularly during periods of high phytoplankton-based primary productivity in the spring. Here we show three years of observations from shallow water habitats and the river mainstem indicating that phytoplankton and zooplankton abundances and species composition are influenced by the dynamics of river flow and the degree of connectivity between shallow habitats and the mainstem river. Given that phytoplankton and zooplankton likely play a more important role in salmonid food webs relative to historical times, identifying the factors that drive patterns in their abundance and composition is critical to evaluating resource availability for key species of interest. Better characterization of the influence of river flow as a determinant of the abundance, species composition, and connectivity among lower trophic level populations may inform system-scale strategies for habitat preservation or improvement.

A metagenomic study of the microbial communities of the Columbia River Estuary

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The Center for Coastal Margin Observation and Prediction (CMOP) at Oregon Health & Science University (OHSU) seeks to transcend traditional scientific, educational and societal boundaries to understand issues pertaining to coastal margins of the Pacific Northwest including the Columbia River Estuary (CRE). As one of the largest and most influential river systems in North America, a comprehensive understanding of this estuary is imperative to enable a better understanding of anthropogenic impacts on this type of ecosystem, as well as enabling better prediction of potential disturbances impacting this ecosystem. By understanding microbial assemblages with in the estuary we will detail how nutrients are transformed and transported throughout the estuary, and ultimately exported to the coastal margin. A metagenomic approach is currently underway to elucidate how sediments from lateral bays may influence microbial dispersion in the estuary, how particles from these sediments may become entrained in the water column, and the role microbes play in transient events such as estuarine turbidity maxima. For my project, a metagenomic analysis of the microbial community associated with the estuary gives insight to the genetic potential of the microbial community and helps us to understand the biogeochemical processes that may be underway within the estuary.

Does high water temperature affect subyearling Chinook salmon density or condition in the lower Columbia River and estuary?

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We examined the hypotheses that density and morphometric condition of subyearling juvenile Chinook salmon (*Oncorhynchus tshawytscha*) would decline during periods of high water temperatures in the lower Columbia River and estuary. The hypotheses were tested using salmon density measurements and a condition anomaly calculated from residuals of the length-weight linear regression relationship of 5536 subyearlings collected from brackish estuarine and tidal freshwater habitats. We found Chinook salmon at all temperatures encountered (4.2-23.5°C). In the tidal freshwater zone, densities were highest at optimal temperatures and lowest at suboptimal and supraoptimal temperatures, while in the estuary no differences were found among different temperature regimes. Salmon condition was lowest in winter, when temperatures were suboptimal, and highest in summer, when temperatures were supraoptimal. Pairwise comparisons between condition during optimal temperatures (spring), and those during supraoptimal or stressful temperatures (summer), showed little change in the estuary, but a large positive increase with temperature in the tidal freshwater zone. Similarly, we examined seasonal differences in the condition of fry between 50 and 60 mm, and again found condition to be lowest during winter and highest in summer. Known hatchery fish had lower condition than unmarked fish in summer but not spring. Finally, using genetic information, we found stock-specific differences in migration timing, and concluded that most large yearling and many subyearling fish migrated in late winter or spring, and thus were never exposed to high temperatures. Other prevalent stocks persisted in the estuary during periods of elevated temperature; however condition of these salmon stocks also tended to be higher or neutral in summer than in spring. High temperatures appear to influence migration timing as evidenced by reduced density in tidal freshwater reaches in summer. However, we found little support for the hypothesis that condition of juvenile Chinook salmon is reduced during periods of high water temperatures in the lower Columbia River and estuary.

