Columbia River Estuary Conference

Recent Anomalous Environmental Conditions - Drivers and Consequences

May 24-26, 2016

Liberty Theater • Astoria, Oregon

2016 Columbia River Estuary Conference:
Recent Anomalous Environmental Conditions – Drivers and Consequences

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Thanks to the many sponsors, we are able to put on the 2016 Columbia River Estuary Conference for a greatly reduced cost to participants. Without their continued support, this conference would not have been such a great success! We are tremendously grateful to our sponsors:

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AN INTRODUCTION TO OUR KEYNOTE SPEAKERS

Phil W. Mote

Director, Oregon Climate Change Research Institute and Oregon Climate Services
Oregon State University

Philip W. Mote is a professor in the College of Earth, Oceanic, and Atmospheric Sciences at Oregon State University; director of the Oregon Climate Change Research Institute (OCCRI) for the Oregon University System; and director of Oregon Climate Services, the official state climate office for Oregon. Dr. Mote's current research interests include scenario development, regional climate change, regional climate modeling with a superensemble generated by volunteers' personal computers, and adaptation to climate change. He is the co-leader of the NOAA-funded Climate Impacts Research Consortium for the Northwest, and also of the Northwest Climate Science Center for the US Department of the Interior. Since 2005 he has been involved in the Intergovernmental Panel on Climate Change, which shared the 2007 Nobel Peace Prize. He is also a coordinating lead author and advisory council member for the US National Climate Assessment, and has served on numerous author teams for the National Research Council (NRC). Dr. Mote earned a B.A. in physics from Harvard University and a Ph.D. in atmospheric sciences from the University of Washington, and arrived at OSU to establish OCCRI in 2009.

Presentation Summary - Dr. Mote's presentation will provide an update of the science of climate change relevant to the Columbia River estuary. New modeling by global and regional models continues to refine our projections of future climate, emphasizing that the pace of climate change will largely be determined by global emissions. Changes in precipitation and air temperature have already affected hydrology and water resources in the Northwest. In most watersheds (except those with little snow), as snow accumulation diminishes, spring peak flows shift earlier, winter flow increases, and late-summer flow decreases. Dry years are becoming drier everywhere; the 2014-15 drought was driven in large part by high temperatures, and is an example of conditions that will become common in a few decades. Climate driven changes will likely be profound for Northwest coasts and associated ecosystems. Sea levels here are projected to rise 4-56" by 2100 relative to 2000, with some local variations; the largest contributor to that uncertainty has to do with the behavior of the Antarctic ice sheet.

Nick Bond

State Climatologist and Research Meteorologist

Nick Bond is a senior research scientist with the Joint Institute for the Study of Atmosphere and Ocean (JISAO) of the University of Washington (UW) and also is an affiliate associate professor with the Department of Atmospheric Sciences at UW. His research is on a broad range of topics with a focus on the weather and climate of the Pacific Northwest, and the linkages between the climate and marine ecosystems of the North Pacific. He has a PhD in Atmospheric Sciences from the UW. Most of Dr. Bond's past research (and some ongoing research) involves the collection and analysis of low-level atmospheric observations over the ocean, based on special field measurements from moored buoys and aircraft. Notable examples have involved documenting the effects of the terrain along the U.S. West Coast on landfalling storms during the winter.

As part of the Climate Variability and Predictability (CLIVAR) program, air-sea interactions are being studied in the western sub-tropical Pacific. A majority of his current work is under the broad umbrella of the Fisheries-Oceanography Coordinated Investigation (FOCI). Here the focus has been on the variability in climate and atmospheric forcing of the Bering Sea, and topographical effects on coastal winds in Alaska. The results from this work are being applied to issues related to the marine ecosystems in Alaskan waters, with a special emphasis on the impacts of climate.

Presentation Summary - Remarkable warm temperature anomalies developed in the eastern North Pacific during the winter of 2013-14. This presentation will describe the mechanisms responsible for the development of these warm conditions, and its evolution from an offshore to more coastal signature. It will also include a quick look at the year ahead.

Bill Peterson
Oceanographer

Bill Peterson spent the first ten years of his life in Vancouver WA. He went to High School in Salem and college at Pacific Lutheran in Tacoma. His M.S. is in Oceanography at the University of Hawaii and Ph.D. from Oregon State University (in 1980). He was an Assistant Professor at Stony Brook University (Long Island) but left there in 1987 for a Senior Research Officer post at the University of Capetown where he spent two delightful years. Next up was a job with NOAA, in Monterey CA, where he served as Supervisory Physical Scientist at the Center for Ocean Analysis and Prediction. After two years in Monterey, he was approached to come to Washington D.C. and serve as Program Manager for the U.S. GLOBEC program, which he did from 1992-1995. He returned to Oregon in late 1995, to Newport. Soon after, he initiated a set of biweekly oceanographic cruises to continental shelf waters off Newport, collecting data which tracks inter-annual variability in hydrography, zooplankton, krill and larval fish. This program is now in its 21st year.

He has served as a Review Editor for Marine Ecology Progress Series (2005-2007) and a Contributing Editor from 2008-2010; he currently serves on the Advisory Board of the South African Journal of Marine Science and the TINRO-Centre Bulletin, Vladivostok Russia (2013-present) and continues to serve on the editorial board of the Journal of Plankton Research. He has received several Bronze Awards from NOAA and was recently honored with the prestigious Distinguished Career Award.

Presentation Summary - The Gulf of Alaska (GOA) became anomalously warm in autumn/winter 2013-14 due to a lack of cyclonic storms that usually mix (and subsequently cool) the water column. Warming continued through spring/summer 2014, spreading across the North Pacific (NP) Ocean, resulting in SST anomalies of +4.5°C. This warm mass of water, named colloquially "The Blob," began to shift eastward in spring 2014 but was held offshore of California, Oregon and Washington by offshore Ekman transport associated with coastal upwelling in spring and summer. However, in mid-September, northerly winds weakened, and the Blob moved onshore, raising SST off Oregon by 6°C in five hours, and soon occupied the upper 80 m of continental shelf waters off Oregon, bringing ~ 20 species of phytoplankton and copepods that were either new records for the northern California Current or known to occur only in waters far offshore of Oregon and/or during past major El Niño events (1983, 1998). Many of the unusual species have NP Gyre and/or NP Transition Zone affinities indicating that the source waters of the "Blob" were of offshore and subtropical/tropical origin. Other notable effects observed in coastal waters included a toxic diatom bloom (*Pseudo-nitzschia*) off Washington, Oregon and California that persisted from April-November 2015, a reduced biomass of krill, and high abundance of larvaceans, doliolids, and salps (indicators of oligotrophic ocean conditions). Furthermore, the media reported the presence of many warm water vertebrate species dislocated 1000's of km north of their normal range: sea snakes, green and olive Ridley turtle, moonfish (opah) throughout the California Current (CC), and ocean sunfish, pomfret, pompano, mackerels, tropical tunas and sharks in the CC and GOA.

AGENDA
2016 Columbia River Estuary Conference:
Recent Anomalous Environmental Conditions – Drivers and Consequences

May 24, 2016	
8:00 AM	**Registration**
9:00 AM	**Invocation** *Tanna Engdahl, Cowlitz Indian Tribe*
9:20 AM	**Welcome and Introduction to the Columbia River Estuary Conference** *Catherine Corbett, Chair Steering Committee*
9:30 AM	**Keynote Address – Predicted Climate Change Impacts in Pacific Northwest** *Phil Mote, Director, Oregon Climate Change Research Institute and Oregon Climate Services, Oregon State University*
Session 1: Integrating Climate Change Impacts and Multiple Species in Restoration Design and Resource Management	
Session Moderator: Patty O'Toole	
10:00 AM	**Integrating Multi-Species and Climate Change Impacts into Restoring the Lower Columbia River Ecosystem** *Catherine Corbett*, Keith Marcoe, Matt Schwartz, Chris Collins
10:20 AM	**More Than One Look: Using Hydrodynamic and Ecosystem Models to Predict Habitat Changes at Restoration Sites** *Matthew Schwartz*, Paul Kolp, Alex Uber, and John Hickey
10:40 AM	**Break**
11:00 AM	**Salinity in the Willamette River? Seriously?!? Estuarine tales of rising seas, seismic subsidence and uncertainty** *António M. Baptista*, Mojgan Rostaminia, Paul J. Turner, Tuomas Kärnä and Jesse Lopez
11:20 AM	**Mapping the extent of West Coast tidal wetlands using extreme water level data and LIDAR** *Laura Brophy*, Hiroo Imaki, Van Hare, Brett Holycross, Correigh Greene, Andy Lanier
11:40 AM	**Tidal wetland response to changes in inundation patterns in the lower Columbia River and estuary** *Amy B. Borde*, Heida L. Diefenderfer, David A. Jay, Shon A. Zimmerman, Ronald M. Thom, Amanda C. Hanson, Catherine Corbett

12:00 PM	Question and Answer Period
12:10 PM	**Lunch** (on your own)
Session 2: Lessons Learned in Habitat Restoration	
Session Moderator: Jason Karnezis	
1:30 PM	**Lower Columbia River Habitat Floodplain Revegetation in a Changing Climate** *Marshall Johnson*
1:50 PM	**Tidal Wetland Restoration and Sea-level Rise: Native and Non-native Plant Community Seed Bank Response to Changes in Tidal Flooding and Salinity** *Sarah Kidd*, Alan Yeakley
2:10 PM	**Comparisons of Macroinvertebrate Structure and Availability in Reed Canarygrass and Lyngbye's Sedge Habitats** *Mary Ramirez*, Jeff Cordell, and Amanda Hanson
2:30 PM	**Effects of Invasive Reed Canarygrass (Phalaris arundinacea) on Juvenile Chinook Salmon in the Upper Columbia River Estuary** *Rachael Klopfenstein*, Daniel L. Bottom, Michael Harte, and Charles A. Simenstad
2:50 PM	**Break**
Session 2: Lessons Learned in Habitat Restoration (cont)	
Session Moderator: Gary Johnson	
3:10 PM	**Predicted Impacts of Sea Level Rise to Cultural Resources** *Briece Edwards*
3:30 PM	**Restoration Approach in a Tidally Influenced Tributary Floodplain: La Center Wetlands Project Modeling, Design, and Outcomes** Caitlin Alcott, Paul Kolp, *Keith Marcoe*
3:50 PM	**Hydraulic Response of Newly Created Marsh-Wetland Area Affected by Tidal Forcing, Upland Discharge, and Groundwater Interaction** *Hans R. Moritz*, Rachel Hanna, James Burton, Chris Humphries, Barbara Cisneros, Brian Able
4:10 PM	**Evaluating the Effectiveness of Constructed Beaver Dam Analogs in Recently Restored Floodplains of the Lower Columbia River Estuary** *Ava Laszlo* and Curtis Loeb, PE
4:30 PM	**Large Wood in Estuaries: Structure, Hydrologic and Ecological Functions, and Influence on Fish Survival** *Kim K. Jones*, Daniel L. Bottom, W. Gregory Hood, Gary E. Johnson, Kirk L. Krueger, and Ronald M. Thom

4:50 PM	**Effectiveness of a Channel Habitat Reconnection in Tidal Freshwater of the Columbia River: Sandy River Delta** *Gary E. Johnson* and Nichole K. Sather
5:10 PM	Question and Answer Period
5:30 PM – 7:30 PM	**Poster Session** (McTavish Room upstairs)

May 25, 2016	
8:00 AM	**Registration**
8:30 AM	**Welcome** *Catherine Corbett, Chair Steering Committee*
8:40 AM	**Invocation** *Tony A. Johnson, Chairman, Chinook Indian Nation*
Session 3: Recent Anomalous Environmental Conditions – Drivers and Consequences	
Session Moderator: Curtis Roegner	
9:00 AM	**Keynote Address – Physical Ocean Conditions and Development of "Warm blob"** *Nick Bond, Research Meteorologist, Joint Institute for the Study of Atmosphere and Ocean, University of Washington*
9:30 AM	**Keynote Address – Ecosystem Effects from Recent Ocean Conditions** *Bill Peterson, Oceanographer, NOAA Northwest Fisheries Science Center*
10:00 AM	**Anomalous hydrologic and biogeochemical conditions in the Columbia River estuary during 2014-2015** *Joseph A Needoba*, Tawnya D. Peterson, Charles Seaton, Sarah F. Riseman, and António M. Baptista
10:20 AM	Question and Answer Period
10:30 AM	**Break**
Session 3: Recent Anomalous Environmental Conditions – Drivers and Consequences (cont)	
Session Moderator: Joe Needoba	
10:50 AM	**Climate-Linked Anomalies Force Eelgrass (Zostera marina L.) variability in the Pacific Northwest: Recent Evidence from the Columbia River Estuary** *Ronald Thom*, Amy Borde, John Vavrinec, Kate Buenau, Dana Woodruff, Curtis Roegner, Joseph Needoba

11:10 AM	**Inter-annual variability in phytoplankton dynamics in off-channel habitats of the Columbia River estuary** *Claudia Tausz*, Joseph Needoba, Michelle Maier, Whitney Hapke, Amanda Hanson, Catherine Corbett
11:30 AM	**Invasive Species and Plankton Dynamics of the Columbia River Estuary** *Stephen Bollens*, Gretchen Rollwagen-Bollens, Eric Dexter, Whitney Hassett, Jesse Adams, Alise Bowen, Julie Zimmerman, Jeffery Cordell, Olga Kalata, and Tim Counihan
11:50 AM	Question and Answer Period
12:00 AM	**Lunch** (on your own)
Session 3: Recent Anomalous Environmental Conditions – Drivers and Consequences (cont)	
Session Moderator: Jennifer Morace	
1:00 PM	**The Ecosystem Monitoring Program: Food Web Dynamics in the Lower Columbia River** *Amanda Hanson*, Amy Borde, Tawnya Peterson, Joseph Needoba, Catherine Corbett
1:20 PM	**Juvenile Salmon Occurrence in the Lower Columbia Estuary: Ecosystem Monitoring Program Findings in an Unusual Climate Year** *Lyndal Johnson*, Dan Lomax, Sean Sol, Amanda Hanson and Catherine Corbett
1:40 PM	**Effects of the Warm 'blob' on May and June 2015 Juvenile Salmon in the Columbia River Plume and Nearshore Ocean** *Elizabeth A. Daly* and Richard D. Brodeur
2:00 PM	**Fine-scale spatial and stock variations among juvenile Chinook salmon and steelhead in the Columbia River Plume: May 2015** Kym C. Jacobson, Cheryl A. Morgan, Brian R. Beckman, Brian J. Burke, Laurie A. Weitkamp, Jessica A. Miller, Donald M. Van Doornik, and *Kurt L. Fresh*
2:20 PM	Question and Answer Period
2:30 PM	**Break**
Session 4: New Understanding of the Lower Columbia River and Plume Ecosystem	
Session Moderator: Carla Cole	
3:00 PM	**Stock-specific use of tidal freshwater wetlands** *Regan A. McNatt*, Susan A. Hinton, Daniel L. Bottom
3:20 PM	**Characterizing the condition of outmigrating Chinook and steelhead in the Columbia River estuary** *Kurt Fresh*, Laurie Weitkamp, Don Van Doornik, Curtis Roegner, Kym Jacobson

3:40 PM	**A Life Cycle Modeling Approach to Evaluating Population Response to Variable Life History Patterns of Coho Salmon and Alternative Restoration Scenarios in Coastal Watersheds** *Gabe Scheer*, Darren Ward, Seth Ricker
4:00 PM	**Estimation of Survival and Run Timing of Adult Spring/Summer Chinook Salmon from the Columbia River Estuary to Bonneville Dam: A Cooperative Effort Between NOAA Fisheries and Columbia River Commercial Fishermen** *A. Michelle Wargo Rub*, Ben Sandford, Don Van Doornik, Brian Burke, Kinsey Frick, Mark Sorel, Matthew Nesbit, and Samuel Rambo
4:20 PM	**Genetic Analysis of Caspian Tern (Hydroprogne caspia) and Double-crested Cormorant (Phalacrocorax auritus) Salmonid (Oncorhynchus) Consumption in the Columbia River Estuary 2006-2013** *David Kuligowski*, Daniel Roby, Donald Lyons, Ken Collis, Allen Evans, Donald Van Doornik, Lauren Reinalda, Laurie Weitkamp, Curtis Roegner, Tim Marcella, Peter Loschl, Kirsten Bixler and David Teel
4:40 PM	**Ocean avian predation risk and early marine survival of salmon in the Columbia River Plume** *Jeannette E. Zamon*, Brian Burke, Mary Hunsicker, David Teel, and Elizabeth M. Phillips
5:00 PM	Question and Answer Period
5:10 PM	**Adjourn**
5:30 PM – 8:00 PM	**Optional Field Visit to WDFW's Chinook River Restoration Project**

May 26, 2016	
8:30 AM	**Registration**
9:20 AM	**Welcome** *Catherine Corbett, Chair Steering Committee*
Session 4: New Understanding of the Lower Columbia River and Plume Ecosystem (cont)	
Session Moderator: Cindy Studebaker	
9:30 AM	**How extreme were 2015 water temperatures in the lower Columbia and Willamette Rivers?** *S.A. Talke* and D.A. Jay

9:50 AM	**Looking at Extreme Events in Historic Tide Data, 1853 to 1876** *David Jay*, Stefan Talke, Drew Mahedy, and Sam Hawkinson
10:10 AM	**Modeling Historic Salinity Intrusion in Lower Columbia River Estuary** *Lumas Helaire*, Stefan A. Talke, David A. Jay, Drew Mahedy, Austin Hudson
10:30 AM	**Break**
Session 4: New Understanding of the Lower Columbia River Ecosystem (cont)	
Session Moderator: Nicole Czarnomski	
11:00 AM	**Can Tide/River-Flow Interactions in the Columbia River Estuary Be Observed in the Coastal Ocean?** *Edward D. Zaron*
11:20 AM	**Underwater video measurements of Dungeness crab (Cancer magister) responses to thin-layer dredged material disposal** *Stephanie Fields*, Sarah Henkel, Curtis Roegner
11:40 AM	**Acoustic telemetry measures of Dungeness crab movement and behavior relative to a nearshore sediment disposal site** *Curtis Roegner*, Stephanie Fields
12:00 PM	Question and Answer Period
12:10 PM	**Lunch** (on your own)
Session 5: Innovative Technologies and New Data Products	
Session Moderator: Matt Van Ess	
1:30 PM	**Sediment Acoustics - Real-Time Continuous Suspended Sediment Data in the Lower Columbia River** *Paul Diaz Jr*, Marc A Stewart
1:50 PM	**Refining the Edges of the Columbia River Eulachon Run – A New Application for Environmental DNA** Joe Krieter, *Taal Levi*, Maria Sandercock, Andy Clodfelter, Michelle Hollis
2:10 PM	**Monitoring Opportunities in the Estuary with Unmanned Aerial Vehicles (UAVs)** *Ian Sinks* and Keith Steele
2:30 PM	Question and Answer Period
2:40 PM	**Closing Remarks**
3:00 PM	**Adjourn**

MAY 24, 2016
SESSION 1: INTEGRATING CLIMATE CHANGE IMPACTS AND MULTIPLE SPECIES IN RESTORATION DESIGN AND RESOURCE MANAGEMENT

Integrating Multi-Species and Climate Change Impacts into Restoring the Lower Columbia River Ecosystem

*_Catherine Corbett_, Keith Marcoe, Matt Schwartz, and Chris Collins

Lower Columbia Estuary Partnership, Portland, OR

*_Presenting author_ (email: ccorbett@estuarypartnership.org)

Native species evolved under ecological conditions and habitats which persisted for thousands of years prior to large-scale human development. Given a high degree of habitat connectivity, native species could relocate or, as environmental conditions shifted and became more favorable to other species, were displaced or lost. Since the late 1800's, the lower Columbia River ecosystem has lost over 50% of its historic habitat coverage, with more severe losses of over 70% historic habitat in the urban corridor between reaches D - G. Protecting remaining native habitats and restoring historic conditions are consistently used as end points in protection and restoration approaches throughout the Pacific Northwest, including the lower Columbia. However, we argue that our land management and restoration activities are creating a _de facto_ reserve system that favor some species (e.g., Pacific salmon, waterfowl, Columbia White-tailed deer) over others (e.g., herptiles, songbirds). Additionally, targeting historic conditions without integrating sea level rise, warming temperatures, altered precipitation patterns and resulting species shifts will result in a further loss of floodplain wetland habitats, further imperilment of native species and jeopardize the millions in public dollars annually financing our protection and restoration activities. We provide a detailed strategy to overcome these issues for the lower Columbia River:

- Multi-Species Approach: The Estuary Partnership Board approved voluntary quantitative habitat coverage targets by river reach. The targets focus on protecting common species from becoming imperiled and include: 1) no net loss of native habitats as of the 2009 baseline, 2) recover 30% of the historic coverage of priority habitats by 2030, and 3) recover 40% of the historic coverage of priority habitats by 2050. By meeting these targets, assuming no conversion of existing native habitats, we will reach between 46-88% of our historic habitat coverage by 2050, depending on river reach, with an average of 60% historic habitat coverage. Based on species-area curves, this quantity of remaining habitat could support 85-95% of our historic native species (MacArthur and Wilson 1967). Identifying species-specific conservation targets for imperiled species and habitat requirements to meet those conservation targets is an important next step. This additional information will allow us to explicitly recognize the tradeoffs in our land management and apply new tools (like ecological function models) to evaluate the impact of our restoration activities on multiple species at the site scale. These tools can help us ensure a heterogeneous mosaic of habitats across the landscape to benefit the wide diversity of native species and offset further declines.
- Integrating Climate Change Impacts: Expected climate change impacts for the lower Columbia include further loss of floodplain habitats through the submersion, conversion and erosion of estuarine habitats by rising sea levels; introduction of low dissolved oxygen levels and ocean acidification through increased tidal exchange with sea level rise; reductions in cold water refugia, vital for cold water species such as salmon and steelhead; and alterations to habitat structure by changing precipitation, temperature, and CO_2. As yet, restoration practitioners, resource managers, funding agencies and land use planners lack downscaled, detailed data for the lower Columbia that would allow us to integrate mitigation measures in our on-the-ground actions. We are working on several on-going efforts to address these key information gaps, such as cold water refugia mapping and evaluation of potential vegetation changes we should plan for in our restoration designs. A key remaining information gap is the extent of sea level rise and its impact on floodplain habitats and instream water quality.

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More Than One Look: Using Hydrodynamic and Ecosystem Models to Predict Habitat Changes at Restoration Sites

*Matthew Schwartz[1], Paul Kolp[1], Alex Uber[2], and John Hickey[3]

[1]Lower Columbia Estuary Partnership, Portland, OR
[2]Washington Department of Fish and Wildlife, Vancouver, WA
[3]US Army Corps of Engineers – Hydrologic Engineering Center, Davis, CA

**Presenting author* (email: mschwartz@estuarypartnerhsip.org)

Predicting the outcomes of habitat restoration actions in the lower Columbia River and Estuary has largely been based on qualitative or quantitatively static models which tend to be limited spatially and temporally. Current restoration site planning and design efforts have largely relied on the experience of the practitioner, generalized peer reviewed metrics to anticipate post-restoration conditions, and hydrodynamic models focused on evaluating physical metrics to determine hydraulic conditions. In the lower Columbia River and Estuary, these approaches have been sufficient for single species restoration at project sites. As restoration efforts continue in the region it will be necessary to consider high risk/high reward sites with multiple species management objectives. New methods will be required for restoration practitioners to evaluate the feasibility of a restoration project with complex management objectives and provide information to allow managers to make informed decisions about potential projects. Hydrodynamic modeling has become ubiquitous during project feasibility and coupling a hydrodynamic model to ecological functions model can provide valuable information to answer questions related to project design, including changes in habitat for multiple species. The Estuary Partnership used a new version of the Hydrologic Engineering Center Ecosystem Functions Model (HEC -EFM) to develop a statistical analysis between a 2-D hydrodynamic model and ecological inputs. We coupled the 2-D hydrodynamic model with vegetation data from reference sites, fish suitability, and wildlife habitat suitability data to construct a model to answer questions about the timing and frequency of inundation through different seasons related to different restoration design alternatives and how these changes ultimately will affect habitat for multiple species. HEC-EFM can predict acres of potential habitat which can be compared to existing conditions to help determine the net change in habitat for species across the restoration site. Based on modeled results, the spatial and temporal changes to habitat can be mapped at the project sight to better inform design and feasibility questions.