Characteristics of Juvenile Salmon in Tidal Freshwater Habitats of the Columbia River

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Tidally-influenced habitats from fresh to salt water support critical life phases for anadromous juvenile Pacific salmon (*Oncorhynchus* spp.). While the knowledge base for juvenile salmon ecology in estuarine water is substantial, the role of tidal freshwater habitats in juvenile salmon ecology is not as well understood. Tidal freshwater ecosystems are not as prevalent or extensive as brackish systems, and generally, have been understudied compared to other aquatic environments .This is especially true for the largest tidal freshwater expanse in the Pacific Northwest, the Columbia River. The need for understanding aspects of juvenile salmon in tidal freshwater habitats of the Columbia River is driven by uncertainties about the interaction between juvenile salmon and the variability in habitats within the estuarine-tidal freshwater gradient. This paper describes early life history characteristics (size, density, spatial and temporal distribution, and genetic stock) of Chinook salmon (*O. tshawytscha*) and examines relationships between these characteristics and environmental conditions within shallow tidal freshwater habitats of the Columbia River. We established sampling regimes in two distinct study areas in LCRE tidal freshwater: the Sandy River Delta (SRD; rkm 188–202) and the Lower River Reaches (LRR; rkm 110–141) where fish and environmental data were collected. The objectives were to 1) determine the density, size distribution, and genetic stock composition of Chinook salmon through time at the SRD study area; 2) determine the density, size distribution, and genetic stock composition of Chinook salmon in three habitat types in the LRR; and 3) examine relationships between salmon density and environmental covariates. In this paper we find that juvenile Chinook salmon occupy various habitat types and geographic locations under a range of environmental conditions in tidal freshwater of the Columbia River. These findings provide fundamental information for an ecosystem-based strategy to restore shallow tidal freshwater habitats of the Columbia River.

Post-evaluation of the effects of Columbia River Channel Improvement Project

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The Columbia River Channel Improvements Project (CRCIP) deepened the navigation channel to 43 ft, from 40 ft. We are using a 3D numerical model of circulation (SELFE) to evaluate changes from 2003 (pre-dredging conditions) to 2012 (post-dredging), relative to 4 ecologically relevant metrics (plume volume, salinity intrusion length, salmon habitat opportunity, and shallow water habitat). Three contrasting bathymetry conditions are being considered: (1) pre-deepening conditions (2003); (2) 2003 conditions altered to include the 2012 channel, and (3) "current" conditions (2012, which differ from 2003 due to factors both inclusive and beyond the channel deepening). Results to date suggest that—although the estuary has changed as a whole from 2003 to 2012—changes due to the new channel geometry are minimal, for all metrics considered. This investigation has been conducted at the request and in coordination with the multi-agency CRCIP Adaptive Management Team.

Species diversity and non-native fish species at the Mirror Lake complex in Oregon USA

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Observation of salmon at the lake and creek during a fish spawning survey prompted restoration and enhancement of the Mirror Lake Complex, which is connected to Rooster State Park, Oregon, USA, by the Interstate-84 culvert at the base of Rooster Rock. A number of restoration enhancement activities, including building of a bridge to replace a failing earthen dam, planting of native plants, placement of large woody debris in the streambed to provide refugia for juvenile salmon, and enhancements to the culvert to increase water flow, were made to increase salmon abundance and diversity at the complex. As a part of the Lower Columbia Estuary Partnership's Restoration Action Effectiveness Monitoring program, five sites in Mirror Lake Complex were monitored for fish species composition from 2008-2012. Sampling sites included the lagoon (Culvert) just below the I-84 culvert, which merges with the Columbia River; Mirror Lake (Lake) located on the other side of the I-84 culvert; Latourell Creek and Youngs Creek, two small streams that feed the emergent wetland at Mirror Lake located 1 and 2 miles from the lake, respectively; and the confluence of Latourell Creek and Youngs Creek, located 0.6 miles upstream from the lake. Initial results showed no clear trends in salmon diversity at the complex following the restoration enhancement until 2011 and 2012, when both Chinook and coho salmon were observed at the confluence site for the first time. Total fish species diversity was higher at the Culvert and Lake than upper sites, and the proportion of non-native species present was also highest at these same sites. Non-native species were absent from the upper sites in the earlier years of the study but their proportion increased in the later years. Seasonal variation in water level influenced by Columbia River flow and changes in water temperature seemed to have an effect on the diversity of native and non-native species at the upper sites, making them warmer and more accessible to non-native species from the Columbia River and the sites below.