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Salinity in the Willamette River? Seriously?!? Estuarine Tales of Rising Seas, Seismic Subsidence and Uncertainty

*_António M. Baptista_, Mojgan Rostaminia, Paul J. Turner, Tuomas Kärnä, and Jesse Lopez

NSF Science and Technology Center for Coastal Margin Observation & Prediction (CMOP), Oregon Health & Science University, Portland, OR

*_Presenting author_ (e-mail: baptista@ohsu.edu)

The Columbia River has a compressed estuary and a very large plume, both of which are highly variable and strongly responsive to river discharge, tides, and (for the plume) coastal winds. The variability of the estuary and plume deeply influence ecosystem function, and must be accounted for in policy and management, from salmon recovery and habitat restoration to navigation improvements and hydropower operation. Both a seismic Cascadia Subduction Zone (CSZ) event and sea level rise (SLR) will change the ocean influences in the estuary, and, in consequence, the plume characteristics. To explore what the estuary and plume might look like by 2100, we used a modeling system that was built for collaborative science and management (Baptista et al., 2015) and was skill assessed (Kärnä and Baptista, 2016) against an extensive set of contemporary observations. The results suggest a vastly transformed system, where—for low discharges, and under high-end SLR scenarios—salinity will propagate upstream beyond Portland, and the plume will effectively disappear as a major oceanographic feature. If these changes were confirmed, the implications on the ecosystem and salmon populations would be substantial—and many regional strategies, including the operation of the Federal Columbia River Power System, would need to be rethought. However, there are uncertainties in (especially) the definition and (also) the simulation of the scenarios of change that we analyzed. It is thus imperative to carefully review our results—both scientifically and through the scrutiny of regional stakeholders—prior to them being of use for management purposes. This presentation is a part of an evolving review process that is meant to be extensive and broadly encompassing. Here, we will summarize changes of well known estuarine and plume metrics in response to multiple scenarios of sea level rise, and to a large seismic subsidence—as described by our models. We will show tipping points in metric behavior as sea level changes, and we will also contrast the type of system response induced by sea level change with that induced by seismic subsidence. We will describe the underlying assumptions and models, and will point to strengths and limitations of the approach. Finally, we will suggest (and invite suggestions on) collaborative avenues to narrow the uncertainties associated with our current analysis.

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Mapping the Extent of West Coast Tidal Wetlands Using Extreme Water Level Data and LIDAR

*Laura Brophy**[1], Hiroo Imaki[2], Van Hare[3], Brett Holycross[3], Correigh Greene[2], Andy Lanier[4]

[1] Estuary Technical Group, Institute for Applied Ecology, Corvallis, OR
[2] NOAA Fisheries, Seattle, WA
[3] Pacific States Marine Fisheries Commission, Portland, OR
[4] Oregon Coastal Management Program, Dept. of Land Conservation and Development, Salem, OR

**Presenting author* (email: brophyonline@gmail.com)

The Pacific Marine and Estuarine Fish Habitat Partnership (PMEP) partners with many organizations and entities to protect, restore and maintain healthy aquatic systems on the West Coast, with a focus on juvenile fish habitat and support for ecological processes in estuaries and nearshore marine environments. PMEP's interest encompasses all estuarine wetland habitats, including emergent tidal marsh, scrub-shrub tidal swamp, and forested tidal swamp that have been highly impacted by drainage, fill, and conversion to non-tidal wetlands. Recognizing these impacts, PMEP needs accurate spatial data to support West Coast-wide planning efforts to restore lost estuarine functions and improve the retention of current functions, particularly in the face of emerging stressors such as climate change and sea level rise. Existing comprehensive West Coast tidal wetland mapping (the National Wetland Inventory) has limitations for these purposes: it does not explicitly map former tidal wetlands (which represent restoration opportunities), nor does it use water level models and elevation data to identify areas within tide range. Therefore, our team of PMEP member organizations has generated updated mapping of tidal wetlands and open water estuary habitats for the entire contiguous U.S. West Coast (Washington, Oregon and California) using digital elevation models derived from high-resolution airborne LIDAR, along with tide height modeling (extreme water level models) from the National Oceanic and Atmospheric Administration's Center for Operational Oceanographic Products and Services (NOAA/CO-OPS). For areas with unique geomorphic characteristics such as the Columbia River Estuary and lagoonal estuaries in California, existing mapping provided by project partners and collaborators was incorporated into the West-coast-wide dataset. To support restoration planning and analysis of wetland loss and conversion, the mapping includes former tidal wetlands within current tide range, such as diked lands. The products of this study modernize the common informational foundation for West Coast estuary management programs and provide the core of an updated coastal spatial framework for estuarine and nearshore fish habitat assessments being conducted for the National Fish Habitat Action Plan (NFHAP) and PMEP. The products will also facilitate landscape planning at smaller spatial scales (e.g. state entities and watershed groups), informing a variety of habitat restoration and conservation actions. This project demonstrates effective convergence and collaboration between Columbia River Estuary scientists and other estuary scientists across the West Coast.

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Tidal Wetland Response to Changes in Inundation Patterns in the Lower Columbia River and Estuary

*Amy B. Borde[1], Heida L. Diefenderfer[1], David A. Jay[2], Shon A. Zimmerman[1], Ronald M. Thom[1], Amanda C. Hanson[3], Catherine Corbett[3]

[1]Pacific Northwest National Laboratory, Sequim, WA
[2]Portland State University, Portland, OR
[3]Lower Columbia Estuary Partnership, Portland, OR

**Presenting author* (email: amy.borde@pnnl.gov)

Inundation of tidal wetlands of the lower Columbia River and estuary (LCRE) has changed dramatically over the past 100 years due to hydropower operations, irrigation, and other water withdrawals in the Columbia Basin. Hydrologic change is predicted to continue into the future as climatic variability affects fluvial inputs and eustatic sea level rise. Hydrology and vegetation data collected over the past 10 years have allowed us to develop a predictive model of wetland response to varying hydrologic conditions. Specifically, we have related a calculated metric of inundation during the growing season, the sum exceedance value (SEV), to wetland distribution, species composition, and vegetative cover. The availability of observations and model results from the late 1800s, the 1940s, and the past 20 years allows us to calculate historical inundation during those time periods and estimate the effects on wetland vegetation communities. We also used the method to evaluate inundation estimated from climate model outputs for 2040. This information allowed us to predict the extent of wetland migration, determine possible changes in vegetation species composition, and estimate changes in productivity and detrital contributions to the food web. Additionally, this predictive model supports the development of resilient restoration designs by predicting the vegetation communities that would likely develop in response to hydrologic restoration actions and by evaluating wetland succession from climate driven hydrologic change. This presentation will focus on changes that have occurred in LCRE wetlands over the past 130 years, discuss variability in the last 20 years, evaluate the effects of anomalous 2015 climatic conditions, and elucidate possible future climatic effects on LCRE wetlands.

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MAY 24, 2016
SESSION 2: LESSONS LEARNED IN HABITAT RESTORATION

Lower Columbia River Habitat Floodplain Revegetation in a Changing Climate

Marshall Johnson

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Climate change is likely to impact lower Columbia River habitat projects by altering hydrologic, chemical and other biogeophysical conditions. Although the types of changes that are expected to occur are generally predictable (such as temperature, decreased snowpack, sea level rise, and increased drought), significant uncertainty remains regarding the magnitude and expected impacts of these changes. Despite the increasing availability of predictive models, the numerous environmental variables that are involved make prediction challenging, and restoration practitioners remain in the difficult position of managing for an uncertain future. Current recommendations suggest incorporating resistance, resilience and facilitated response to help deal with the uncertainty, but more specific guidelines should be developed and made intrinsic to feasibility assessment and design. The Pacific Northwest Research Station of the US Forest Service released a report by David Peterson, Becky Kerns and Erich Dodson in September 2014 called "Climate Change Effects on Vegetation in the Pacific Northwest: A Review and Synthesis of the Scientific Literature and Simulation Model Projections" which presents a summary of available science (including model projections) on the vulnerability of five major biome types in the Pacific Northwest to climate change. The report offers a wealth of information about climate change and Pacific Northwest vegetation, however it does not address the floodplain habitats (e.g. lower elevation riparian, bottomland hardwood and forested wetland) which are the focus of many Lower Columbia River habitat restoration projects. We review findings from this report that may help to evaluate potential risks associated with floodplain revegetation efforts in a changing climate, and offer recommendations for incorporating resistance, resilience and facilitated response into restoration projects in this setting. Recommendations include selection of a species mix adapted to dynamic conditions, incorporating topographic gradients within the site and promoting beaver dams in order to help mitigate climate change impacts.

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Tidal Wetland Restoration and Sea-level Rise: Native and Non-native Plant Community Seed Bank Response to Changes in Tidal Flooding and Salinity

*Sarah Kid** and Alan Yeakley

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**Presenting Author* (email: sarahkidd@pdx.edu)

Restoring and maintaining native tidal wetland plant communities is one of the main goals of tidal wetland restoration and conservation efforts. The general ubiquity of invasive wetland plant species has made this difficult to achieve. In the oligohaline (0.5-5 ppt) wetlands of Youngs Bay, located at the mouth of the Columbia River Estuary, restoration of desirable native plant communities has been observed to be most successful in the mid to lower marsh elevations, with invasive species primarily dominating the high marsh zone. Based on these observations we hypothesized that the ability of common tidal wetland native plant species *Carex lyngbyei,* lyngbyei sedge, and *Schoenoplectus lacustris,* bulrush, and invasive non-native species *Phalaris arundinacea,* reed canarygrass*,* and *Juncus effusus subsp. effusus,* common rush, to dominate different areas within tidal wetlands could be tied to their abundance in the seed bank and germination responses to tidal flooding and salinity conditions created through restoration. To evaluate these hypotheses representative native and non-native plant community seed bank samples were collected across two tidally reconnected oligohaline wetlands located in the Lewis and Clark National Historical Park near Astoria, Oregon. Seed bank composition and germination response was then examined across a gradient of tidal flooding and salinity treatments in a greenhouse setting. Preliminary results indicate non-native species germinated more readily out of the seed bank under low frequency flooding (1 hour daily, representative of high marsh elevations) and freshwater treatments as compared to medium and high flooding conditions (3 and 6 hours twice daily, representative of mid-low marsh elevations) and low (3 ppt) and high salinity (10 ppt) conditions. Native species germinated at similar densities across all flooding and salinity treatments. Non-native species were the most abundant seed type identified across both native and non-native seed banks. The widespread distribution of non-native species throughout the wetlands' seed banks and the differential germination response across tidal flooding and salinity treatments supports the hypothesis that tidal flooding and salinity conditions created during restoration are an important driver of non-native seed germination and plant community development. These results are essential to predicting plant community response to changes in tidal flooding and salinity from future restoration efforts and sea level rise.

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Comparisons of Macroinvertebrate Structure and Availability in Reed Canarygrass and Lyngbye's Sedge Habitats

**Mary Ramirez*[1], Jeff Cordell[1], and Amanda Hanson[2]

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Reed Canarygrass (*Phalaris arundinacea*) is a dominant invasive plant species in riparian marsh habitats in the lower Columbia River and estuary. Juvenile salmon utilize emergent wetland habitats for foraging and refuge during outmigration. Macroinvertebrates, such as Diptera (Chironomidae, in particular) are a preferred prey item for juvenile Chinook salmon, thus production and availability of these prey in wetland habitats are crucial for rearing success. We conducted a study to measure macroinvertebrate abundance, diversity, and community structure in emergent wetlands dominated by either *P. arundinacea* or native Lyngbye's sedge (*Carex lyngbyei*), with a particular focus on important salmon prey taxa. Sampling was conducted at twelve freshwater, tidal marshes in April, May, and June 2014. To capture a range of life stages utilizing different habitats in the study area, macroinvertebrates were sampled using three trap types: fall out traps, emergence traps, and benthic cores. Results from fallout and emergence traps showed seasonal shifts and increases in abundance in the macroinvertebrate community throughout the sampling period. When all invertebrate taxa were considered, the abundance and biomass of fallout and emergence traps were similar between habitats dominated by *P. arundinacea* and habitats dominated by *C. lyngbyei*; however, the abundance of all taxa combined was greater in benthic cores collected from *C. lyngbyei* sites than *P. arundinacea* sites ($p = 0.003$). For salmon prey taxa, the abundance of Diptera and Chironomidae from fallout traps and benthic cores, as well as the biomass from fallout traps was greater in *C. lyngbyei* habitats than in *P. arundinacea* habitats ($p < 0.05$). Emergent Diptera and Chironomidae abundance and biomass, however, were generally similar between the two vegetation types. The overall macroinvertebrate community assemblage and diversity did not appear to be negatively affected by habitats dominated by *P. arundinacea*; however, we found that salmon prey taxa (Diptera and Chironomidae) were reduced in *P. arundinacea* sites. The greater density and biomass of salmon prey taxa from fallout traps and benthic cores in *C. lyngbyei* habitats indicates a possible negative effect of *P. arundinacea* on the production of these taxa. Other studies have shown detritivores (such as larval chironomids) to be less affected by invasive plants when compared to other feeding types, and that loss of macroinvertebrate diversity is often directly associated with loss of plant species richness. Thus, because our study sampled largely monotypic stands of two herbaceous species and samples were generally dominated by organisms with partly or exclusively detritivorous life histories, the difference between the two vegetation types may not be of a magnitude that affects juvenile Chinook salmon trophic function. Additional study focusing on prey production in different vegetation types with a comparison to juvenile salmon insect consumption would contribute to reducing uncertainty.

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Effects of Invasive Reed Canarygrass (*Phalaris arundinacea)* on Juvenile Chinook Salmon in the Upper Columbia River Estuary

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Thirteen native Columbia River salmon stocks are listed under the Endangered Species Act, impacting one of the Pacific Northwest's most important recreational, commercial, and subsistence fisheries. Both juvenile Chinook and coho salmon utilize wetlands for rearing habitat; therefore, many resource managers in Oregon and Washington are working, in compliance with the Federal Columbia River Power System Biological Opinion, to restore tidal wetland habitats. Reed canarygrass (*Phalaris arundinacea*) (PHAR) is a highly invasive perennial grass that affects a number of wetlands throughout the Columbia River estuary and is both difficult and costly to remove. PHAR is the most dominant species at the site of this study, Multnomah Channel Marsh, a restored wetland along Multnomah Channel. The presence of PHAR undoubtedly reduces plant diversity, but how it impacts juvenile salmonids is unclear. To better inform salmon recovery and estuary restoration, this study elucidates the role of PHAR and its effects on salmonid rearing habitat as indicated by invertebrate prey availability and salmon performance (i.e., feeding and growth). We compared relative growth potential and feeding success of hatchery-raised juvenile Chinook salmon placed in experimental pens on floodplain microhabitats dominated by PHAR and by natural emergent vegetation (i.e., *Carex aperta*). Invertebrate prey compositions from the 2015 (March-June) fallout and emergence traps were similar, but salmon growth during the net pen experiment differed significantly between the two vegetation types. The average density (per m^2) of invertebrates in the emergence traps in the natural emergent vegetation and in PHAR was 124 (±46) and 177 (±103), respectively, and for the fallout traps was 446 (±136) and 517 (±200), respectively. Juveniles grew an average 6.4 mm in the natural emergent vegetation compared to 4.7 mm in PHAR, and consumed more zooplankton and fewer dipterans in PHAR over the 10 days. Zooplankton, primarily cladocera, made up 67% of the average composition by biomass (n=28) for juveniles reared in PHAR, compared to 34% for juveniles reared in natural emergent vegetation (n=30). Macroinvertebrate sampling and growth experiments will continue in the spring of 2016 and a fish bioenergetics model will be utilized to better understand the initial growth differences detected. Although restoration of tidal wetlands is important for improving degraded conditions in the Columbia River estuary, it is uncertain whether additional changes in the ecosystem (e.g., spread of invasive species) will limit the effectiveness of wetland restoration for juvenile salmon habitat and recovery. The results of this study seek to broaden our understanding of these changes, by informing wetland restoration practices and management of PHAR.

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Predicted Impacts of Sea Level Rise to Cultural Resources

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Cultural resources are markers of place and action that can be contextualized on a landscape to create a greater understanding of the past. Today, increased storm energy, accelerated sea level rise, and a preponderance of 'at risk' cultural resources are converging at a point that will result in impacts to physical resources. However, cultural understanding and connection to place will persist as it has for generations. The places of importance and the knowledge that accompanies them continue to be held in community. Recently the Historic Preservation Department of the Confederated Tribes of Grand Ronde began examining the question "What resources are at risk of sea level rise?" Through ethnographic records and oral traditions there are lessons by which we can identify potential avenues or examples of resilience used by tribal people of this place at other times of rapid environmental change. Though the effects resulting from climatic change are often severe, there are multiple lines of evidence for past adaptive measures employed by populations within coastal inundation zones. This presentation will highlight some of the Tribe's resource concerns, perspectives of past impacts, and examples of applied projects.

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Restoration Approach in a Tidally Influenced Tributary Floodplain: La Center Wetlands Project Modeling, Design, and Outcomes

Caitlin Alcott[1], Paul Kolp[2], and *Keith Marcoe*[*2]

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**Presenting author* (email: kmarcoe@estuarypartnership)

The La Center Wetlands, a 453 acre floodplain location along the lower East Fork Lewis River, was the site of an Estuary Partnership restoration project which was constructed during the fall of 2015. Restoration actions included levee breaching, culvert removal, and channel construction in order to increase inundation within the interior floodplain and wetlands. The site is situated in a highly variable convergence zone of tidal and fluvial forces which can influence the site in different ways at any given time depending on their relative magnitudes. This dynamic situation presents unique challenges with respect to quantifying physical and ecological benefits as well as for selecting project design elements. As a result of these factors, an intensive project feasibility effort was undertaken to evaluate a suite of restoration actions. Upon project completion, the Pacific Northwest experienced one of its wettest late fall periods on record, with several significant flooding events (including an estimated 10- year and 80-year magnitude flood events). This coincidence of events, occurring before vegetation was established provided a unique opportunity to evaluate feasibility and model predictions, physical responses, and project outcomes with regard to risk and durability of designed restoration actions.

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Hydraulic Response of Newly Created Marsh-Wetland Area Affected by Tidal Forcing, Upland Discharge, and Groundwater Interaction

*Hans R. Moritz[1], Rachel Hanna[2], James Burton[2], Chris Humphries[3], Barbara Cisneros[4], Brian Able[5]

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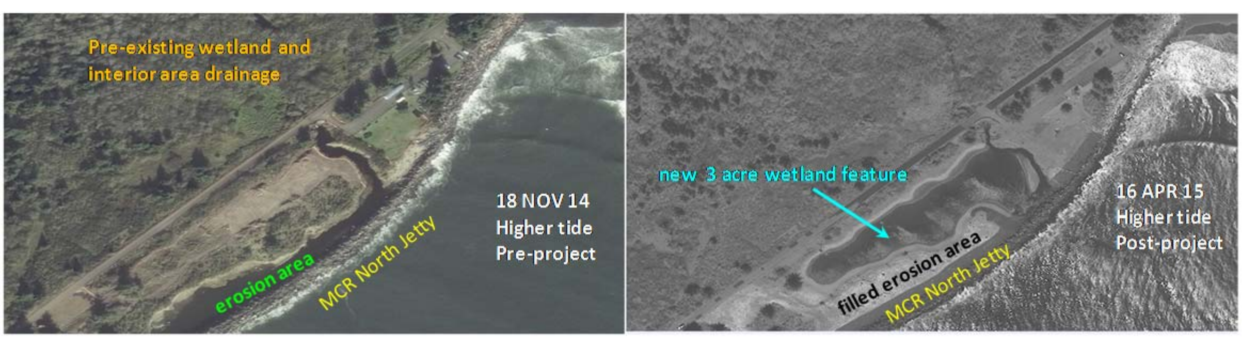
During November 2014 to April 2015, Portland District-USACE created a 3-acre marsh and intertidal wetland along the landward based of the North Jetty at the Mouth of the Columbia River, within Cape Disappointment State Part, WA. Construction of the new marsh-wetland feature provided 40,000 cubic yards of sand which was used to fill a chronic erosion area which had been destabilizing the foundation of the North Jetty. The new marsh-wetland was designed to receive inflow from an upland drainage within the park (McKenzie Lake as source) and be inundated with controlled tidal flow through the North Jetty. Tidal flow into the new marsh-wetland was baffled by emplacement of a rock-weir control structure, having crest elevation of 6 ft NAVD. The new marsh-wetland was designed to not alter the present drainage (and tidal exchange) affecting an existing wetland, adjacent to the project site. The new marsh-wetland is founded on a sandy substrate, and is inundated through functional elevation range of 3 ft to 8 ft NAVD. Total inundation during storm-tide events can approach 11 ft NAVD. Monitoring of water levels throughout the project site has been ongoing pre-and post project implementation. The feature was appropriately vegetated with Carex Lyngbyei plantings within the emergent marsh zone (1.5 acre, 5.5 to 6.5 NAVD), suitable native forbs-grass plantings and large woody debris broadcast through the upper marsh zone (0.4 acre, 6.5 to 8 ft NAVD), and sedges with small native tree species within the upland perimeter bordering the new lagoon (8 to 13 ft NAVD). The wetland area within the new lagoon (1 acre, below 5.5 ft NAVD) was unplanted and expected to colonize native species. The presentation will: 1) describe the rationale for creating a new 3-acre intertidal marsh-wetland along the landward base of the MCR North Jetty, 2) illustrate how the new wetland is inundated by tides passing through a rock weir control structure, 3) show how the newly created wetland hydrology interacts with adjacent groundwater and pre-existing wetland drainage during summer and winter. The presentation will also compare select hydraulic parameters between the pre- and post-wetland creation conditions. Lessons learned from the project (interaction of the hydraulic forcing) can be applied to other project locations, where similar estuarine/coastal ecology is being restored or improved.



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Evaluating the Effectiveness of Constructed Beaver Dam Analogs in Recently Restored Floodplains of the Lower Columbia River Estuary

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Increasing research has documented the positive effects of beaver dams on hydrologic, geomorphic, and ecologic processes within rivers, streams, and their adjacent floodplains. Beneficial effects can include increasing pool refugia habitat, sediment retention and channel bottom aggradation, reconnection of incised channels to floodplains, moderation of water temperature, reduction of streambank erosion, among others (Pollock et al 2012; Pollock et al 2014; Majerova et al 2015; Hood and Bayley 2008). Efforts have been made to understand the ecological benefits of beaver activity, likelihood of dam occurrence, and dam density through modeling and observation (Burchsted et al 2010; Wheaton 2013; Alza 2014; Macfarlane et al 2015; Jordan et al 2015; Pollock et al 2015). Beaver, generally thought of as freshwater animals, can also play a significant role in habitat enhancement in estuaries, tidal channels and marshes, and other brackish areas (NYDEC 2006; Pollock et al 2015). In the Puget Sound, dams have been shown to significantly increase the capacity of suitable juvenile salmonid habitat, particularly in low-tide channel pools and shallows of estuarine shrub marshes (Hood 2012). As a result, the consideration of beaver dam analogs (BDAs), i.e., manmade beaver dams, within the Lower Columbia River Estuary LCRE is gaining momentum among restoration practitioners. However, guidance on the suitability, general efficacy, design considerations, and actual utilization of BDAs within the LCRE is limited.

As an initial effort towards addressing this knowledge gap, preliminary reconnaissance data were collected at over a dozen restoration sites throughout the LCRE. Investigations spanned Hydrogeomorphic Reaches A through H of the estuary and involved over 30 total natural dams and constructed BDAs. Parameters examined included: evidence of use, channel geometry and longitudinal slope, hydraulic conditions, availability of vegetation as a food source, type of hydrologic dominance (tidal, fluvial, mixed, etc.), wetland or floodplain type and associated characteristics (e.g. incised stream banks, presence of water control structures, etc.), and quantity of ponded habitat upstream of the dam. Particular attention was paid to dam elevation relative to the tidal range. Photos and construction drawings were used to compare current conditions to original designs or previously known conditions. Utilization of BDAs was correlated to these parameters in attempt to determine positive and negative relationships. Findings of this preliminary evaluation are intended to provide a better understanding of the factors affecting BDA use and persistence in tidal and non-tidal floodplains. Information will fill the discernable gap in understanding of beaver utilization within the LCRE. It will also generally promote use of nature's river restorers to mitigate the effects of climate change and associated anomalous hydrologic events. Information will be relevant to regulatory and grant funding review agencies, implementation organizations, and habitat restoration designers.

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Large Wood in Estuaries: Structure, Hydrologic and Ecological Functions, and Influence on Fish Survival

Estuary Regional Technical Group

Kim K. Jones[1], Daniel L. Bottom[2], W. Gregory Hood[3], Gary E. Johnson[4], Kirk L. Krueger[5], and Ronald M. Thom[6]

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Large wood is commonly placed in tidal channels to improve the habitat for juvenile salmonids during wetland restoration projects. Yet, the historical prevalence, and ecological and hydrological functions of large wood in tidal systems are not well understood or documented. Tidal habitats are quite diverse, ranging from forested to shrub-scrub swamps, to emergent marshes (complex or fringing) and sand or mud flats. Historically and currently these habitats would have experienced an influx of large wood from local (e.g., Sitka spruce forests) or from riverine (upstream) or ocean (downstream) environments. Tidal and riverine forces, depending on location and season, influence the amounts, temporal pulses, movement, and retention of large wood in the estuary. In sharp contrast to the substantial literature describing the ecological influence and restoration potential of large wood in river and stream ecosystems, very few studies or literature have explored the influence of large wood on habitat structure or ecological processes in estuary ecosystems. The estuary is a dynamic system in which wood moves, creates depressions and other features, and redistributes relative to prevailing currents, winds, and catastrophic events. We recommend that placement in restoration projects reflect historical distribution as observed in reference marshes. Here we discuss the literature and observations on large wood, and its potential influence on physical and vegetative structure of tidal habitats and associated aquatic communities in estuaries, with a focus on emergent wetland habitats.

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Effectiveness of a Channel Habitat Reconnection in Tidal Freshwater of the Columbia River: Sandy River Delta

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We evaluated the effectiveness of a restoration action completed in 2013 to remove an earthen dam and rechannelize the Sandy River delta in tidal freshwater of the Columbia River (rkm 190). The working hypotheses were that the restoration action would 1) increase access for juvenile salmon to shallow water habitats in the SRD; 2) reduce non-native fish populations; and 3) increase flow and channel cross-sectional area. The statistical design was a before-after-control-impact (BACI) design that entailed two pairs of impact/control sampling sites. Pre-restoration (before) data were collected during 2007 through 2012. Post-restoration (after) data were collected during July 2015 and March 2016. Post-restoration sampling is scheduled to be completed in summer 2016. Visual observations revealed a dramatic change in the physical environment; where once was a backwater slough is now a free-flowing tidal river. Preliminary data indicate changes to the fish community as well.