Potential cyanoHAB (cyanobacterial harmful algal bloom) threats to ecosystems of the Lower Columbia River

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Phytoplankton and zooplankton samples were collected approximately monthly between April and July from four shallow water habitat sites along the lower Columbia River over a three year period (2011-2013) as part of an Ecosystem Monitoring Program to assess status and trends of salmonid habitat characteristics. Significant contributions of cyanobacteria were observed in the two sites furthest upriver (Campbell Slough in Ridgefield National Wildlife Refuge and Franz Lake Slough), with dramatic abundance increases (both relative and absolute) during summer months (June and July). Included in the cyanobacterial populations were the known microcystin-producing genera *Anabaena* and *Microcystis*. Microcystin is a potent hepatotoxin known to be fatal to wildlife and livestock if ingested, as well as humans if concentrations are high enough. Since cyanotoxins are known to bioaccumulate in zooplankton, high cyanobacteria concentrations pose a toxin exposure risk to fish via food web transfer pathways, including direct consumption of zooplankton or by consumption of invertebrate prey that may feed on zooplankton and cyanobacteria. High cyanobacteria abundances were associated with warm temperatures, and preliminary data showed a positive correlation between total dissolved phosphorus concentrations and cyanobacteria abundance. To assess the potential risk of wildlife exposure to cyanotoxins, we recommend additional monitoring of phytoplankton abundances during the warm summer months as well as monthly measurements of cyanotoxins, especially microcystin. Analysis of relationships between cyanobacteria population dynamics, toxicity, and environmental variables will aid in the identification of seasonal patterns and drivers of toxin production for potential prediction and mitigation of this emerging public health threat.

Distribution of polyphosphate accumulating organisms in the Columbia River estuary

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Polyphosphate accumulating organisms (PAOs) are used in wastewater treatment for biological phosphorus removal. The importance of this process has led to intensive research on their metabolism and functional characteristics, however it is only recently that their role in the environment is being better elucidated. We have detected the presence of an important PAO, *Candidatus Accumulibacter phosphatis* (CAP) in association with particles in Estuarine Turbidity Maximum (ETM) events in the Columbia River estuary. Utilizing culture-independent methods (PCR, cloning) we have identified DNA sequences that show the presence of CAP associated with variable dissolved oxygen environments where phosphorus is rapidly transformed, as determined from environment data collected from several years of ship-based sampling, in situ sensor measurements, and bottle-based growth experiments. These measurements suggest biological conversions of particle-bound phosphorus in the salinity transition zone resulting in release of inorganic phosphorus. We hypothesize that particle-based biogeochemistry within the ETM offers an important niche for PAOs metabolism and subsequent release of phosphorus in the salinity transition zone, and therefore plays a significant role in phosphorus cycling in the estuary.

SATURN observation network: the workings and output of a long term biogeochemical observatory in the Columbia River estuary

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SATURN and its predecessor CORIE have been collecting oceanographic data in the Columbia River estuary and nearby Pacific Ocean since 1996. Originally focused on physical oceanographic measurements, in recent years the observatory has expanded to include the collection of a wide array of biogeochemical parameters. This expansion has required the development of novel approaches to data collection and detailed attention to quality control. Collection methods have expanded from a simple C-T on a pile to include a remote automated profiler, pumped systems on piers of convenience, ocean buoys and autonomous gliders. Data collected by the SATURN observatory is immediately and freely available to all, with processed data available at a later date. Here we describe the data currently being collected, how to access the archive of data and what strategies are employed to verify it. While SATURN also has freshwater stations, the focus of this poster is on assets in the estuary and on the continental shelf.