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MAY 25, 2016
SESSION 3: RECENT ANOMALOUS ENVIRONMENTAL CONDITIONS – DRIVERS AND CONSEQUENCES

Anomalous Hydrologic and Biogeochemical Conditions in the Columbia River Estuary During 2014-2015

Joseph A Needoba, Tawnya D. Peterson, Charles Seaton, Sarah F. Riseman, and António M. Baptista

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Anomalous coastal ocean and watershed conditions were present in the Pacific Northwest during 2014 – 2015 as a result of unusual climate patterns that led to warm coastal water temperatures and low snowpack in the Columbia Basin. Observations from the NSF Center for Coastal Margin Observation and Prediction (CMOP) demonstrate that concurrent anomalous conditions in the Columbia River estuary were caused by the direct hydrological inputs from both the ocean and the watershed. The water temperature, nutrients, and water quality conditions in the estuary during 2014 and 2015 were distinctly different from climatology records and from other unusual years including: 1) a strong El Niño (1997), 2) exceptionally reduced river discharge (2001), and 3) delayed seasonal upwelling (2005). We will discuss the time series observations from the CMOP sensor network demonstrating changes relative to historical records for temperature, salinity, and dissolved nutrients in the lower estuary. Anomalous conditions were related to the nearshore presence of the North Pacific Temperature Anomaly (commonly known as "the blob") between September 2014 and May 2015. In addition, low winter snowpack during winter of 2014-1015 resulted in reduced river discharges and increased water temperatures in spring and summer of 2015 relative to the long-term average. Finally, biogeochemical anomalies resulting from changes to summertime upwelling intensity during 2015 were also measured in the estuary. These results are important for predicting how water quality and nutrient availability in the lower estuary may response in the future to changes in the Columbia Basin snowpack and/or the strength of upwelling on the continental shelf.

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Climate-Linked Anomalies Force Eelgrass (*Zostera marina* L.) Variability in the Pacific Northwest: Recent Evidence from the Columbia River Estuary

*Ronald Thom[1], Amy Borde[1], John Vavrinec[1], Kate Buenau[1], Dana Woodruff[1], Curtis Roegner[2], and Joseph Needoba[3]

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To what degree will climate change affect seagrass productivity, abundance and distribution? In 2014, we published a paper that illustrated a strong connection between climate-forced mean sea level changes and the growth and abundance of eelgrass in Northwest estuaries spanning the period of 1991 through 2013. The recent anomalous atmospheric and oceanic conditions attributed to El Nino and the warm ocean conditions termed "the Blob" suggested that warmer conditions could force even more pronounced affects on eelgrass. In 2007, we assessed the distribution and conditions for eelgrass in the Columbia River estuary and conducted experimental eelgrass plantings to evaluate whether the very limited distribution of eelgrass could be expanded. To facilitate this effort we used outputs from numerical models of water properties and current velocities to develop eelgrass habitat suitability maps. Our experimental work showed that eelgrass can tolerate salinities as low as 5psu, but requires a salinity of ~30psu to thrive. It was clear that salinity and turbidity in the estuary might be the most important factors restricting the distribution of eelgrass. In a separate study conducted in 2015 by the U.S. Army Corps of Engineers (Deborah Shafer) maps of eelgrass distribution in Baker Bay were developed using sonar and videography. The 2015 maps revealed a large increase in eelgrass areas as compared with 2007. Other studies by PNNL and the Lower Columbia Estuary Partnership revealed that the fresh/brackish water submerged macrophyte *Zannichellia palustris* was replaced by the non-native seagrass *Zostera japonica* in Ilwaco channel in 2015. Data taken on water properties over the past several years by PNNL, CMOP, and the LCEP Ecosystem Monitoring Program in Baker Bay showed a substantial increase in salinity as compared with 2007. Water clarity data were less available but may have been greater in 2015. We tentatively attribute the change in eelgrass to higher salinities and perhaps greater water clarity. We suggest that these changes were due to lower river flows in 2014 – 2015, which allowed greater intrusion of salty ocean water into the estuary. We understand that lower flows in the river are attributable to a decrease in winter precipitation and snowpack levels caused by anomalous climatic conditions. Our results suggest that lower river flows will result in expanded distribution of eelgrass in the estuary until increased water temperatures force reduced net productivity rates and survival.

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Inter-annual Variability in Phytoplankton Dynamics in Off-channel Habitats of the Columbia River Estuary

*Claudia Tausz[1], Joseph Needoba[1,2], Michelle Maier[1,2], Whitney Hapke[3], Amanda Hanson[4], Catherine Corbett[4] Andrew Bryn[1] and Tawnya Peterson[1,2]

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Shallow, off-channel sloughs in the lower Columbia River provide critical habitat to 13 stocks of threatened or endangered juvenile Pacific salmon (*Oncorhynchus* spp.). We examined water quality parameters (temperature, dissolved oxygen, and nutrients) and phytoplankton abundance and species composition in three off-channel habitats of the lower Columbia River (Whites Island, Campbell Slough, and Franz Lake Slough) that differ in terms of hydrogeomorphic features in the spring and summer months between 2011 and 2015. The years of study included two that had higher-than-average discharge (2011, 2012), two that had near-average discharge (2013, 2014), and one that had below-average river discharge (2015), thus providing an excellent spectrum of conditions for investigation. Differences in water quality and phytoplankton species composition between shallow habitats and the river's mainstem were accentuated during low-discharge periods. Analysis using Non-metric Multidimensional Scaling (NMDS) showed that variations in phytoplankton species composition were linked to seasonal patterns of river discharge and relative connectivity between the mainstem and off-channel habitats. In addition, high abundances of cyanobacteria (up to 450,000 cells mL^{-1}) were observed during the summer months at the two sites with slower water exchange with the mainstem and thus lower connectivity (Campbell Slough and Franz Lake Slough); these included several toxin-producing taxa, including *Microcystis* sp., *Dolichospermum* sp. and *Merismopedia* sp., which dominated the cyanobacteria assemblages. The variation between off-channel habitats and the mainstem stemmed from differences in dissolved inorganic phosphorus concentrations and water temperature, which explained the greatest proportion of variance among phytoplankton assemblages, according to Canonical Analysis of Principal Coordinates (CAP). The data highlight the importance of connectivity as a driver of phytoplankton population dynamics, and show that shallow water habitats may be vulnerable to periods of poor water quality in the summer months when river discharge is low.

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Invasive Species and Plankton Dynamics of the Columbia River Estuary

Stephen Bollens[1], Gretchen Rollwagen-Bollens[1], Eric Dexter[1], Whitney Hassett[1], Jesse Adams[1], Alise Bowen[1], Julie Zimmerman[1], Jeffery Cordell[2], Olga Kalata[1,2], and Tim Counihan[3]

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We have been investigating the plankton dynamics of the Columbia River Estuary (CRE), with special emphasis on invasive species, for more than a decade. Several important findings have emerged from our field and experimental studies. First, that several species of Asian copepods have invaded the CRE, with one species in particular, the calanoid copepod *Pseudodiaptomus forbesi*, becoming extremely widespread (penetrating several hundred kilometers upriver) and very abundant in late summer and early autumn (it is the overwhelming dominant mesozooplankter at this time of the year). Second, *P. forbesi* feeds on diatoms, ciliates, flagellates, and dinoflagellates, and exhibits a general preference for diatoms and ciliates (which suggests potential competition with native copepods), and an avoidance of chlorophytes and cyanobacteria. Third, that *P. forbesi* can be preyed upon by a range of native CRE predators, including juvenile chinook salmon, three-spined stickleback, northern pikeminnow, and mysids, and that some (but not all) of these native predators select for native zooplankton over *P. forbesi*. Fourth, that an invasive Asian clam, *Corbicula fluminea*, is also extremely widespread and abundant. Fifth, that dreissenid (quagga and zebra) mussels have not yet (to our knowledge) invaded the Columbia River Basin, but that these mussels represent a major threat for future invasion. These results will be presented and discussed in the context of food web impacts and potential climate change effects.

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The Ecosystem Monitoring Program: Food Web Dynamics in the Lower Columbia River

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Off-channel habitats in the Lower Columbia River and estuary provide important rearing and refugia habitat for migrating juvenile salmonids, support prey production, and flux of organic matter. The Ecosystem Monitoring Program (EMP) is a collaborative effort among multiple regional partners to monitor a range of ecological indicators and assess habitat structure and function in the lower river. The program is designed to monitor long term ecological indicators and detect trends over time in relatively undisturbed tidally-influenced wetlands in the lower Columbia River. Large-scale land use conversion, diking, and hydrosystem development have reduced the quantity and quality of undisturbed habitat in the lower river. Particularly, reduction of macrodetrital inputs and increased fluvial phytoplankton production have altered the base of the salmon food web. The influence of this ecological shift on the overall salmon food web is not well understood. Our monitoring data show spatial and temporal patterns in availability of organic matter, with hydrology playing an important role in these dynamics. Ultimately, macrodetritus and fluvial phytoplankton may both be important energetic resources available to salmon prey. However, fully partitioning out the source and timing of these resources requires continued study. In addition, the high temperatures and low flows that characterized conditions in the lower river during 2015 provided a unique opportunity to observe how habitats and food web components respond under such extreme conditions. The long-term dataset established by the EMP allows for a greater understanding of ecological variation, addresses scientific uncertainties, provides context for management actions, and establishes a baseline to which future conditions under a changing climate might be compared.

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Juvenile Salmon Occurrence in the Lower Columbia Estuary: Ecosystem Monitoring Program Findings in an Unusual Climate Year

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There is increasing concern about the potential impacts that climate change might have on the recovery of threatened and endangered Pacific salmon stocks. It has been proposed that rising water temperatures, altered flow regimens, reduced snow pack, and other changes related to climate change could reduce the quality of freshwater habitats that support juvenile salmon, and reduce their survival and productivity. In 2015, this region experienced especially unusual weather conditions that may become increasingly frequent due to climate change: low snow pack, a prolonged summer drought, low summer flows, and high water temperatures. 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, allowing us to compare patterns of salmon occurrence in 2015 to those in more typical years. During this sampling season, we saw some unusual patterns of juvenile salmon occurrence at our sampling sites (Ilwaco Slough in Reach A, Welch Island in Reach B, Whites Island in Reach C, Campbell Slough in Reach F, and Franz Lake in Reach H) apparently associated with drought conditions. For example, juvenile salmon densities were lower than in previous years at Welch Island and Whites Island. The large numbers of unmarked Chinook salmon fry that are typically caught at these sites early in the sampling season were absent, and the proportion of fry in catches was lower than normal. Juvenile chum salmon were also absent from our sampling sites in March and April, when they are usually most abundant, though a small number were collected in May. At all sites, we observed especially low densities of juvenile salmon during the summer months. Densities were lower in June compared to most years, and Chinook salmon were absent from all sites in July and September, when densities are typically low but a small number of fish are generally present. The absence of salmon from these sites was associated with high water temperatures. By June, water temperatures were already above the preferred range for juvenile Chinook salmon. At Welch and Whites Island were 19°C, while in past years temperatures were in the 13-17°C range. At Campbell Slough and Franz Lake, the temperature was greater than 22°C by June. Changes were also observed later in the sampling season; juvenile salmon were absent from all sampling sites in November and December, when small numbers of coho salmon and spring Chinook salmon are generally present. Our findings suggest that the low summer flows and increased summer temperatures in 2015 may have decreased the rearing capacity of the tidal freshwater emergent marsh areas that we sample in the EMP, and that suggest that conditions associated with climate change, may not be favorable to salmon productivity.

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Effects of the Warm 'Blob' on May and June 2015 Juvenile Salmon in the Columbia River Plume and Nearshore Ocean

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Anomalously warm ocean conditions persisted throughout winter, spring, and summer of 2015 (+2°C above normal). Warm winter conditions occurred when the prey resources of juvenile salmon developed and in the spring and summer as the salmon entered the ocean. The biomass of ichthyoplankton in January-March is inversely related to October-December PDO conditions the prior year and positively to adult salmon returns several years later. PDO conditions in late 2014 were almost double (warmer) than those of any year in our 18 year time series, and would have predicted a biomass 95% less than the amount that was actually sampled in January-March of 2015.

The increased biomass was primarily due to abnormally high biomasses of Northern anchovy and rockfish larvae. May diets of juvenile yearling Chinook salmon collected in coastal waters of the Northern California Current reflected higher proportions of juvenile rockfish being eaten, but no evidence of Northern anchovies being consumed. The May Chinook salmon diet composition most closely resembled those of other warm years of our study period. June diets also reflected a warm prey community being consumed with higher amounts of juvenile rockfish, crab megalopae and juvenile Northern anchovies being eaten, somewhat resembling the diets from the 1998 El Niño period. Both May and June Chinook salmon had one of the highest percentages of empty stomachs but overall stomach fullness was average for May but very low in June. Residuals of length-weight relationships showed that most salmon (not just Chinook salmon) were below average weight for their length. For Chinook salmon in 2015, they weighed 17.6% less that the same size fish in a cold ocean year (2008). Higher condition or fatness of spring Chinook salmon relates to increased adult returns two years later which suggests that the prospects for the 2015 ocean-entry smolts are not that favorable.

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Fine-scale Spatial and Stock Variations Among Juvenile Chinook Salmon and Steelhead in the Columbia River Plume: May 2015

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In 2015, NOAA fisheries re-invented its May juvenile salmon survey with a focus on assessing juveniles from Interior Columbia River stocks soon after they emigrated from the Columbia River Estuary and while they were still within the plume. From May 24th – 27th, 2015 approximately 400 yearling Chinook salmon and almost 300 juvenile steelhead were collected within 20 nautical miles of the Columbia River mouth. A high diversity of genetic stocks were captured; including Chinook salmon from Snake River spring, Mid-/upper Columbia River spring and Upper Columbia River summer-fall stocks. An unexpected and interesting result was the high catches of juvenile steelhead from Salmon River, Clearwater River, Mid & upper Columbia river/Lower Snake, and Lower Columbia River stocks. Significant differences were found among both Chinook salmon and steelhead stocks in length and growth, as indicated by Insulin-like growth factor 1 (IGF1) levels, and condition factor. Most of the Chinook salmon examined did not have elevated Sr:Ca within their otoliths, which indicates that they recently (<3 days) entered marine waters. Chinook salmon that had elevated otolith Sr:Ca were longer, growing faster (IGF1), and in better condition than those that did not have elevated otolith Sr:Ca, perhaps lending insight into the role of initial marine residence (estuarine and early ocean) on performance of juvenile Chinook salmon in the Columbia River Plume.

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MAY 25, 2016

SESSION 4: NEW UNDERSTANDING OF THE LOWER COLUMBIA RIVER AND PLUME ECOSYSTEM

Stock-specific Use of Tidal Freshwater Wetlands

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Since the early 2000s research on juvenile salmonid use of estuarine wetlands in the lower Columbia River has intensified. Estuary studies have provided a wealth of information that has helped guide recent estuary restoration actions. Advances in technology, such as higher resolution genetic assignment and radio/acoustic telemetry, have also led to a greater understanding of the relative importance of tidal wetlands to various life histories and stocks of juvenile salmonids. This study utilizes passive integrated transponder (PIT) technology to document use of tidal wetlands by a greater variety of juvenile salmonid stocks and life histories than previously reported.

During 2008-2014 we deployed PIT tag detection arrays at various off-channel wetlands in the tidally influenced portion of the Columbia River. We detected 235 Chinook Salmon (*Oncorhynchus tshawytscha*), 13 Coho Salmon (*O. kisutch*), and 16 steelhead trout (*O. mykiss*) that had been previously tagged from upriver sources. These fish represented 15 evolutionarily significant units and distinct population segments. Endangered Species Act (ESA)-listed stocks from the interior Columbia River Basin accounted for 10% of the salmonids detected. This finding contrasts with other recent studies in the lower Columbia River that found only 0.03–2.0% of salmon in shallow-water habitats originated from ESA-listed interior stocks.

A comparison of PIT tag detection data of listed interior stocks and lower river stocks provides a possible explanation for the greater proportional abundance of listed interior stocks detected by PIT arrays versus other traditional methods of sampling. Interior stocks tended to enter and exit tidal wetland channels during a narrow portion of the tidal cycle—at or just after slack high tide—when water depths were greatest. Whereas lower river stocks tended to enter tidal channels over a broader portion of the tidal cycle—flood through mid-ebb tide—and stay for longer periods. Average water depth at time of channel entry for listed interior stocks was 0.4 m higher than for lower river stocks. Traditional sampling methods such as beach seines or trap nets may miss stocks that access the habitat during slack high tide, since beach seines are often deployed at lower tides to provide a shoreline for ease of sampling, and trap nets sample fish that have entered a channel during the flood tide only.

Knowledge of water depth-mediated use of tidal wetlands by interior stocks can help managers plan strategic restorations actions aimed at particular stocks of interest. However, targeted restoration actions could be derailed if abnormally low river flows and water levels, which may prevent certain stocks from accessing productive habitat, become more frequent.

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Characterizing the Condition of Outmigrating Chinook and Steelhead in the Columbia River Estuary

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The Columbia River estuary is the site of one of the largest habitat restoration programs in the United States, as tidal inundation is being restored to 1000s of acres of former wetland habitat. A fundamental management question about this effort is whether the estuary wetland restoration actions are achieving expected biological and environmental benefits, especially with respect to juvenile salmon. Salmon can potentially benefit from restoration in two ways. First, they can directly occupy wetland habitats. Second, they can potentially derive benefits indirectly as a result of transport of organic material (especially insects) from the wetland in that prey transported from the wetland could be consumed by the salmon outside the wetlands. Prey consumed both inside and outside wetlands are potentially beneficial to salmon by increasing their growth as they move downstream before entering the ocean. Responses of salmon to restoration could potentially vary as a function of stock group and life history type. While direct benefits of restoration have been demonstrated for juvenile fall Chinook salmon, which reside in wetland habitats, less is known about the benefits of restored habitats for interior stocks of spring Chinook and steelhead, which receive protection under the U.S. Endangered Species Act. These interior salmon typically take less than a week to migrate the 235 km from Bonneville Dam to the mouth of the Columbia River. This study tests the hypothesis that restored habitats increase the availability of invertebrate prey and therefore increase growth of juvenile salmon of all stocks and life history types as they move downstream. Further, we hypothesize that benefits occur as a result of direct occupation of wetlands and indirectly as a result of transport of prey from the wetlands. To test the hypothesis that wetlands indirectly benefit juvenile salmon, we propose to sample salmon at multiple locations spanning the 235 km-long estuary, using genetics and internal tags to determine stock of origin, and a variety of metrics to characterize fish condition, including physiological metrics that rapidly respond to changes in growth rate. As part of this work we are also measuring the production and export of prey from restored habitat types. Sampling will occur in 2016 and 2017 at multiple times of year. A companion study by Pacific Northwest Labs (PNNL) is looking at direct use of wetland habitats. We are coordinating with studies characterizing juvenile salmon condition farther upstream (NWFSC, University of Washington) and downstream (NWFSC and AFSC ocean studies) so that we can follow a cohort of fish as they move from the headwaters, through the hydrosystem and estuary, and out into the ocean. This type of coordinated study across such geographically and ecologically diverse habitat types has not been attempted before, but we expect it to yield powerful insights into effects of wetland restoration.

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A Life Cycle Modeling Approach to Evaluating Population Response to Variable Life History Patterns of Coho Salmon and Alternative Restoration Scenarios in Coastal Watersheds

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Historic land use practices and associated habitat degradation have led to large declines in Coho Salmon populations across their range. With limited budgets, and high costs of Salmon recovery efforts, it is important to prioritize restoration and recovery actions where they will have the highest potential for population response. Population modeling offers a powerful tool in understanding Salmonid population dynamics as a function of management actions, and habitat restoration efforts. One challenge in developing population models is obtaining parameter estimates specific to the population of interest. Here we used 14 years of life stage specific survival and movement data collected on Freshwater Creek in northern California to build and parameterize a stage structured life cycle model. Subsequent analysis evaluates sensitivity and population response to various restoration and management scenarios. Questions this model addresses are: How do changes in juvenile survival and life history composition affect Coho Salmon population growth and stability? What management regimes will maximize population viability? What are the projected population responses for Coho under various restoration scenarios?

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Estimation of Survival and Run Timing of Adult Spring/Summer Chinook Salmon from the Columbia River Estuary to Bonneville Dam: A Cooperative Effort Between NOAA Fisheries and Columbia River Commercial Fishermen

A. Michelle Wargo Rub, Ben Sandford, Don Van Doornik, Brian Burke, Kinsey Frick, Mark Sorel, Matthew Nesbit, and Samuel Rambo

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Predation by pinnipeds on salmon and steelhead in the Columbia River (CR) has been identified by NOAA's West Coast Regional Office as a severe threat to salmon recovery. Adult salmon returning to the CR during the spring are particularly vulnerable to predation because their presence most overlaps that of the transient sea lion population. In an effort to assess predation on spring/summer Chinook salmon returning to the Middle and Upper Columbia and Snake Rivers, NOAA Fisheries has been working closely with CR commercial fishermen. Together we have marked over 1500 adult salmon within the CR estuary and measured their survival and transit time through the first 145 miles of freshwater. After accounting for harvest and impacts from sampling gear, weighted mean annual survival ranged from 59%-90% from 2010-2015. Lower overall survival was observed during recent years coincident with a growing sea lion population. Within season survival has consistently been lower during periods of peak sea lion presence. Our results imply predation is a significant source of mortality for these fish and that some fish populations may be at higher risk than others based on their behavior.

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Genetic Analysis of Caspian Tern (*Hydroprogne caspia*) and Double-crested Cormorant (*Phalacrocorax auritus*) Salmonid (*Oncorhynchus*) Consumption in the Columbia River Estuary 2006-2013

David Kuligowski[1], Daniel Roby[2], Donald Lyons[3], Ken Collis[4], Allen Evans[4], Donald Van Doornik[1], Lauren Reinalda[3], Laurie Weitkamp[1], Curtis Roegner[1], Tim Marcella[3], Peter Loschl[3], Kirsten Bixler[3] and David Teel[1]

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Caspian terns (*Hydroprogne caspia*) and double-crested cormorants (*Phalacrocorax auritus*), two of the most well-documented consumers of salmonid smolts (*Oncorhynchus*), are predators of concern in the lower Columbia River estuary. Colonies on East Sand Island (Rkm 8) consume upwards of 17 million outmigrating salmonid smolts each year. As a component of a larger study of avian predation on juvenile salmon, we used genetic methods of species identification and mixture analysis to study the diets of Caspian terns and double crested cormorants. Diet samples were obtained by collecting stomach contents from foraging birds during the period of smolt outmigration. Salmonid tissues were genotyped with the mitochondrial DNA marker COIII/ND3 to determine species. Samples were then genotyped with several sets of standardized salmonid microsatellite DNA markers (GAPS, SPAN, etc.) to estimate stock-of-origin. Stock proportions in the bird diets were estimated using regional microsatellite DNA baselines for Chinook salmon, coho salmon, sockeye salmon and steelhead trout. Species identification analysis detected six salmonid species in the bird diets. Caspian tern diet consisted mainly of Chinook salmon and steelhead trout whereas double crested cormorant diet had larger proportions of coho and Chinook salmon. We estimated multiple stock groups in the diets of both species. Caspian terns consumed fish from seven different Chinook salmon ESU's. Double crested cormorant diet had a high proportion (50%) of fall Chinook salmon from the Lower Columbia River ESU. Columbia River and coastal coho salmon and Snake River steelhead were present in both bird diets. We also compared our bird diet results with species and stock compositions obtained from juvenile salmon surveys in potential bird foraging habitats adjacent to the East Sand Island colonies. Our results indicated that Caspian terns and double crested cormorants forage in the deep water habitats used by yearling and large subyearling juvenile salmon prior to ocean entry. Predation impacts on smaller estuary rearing Chinook and chum salmon subyearlings may be relatively small. These results help assess bird predation on specific stocks of Columbia River Basin salmon, particularly for those that are not PIT tagged.

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Ocean Avian Predation Risk and Early Marine Survival of Salmon in the Columbia River Plume

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For more than 20 years, researchers hypothesized that early marine survival of anadromous fishes like Pacific salmon is strongly driven by predation on juveniles, yet there are surprisingly few direct empirical studies of ocean predators and salmon. To investigate the degree to which ocean avian predation may be affecting early marine survival of Chinook salmon from the Columbia River, we applied spatially-explicit models to measure overlap between seabirds and salmon. We also investigated environmental covariates (e.g. distance from shore, salinity, chlorophyll-*a*) for association with spatial distributions. Newly available genetic data for salmon allowed us to derive population-specific risk factors. Data from synoptic seabird and salmon surveys in May and June revealed that two species of seabirds (common murre *Uria aalge* and sooty shearwater *Puffinus griseus*) accounted for ≥80% of birds counted between Newport, OR and the US-Canadian border. We found that birds were spatially associated with the Columbia River Plume, and that bird density is related to plume area/volume. Predator-prey overlap varied in both time and space, in part due to population-specific differences in the marine distribution of salmon. Model results provide a new index of predation risk and insight into mortality factors affecting early marine survival of salmon. Data also suggest that river flow is linked to ocean predation risk.

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MAY 26, 2016

SESSION 4: NEW UNDERSTANDING OF THE LOWER COLUMBIA RIVER AND PLUME ECOSYSTEM (CONTINUED)

How Extreme Were 2015 Water Temperatures in the Lower Columbia and Willamette Rivers?

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In 2015, water temperatures (Tw) exceeded 20 degrees Celsius in the lower Willamette River by early June, approximately 1 month earlier than the previous 5 years. By July, early morning temperatures exceeded 26 degrees. At Bonneville Dam, Tw reached the 20 degree threshold by mid-June, and peaked around 23 degrees. How anomalous was Tw in 2015, and is this the 'new normal'? We address this question by first compiling a unique record of water temperature that extends back to 1881 in the lower Willamette and 1853 in the lower Columbia. Analysis of 85 years of instrumental data suggests that peak temperatures in the Willamette in 2015 were similar to other warm years such as 1889, 1941 and 2009. By contrast, analysis of a 115 year instrumental record suggests that the average Tw in the lower Columbia is now 2 degrees Celsius warmer than the mid-19th century. To investigate the divergent factors driving water temperature in the Willamette and Columbia, we create a physically-based statistical model in which Tw is a function of air temperature and river flow. Results show that changing air temperature, alteration of river flow, and other factors are likely driving changes to Columbia River temperatures. On the other hand, Willamette River temperatures have likely been kept down by the effect of reservoir releases, which have a cooling effect in peak summer. However, the trade-off has been that the length of time over which a threshold like 20 degrees is exceeded has increased over time; in 2015, water temperatures were over 20 degrees for an approximately 100 days, more than 10 days longer than any previous year.

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Looking at Extreme Events in Historic Tide Data, 1853 to 1876

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A historic point of view is useful in interpreting modern processes and extreme events – in what ways are modern events unusual, and how exceptional are they? Tidal records provide valuable perspective for judging extreme events and long-term changes in processes, in that they are our longest marine records. Collection of continuous tidal data with recording tide gauges began along the U.S. West Coast in 1853 or 1854 in San Diego, San Francisco and Astoria. While only the San Francisco record is continuous after 1876 up to the present, the almost two decades of simultaneous data from the 1850s to 1870s from these stations offer many possibilities for analysis of estuarine systems and extreme events. The Astoria record is particularly valuable, because it also includes weather and water temperature observations. However, it is first necessary to validate the data. Application of wavelet tidal analysis methods and more traditional analysis tools to hourly data listings compiled before 1900 suggests that timing errors are the primary weakness of these historic records, though various sorts of transcription errors and gauge malfunctions also occurred. When these hourly data are analyzed, there is a level of apparent variability in tidal properties that is certainly not real. Some of this derives, however, from the limited computational facilities available at the time and can be reduced or removed by reprocessing the records from the original analog marigrams (a paper trace on a roll of paper). Once validated, records from San Francisco and Astoria allow estimation of river inflow to the systems and flood volumes. Also, the marigram record provides information about storminess, because traces of infragravity waves are clearly visible in one-minute data derived from the marigrams. The great floods of the winter of 1861 and 1862 and accompanying storms are, for example, clearly seen in all three records. We will discuss recovery and validation of the data, and present examples of the use of these records to investigate 19th century processes and events.

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Modeling Historic Salinity Intrusion in Lower Columbia River Estuary

Lumas Helaire, Stefan A. Talke, David A. Jay, Drew Mahedy, and Austin Hudson

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The salinity intrusion length, or the maximum extent that saline ocean water intrudes into an estuary is an important estuarine ecosystem parameter. In this presentation we detail the development of a 3-D baroclinic model of the 19th century Lower Columbia River Estuary (LCRE) to assess how much salinity intrusion has changed. Comparisons of historic and modern data and model results indicates that the M2 tide has increased by ~10% due primarily to channel deepening but also reduced freshwater flow (17% decrease in mean discharge and 40-45% in peak discharge). Bathymetric changes and seasonal shifts in flow input have increased salinity intrusion, such that the LCRE has shifted from a seasonally freshwater estuary to one with nearly permanent salinity intrusion. In this study we use a hydrodynamic model to examine the terms in the salt flux in both the historic and the model and examine how the salt flux has evolved over the past 150 years. Mechanisms for the changes include: increased estuarine circulation, increased internal asymmetry, reduced bottom friction and mixing, and decreased river flow. We hope that an understanding of the evolution of the salinity structure over the past 150 years can help us to predict the future state of the LCRE.

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Can Tide/River-Flow Interactions in the Columbia River Estuary Be Observed in the Coastal Ocean?

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Numerous studies have documented variations in tidal properties at Astoria which are not explained by the predictable astronomical tidal forcing. Because extreme water levels are the sum of contributions from mean sea level, tides, and storm surges, there is interest in mapping changing tidal properties as well as understanding their causes. Changing tides in the Lower Columbia River are the result of changes in channel morphology and river flow which are leading to less frictional damping of the tides. Given these changes in the river tides, what is the back-effect on the open-ocean tides? An analysis of satellite altimeter data near the mouth of the Columbia River is conducted to examine the propagation of semi-diurnal and non-linear tides out of the river. A 3 cm signal is detectable in the M2 tide and its seasonal modulates, and in the M4 and MK3 overtides, which decays to an undetectable level at a distance of 140km from the river mouth. Implications of this study are that, (1) tidal rivers act like point sources for tidal anomalies which propagate back into the open ocean, (2) tide corrections for the forthcoming SWOT satellite altimeter mission will need to account for over-tides and seasonal tidal modulations in order to achieve the objective of 1cm accuracy in the coastal ocean.

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Underwater video measurements of Dungeness crab (*Cancer magister*) responses to thin-layer dredged material disposal

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To maintain a safe navigation channel at the mouth of the Columbia River (MCR) the US Army Corps of Engineers (ACE) annually dredges more than three million cubic meters of sediment from the mouth and places the material at designated near and offshore disposal sites. To mitigate for coastal erosion, a nearshore network of beneficial-use disposal sites has been proposed to channel more dredged sediment into the littoral zone. With the planned expansion of disposal sites, there are concerns about the potential impacts on Dungeness crab (*Cancer magister*), a vital fishery in both Oregon and Washington. This work focuses on monitoring Dungeness crab at the first beneficial-use site, the South Jetty Site, where ACE is practicing a thin-layer disposal method to reduce both mounding and organism burial. Historic monitoring of Dungeness crab at disposal sites included crab pots, but concerns still remain about the resilience of Dungeness crab to dredged material disposal as no *direct* observations of behavioral response to dumping have been made. Our project examined the direct effects of dredged material disposal events on crabs in an experimental framework using acoustic telemetry and new video-based approaches. This talk focuses on results from video techniques employing CamPods (baited video landers) and benthic video sleds. We also deployed traditional crab pots. The goal of this research was to determine if dredged material disposal affects Dungeness crab distributions and behavior at impact and control sites. CamPods provided a 'crab's-eye' view of a disposal event, being directly dumped on by the dredge vessel. This documented Dungeness being engulfed by the sediment plume and allowed for pre- and post-plume comparisons of relative abundance. The impact of the disposal plume appeared to be localized and temporary, with crabs displaced by the plume, but returning to the impact area after a disposal event. Abundances based on crab pots did not differ between disposal or control areas. The CamPods provided a snap-shot of disposal impacts that the traditional crab pots did not capture. Video sled data detected more temporal variation in Dungeness densities across the disposal season, rather than spatial. These results indicate that the thin-layer disposal at the nearshore South Jetty Site is an acute impact, but does not appear to significantly affect Dungeness abundances on a longer timescale.

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Acoustic Telemetry Measures of Dungeness Crab Movement and Behavior Relative to a Nearshore Sediment Disposal Site

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The Columbia River estuary and the adjacent nearshore zone are important habitat for Dungeness crab (*Cancer magister*), and these areas support valuable commercial and recreational fisheries. The estuary sustains high densities of juvenile crabs and is thought to function as a nursery, while larger crabs and especially females are believed to migrate to more saline nearshore habitat to mate and release brooded larvae. However, little is known about these crab migrations or indeed crab distributions or movements between habitats in general. One possible impact on crab populations is dredge operations in the mouth of the Columbia and sediment deposition events designed to aid beach nourishment. To learn more about crab movements and the effects of dredge depositions, we have been using benthic video imagery and acoustic telemetry to observe crabs during deposition events. This talk will present results from telemetry experiments. During 2014 and 2015, we conducted paired releases of tagged crabs in control and impact arrays using the Vemco VPS system. Arrays were each composed of a grid of four acoustic receivers arranged orthogonally 300m apart. Crabs were tagged with individually identifiable 9mm V9A transmitters epoxied to the upper carapace. During a tagging experiment, 10 tagged crabs were released in the center of each receiver array, followed soon after by deposition of sediment at the impact array by the USACE hopper dredge *Essayons*. The control array was outside the impact effect. We conducted three tag releases each year during the September period of permitted deposition activities, and the receivers were retrieved in late October. Individual crabs we evaluated for acute effects of deposition (distance, velocity, direction), and metrics were compared between impact and control arrays. We also determined movement and residence from crabs outside of the initial deposition period to evaluate migration and foraging behavior. Results indicate significant displacement of crabs by the sediment plume, but not burial or mortality. Crabs at both arrays were surprisingly mobile and were observed to travel in directed (non-random) movements. Individual crab detections were relatively brief within arrays, but crabs a number of individuals were detected days or weeks after release, suggesting a local residence. In general, the thin-layer sediment deposition utilized by the USACE appears effective at minimizing acute negative effects on crabs, in concurrence with our video measurements. We also deployed oceanographic buoys and moorings at the site, which recorded low dissolved oxygen events, large phytoplankton blooms, and fluctuating high temperatures which appear related to transport to the coast of anomalous warm water ("blob") conditions. These conditions may affect crab behavior in the nearshore zone.

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MAY 26, 2016
SESSION 5: INNOVATIVE TECHNOLOGIES AND NEW DATA PRODUCTS

Sediment Acoustics - Real-Time Continuous Suspended Sediment Data in the Lower Columbia River

**Paul Diaz Jr* and Marc A Stewart

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The ability to calculate suspended sediment flux on a continuous and real-time basis is critically important. Continuous real-time suspended sediment data can be used to determine and compute the timing, source, and quantity of sediment transport in the Lower Columbia River. This information could be used by federal agencies, local governments, and others, interested in effects sediment has on navigation, water quality, biological, and other potential impacts on the Lower Columbia River. The Sediment Acoustics technique is a promising new method that can be used to calculate continuous real-time suspended sediment data. The USGS has acoustic instruments deployed at several key locations in the Lower Columbia River basin. With minimal effort these existing acoustic gages can be calibrated to provide continuous real-time suspended sediment data. Currently the USGS is in the final stages of releasing continuous real-time sediment data at a key stream gage in the Lower Columbia River basin while additional data is being collected at other sites in the Lower Columbia River Basin. These data are to be released in the near future.

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Refining the Edges of the Columbia River Eulachon Run – A New Application for Environmental DNA

Joe Krieter[1], Taal Levi[2], Maria Sandercock[1], Andy Clodfelter[1], Michelle Hollis[3]

[1]Hart Crowser Inc., Natural Resources Division, Portland, OR
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Presenting author (email: joe.krieter@hartcrowser.com)

In November 2015 the Port of Portland (Port) initiated a three year study to help address management questions related to the conservation and recovery of federally listed southern eulachon (*Thaleichthys pacificus)*. Although eulachon monitoring has occurred since the late 1990s in the lower Columbia River (LCR) mainstem and in select tributaries such as the Cowlitz and Lewis rivers, surprisingly little is known about adult run timing and mainstem habitat use within the Portland/Vancouver reach. One of the primary objectives of our study is to refine our understanding of adult run timing, relative to federal and state guidelines for the timing of in-water work, within the most industrialized reach of the LCR.

Our first year pilot study relies on the use of environmental deoxyribonucleic acid (eDNA) sampling techniques, a relatively new approach used to determine the presence of a target organism within an aquatic environment. Sampling for eDNA is non-invasive and has been reported as more sensitive than traditional sampling methods such as seining or trawling, particularly when target animal abundance is low. On the Port's behalf, Hart Crowser is working collaboratively with Oregon State University (OSU) research scientists during the performance of this field study. Hart Crowser aquatic ecologists designed the sampling plan and are leading the field data collection efforts while OSU scientists perform the eDNA laboratory analyses. The Cowlitz Tribe also provides data from their fyke net trapping efforts which we use for method validation.

Preliminary findings indicate that eDNA sampling, using digital droplet Polymerase Chain Reaction (ddPCR) analyses can be used to detect very low concentrations of eulachon DNA in the Columbia River. We have consistently detected eulachon in areas where trapping has confirmed their presence. By extension, we believe our results for areas where eulachon DNA was not detected indicates that the species was not locally abundant in these areas. Spatially distributed eDNA transects sampled throughout the spawning run can yield critical information about the timing and relative distribution of eulachon in reaches of the river that are difficult to sample using traditional techniques, but are nonetheless important from an in-water work management perspective. Over the next two years we hope to apply the knowledge from this first year pilot study to further broaden our spatiotemporal understanding of eulachon uses in the Portland/Vancouver reach.

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Monitoring Opportunities in the Estuary with Unmanned Aerial Vehicles (UAVs)

Ian Sinks[1] and Keith Steele[2]

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[2]Sitka Technology Group, Portland, OR

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As an early adopter of using UAVs to gather high-resolution data in the estuary, Columbia Land Trust has implemented a UAV-based monitoring trial to detect, monitor, and manage invasive reed canarygrass, marsh vegetation development, and other physical features within restoration areas. Partnering with Sitka Technology Group, they flew an initial flight during the winter dormant season (February 2016) where they were able to collect imagery from a commercial UAV to produce orthomosaics of two sites totaling more than 300 acres. The orthoimagery and land surface generated from the imagery provided Columbia Land Trust with an 'as-built' of constructed channels and mounds, large wood structures, and an invasive species baseline. This summer, they will be doing a second round of UAV flights of the same areas to determine vegetation communities, including reed canarygrass. Columbia Land Trust and Sitka Technology Group are working together to develop a program that helps the Land Trust leverage limited conservation funds for more effective land stewardship.

During this presentation, Ian and Keith will provide attendees with:

- An overview of what Columbia Land Trust is doing to control invasive species in the estuary and why UAVs were chosen to augment their stewardship program.
- A primer of the legal requirements and restrictions of using UAV technology.
- An overview of the best practices used in designing their UAV-based program, planning and executing the flights, and analyzing the collected data.
- A review of collected raw images, orthoimagery, and topographic datasets (a point cloud and derivative 3D model).
- Specific examples of how Columbia Land Trust is using UAV-collected data.

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POSTER PRESENTATIONS

Batwater Station Floodplain Restoration

Janice Bell, P.E. and Jenni Dykstra

Presenting author (email: janice@watways.com)

The Batwater Station Floodplain Restoration Project (Batwater Station) reconnected a 26-acre wetland to the lower Columbia River and its tidal influence to benefit threatened and endangered species of salmon and steelhead. The project also benefited several other native species such as turtles, frogs, deer and beaver. Historically, the property was a tidally influenced shrub-scrub wetland. Cries Creek flowed through the wetland to the river and fish and wildlife freely moved between the site and river. Over time, the site changed: the land was cleared, dikes were constructed and tidegates installed, Cries Creek was realigned, a driveway was laid through the middle of the site, and the rich diversity of species was replaced by a homogenized mix of some ash and willow predominated by invasive reed canarygrass.

The restoration of this site was initiated by Karin Hunt (private landowner) and relied upon the collaboration of several project partners, including Bonneville Power Administration, Lower Columbia Estuary Partnership (Estuary Parnership), Lower Columbia River Watershed Council, Columbia Soil and Water Conservation District (CSWCD), Waterways Consulting and Kynsi Construction. The project began in 2011 with initial talks between the landowner, CSWCD and the Estuary Partnership, and was constructed in the summer of 2015. The site will be planted in winter 2016, and monitored by the Estuary Partnership using photo points and gages for physical characteristics such as water surface elevation, sediment accretion and temperature to observe the hydrologic connectivity to the Columbia River, habitat quality, and changes in the floodplain over time.

The diversity of the project partners at Batwater Station provided challenges in gaining a group consensus on the project vision, but the project that emerged included several unique features that allowed all partners to achieve their goals. Specific project elements included:

- Breaching 500 lineal feet of levee and removing a tidegate to reconnect the floodplain and Cries Creek to the Columbia River
- Constructing 1,600 lineal feet of starter tidal channels to provide off-channel habitat and initiate natural tidal channel development
- Installing 14 large wood structures and 4 sets of beaver analog structures in the tidal channels to create habitat complexity, cover for juvenile fish, basking structures for turtles, and to encourage beaver activity
- Planting 11 acres of the site with native wetland trees, shrubs and emergent vegetation to initiate natural ecological processes, hydraulic diversity, control sediment, moderate water temperatures, and provide fish and wildlife habitat
- Treating invasive reed canary grass to enable revegetation and plant establishment
- Raising the level of the driveway to redirect Cries Creek into the restoration area while enhancing the landowner's access to her home, and allowing her to continue to manage the western portion of her property for livestock and as a high-flow refuge for Columbian white-tailed deer
- Installation of hummocks to provide habitat diversity and balance on-site cut/fill

The presentation of this project will include an overview of the project, a description of the tidal channel design process, and highlight the multi-species design components.

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Restoration of Cold Water Refugia in the Columbia River Estuary

**Chris Collins*

Lower Columbia Estuary Partnership, Portland, OR

**Presenting author* (email: ccollins@estuarypartnership.org)

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 an overview of the need for, and potential benefits of, thermal refugia; a summary of site characteristics that are anticipated to provide thermal refugia; a summary of remaining uncertainties associated with the ability of individual sites to provide thermal refugia; and a case study of a recently completed project that provides examples of habitat enhancement techniques that are anticipated to protect and restore thermal refugia.

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Advancing the Integration of Vegetation in Floodplain Modeling and Management to Achieve Multi-Objective Benefits for Flood Risk Reduction

*_Kevin Coulton, P.E., CFM[1],_ Stefan Lorenzato, MS[2], Tom Griggs, Ph.D.[3], Seungjin Baek, Ph.D., P.E.[4], Dale Meck, EIT[5], John Stofleth, MS, P.E.[6], Chris Bowles, Ph.D., P.E.[4]

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Past efforts at "flood control" were often made at the expense of the ecological integrity of rivers and streams by simplifying the systems, constraining key natural processes, and limiting habitat and ecological niches. Today, increasing scientific and public interest in the ecological, and economic, value of floodplains, and changing regulation, especially those related to the improved management of floodplains with consideration for endangered species, all advocate for restoring and sustaining floodplain functions and processes.

Numerical models can be a powerful tool to help achieve these multi-objective benefits in floodplain management; however, the representation of vegetation in models is often rudimentary. Plants play a key role in how processes and functions are expressed and hydraulic roughness is the principle model parameter describing how plants interact with flood water. Roughness is commonly over-simplified in models leading to missed opportunities for risk reduction and ecological enhancement. Aligning plant characteristics to variations in roughness is a key factor in integrative floodplain design.

We will describe recent engineering and ecological research, and explore design concepts and techniques, that advance the integration of vegetation in floodplain modeling and management. Vegetation on floodplains can be designed, modeled, and ultimately managed to achieve engineering and ecological objectives, such as maintaining flood conveyance while accommodating the establishment and growth of riparian plant communities. Case studies will show how placement of plants can direct overbank flows, improve flood storage, reduce scour and erosion, facilitate sediment transport, and alleviate other flood risk factors, while providing critical habitat.

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Quagga and Zebra Mussel Monitoring in the Pacific Northwest, USA: How Much Effort is Needed to Detect Rare Planktonic Taxa in the Columbia and Snake Rivers?

**Timothy D. Counihan*[1], Stephen M. Bollens[2]

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Presenting author (email: tcounihan@usgs.gov)

Recent studies suggest that the ecological and economic costs of an infestation of quagga and zebra (dreissenid) mussels in the Pacific Northwest, USA would be significant. We use information collected from 2012-2014 to characterize the spatial extent of dreissenid mussel veliger monitoring in the Pacific Northwest and place the efforts in the context of introduction and establishment risk. We also estimate the effort needed for high probability detection of rare planktonic taxa in the Columbia and Snake Rivers and whether current efforts provide for early detection of dreissenid mussels. We found that the effort to monitor for dreissenid mussels increased from 2012-2014, that regional efforts were distributed across risk categories ranging from high to very low, and that there are substantial gaps in our knowledge of introduction and establishment risk. The estimated effort required to fully census planktonic taxa, or to provide high detection of rare planktonic taxa, was high. The current level of effort expended does not provide for high probability detection of dreissenid mussel veligers or other planktonic taxa when they are rare in the reservoirs evaluated.

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Columbia Estuary Ecosystem Restoration Program: Restoration Design Challenge of Channel Outlets

**Heida Diefenderfer*[1], Val Cullinan[1], Amy Borde[1], Shon Zimmerman[1], and Ian Sinks[2]

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The channel network is one of the most ecologically important and costly features of tidal wetland restoration projects designed for juvenile salmon habitat functions in the lower Columbia River and estuary (LCRE). The Restoration Design Challenges (RDC) study sought to address the lack of established best management practices for channel network design in tidal wetlands of the LCRE. At the outset of the study, we interviewed restoration practitioners in the LCRE, who prioritized research into the *number of channel outlets* from among several aspects of the channel network initially considered for the study. The focus on channel outlets was needed because available information regarding these confluences between the channels inside of wetlands and the water bodies outside of wetlands was insufficient for design purposes, and the number of outlets was thought to be important to aquatic habitat connectivity as well as channel evolution. Generally, practitioners developed a model based on historical channel network design and modified it to account for limitations caused by local infrastructure, stakeholder requirements, and cost-benefit analysis. However, linear regression models had recently become available, which in most cases indicated that a larger number of outlets than was historically present would be suitable, leading to inconsistent sources of design information. In this study, we developed methods to analyze and summarize channel outlet counts, planform channel perimeter, channel surface area, wetland area, and island area for > 300 reference wetlands using two GIS datasets developed through the Columbia Estuary Ecosystem Restoration Program: 1) the Ecosystem Classification and 2) the Landscape Planning Framework. We separated mainland and island wetlands for analysis yet still found a very high variability of these five wetland channel network properties within the eight hydrogeomorphic reaches. In some reaches there also were significant differences between mainland and island channel networks. We conducted linear regressions of the number of channel outlets, channel perimeter, and channel area, all as a function of wetland area, for island or mainland wetlands in each reach. Through this approach, we identified five predictive models (defined as $R^2 > 80\%$), all of which were located in the lowest three reaches of the river. Four of the models use channel perimeter as the response variable and one uses channel area, however, no models using channel outlets were predictive. In future restoration designs in reaches A, B, and C, these models could be consulted in addition to routine methods, but they should not be viewed as prescriptive given the variability in these metrics. We concluded that 1) for these three response variables, the approach used by practitioners, based on historical channel network design, is not inferior to the use of a regression model; 2) the landscape setting is important to identifying the number of channel outlets; and 3) caution should be used when comparing channel-network reference information between island and mainland wetlands.

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Columbia Estuary Ecosystem Restoration Program: Restoration Design Challenge of Topographic Heterogeneity

Heida Diefenderfer[1], Ian Sinks[2], Val Cullinan[1], Shon Zimmerman[1], and Amy Borde[1]

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Tidal wetland restoration designs in the lower Columbia River and estuary (LCRE) increasingly incorporate topographic heterogeneity, variously described as mounds, berms, natural levees, peninsulas, bar and scroll, or ridge and swale. These are thought to provide ecological functions related to the establishment of woody plants and to mitigate the costs of removing material that is excavated to establish a channel network. The Restoration Design Challenges (RDC) study sought to address the lack of established best management practices for designing topographic heterogeneity and establishing woody vegetation in tidal wetlands of the LCRE. At the outset of the study, we interviewed restoration practitioners in the lower Columbia River and estuary, Puget Sound, and outer coast regions to identify field sites and related studies. We found that planting success has been variable, often requiring years and multiple planting efforts to establish. However, no baseline counts of species planted on mounds through the Columbia Estuary Ecosystem Restoration Program (CEERP) had been collected, so mortality could not be estimated, which led to a recommendation that future restoration projects generate baseline data from new sites for this purpose. Our literature review found that papers tended to focus on microtopography (height or elevation), soil and nutrients, and function but little evidence was available for systems similar to the LCRE (tidal or tidal-fluvial wetlands). Some papers indicated differences in environmental controls (moisture, temperature) based on aspect and elevation. Our field research therefore focused on the qualitative assessment of plant vigor together with environmental parameters potentially related to plant growth in these ecosystems: soil temperature and moisture, the aspect of side slopes, and vertical position on mound. Statistical analysis of the soil temperature and moisture data we collected indicated that soil moisture stratified with the vertical position on the mound, which suggests that practitioners may wish to evaluate the tolerances of locally important native plants, using the hydrologic regime and elevation data as the design basis. Though stratification of soil temperature was less conclusive, temperature appeared to positively vary with elevation. Mound aspect appeared to be less important to temperature and moisture than hypothesized, although field data were collected only in summer. Qualitatively observed differences in plant mortality and the vigor of plantings appeared to correspond to differences in soil organic matter and moisture. Findings on plant vigor and success emphasize the importance of considering the source of mound material, whether it is from the bottom of a slough or the topmost layer of a floodplain, especially regarding organic matter content. Consideration of naturally present topographic heterogeneity—particularly size, number, and configuration—relative to different project goals for marsh, shrub, or forested ecosystems is an important underpinning of site-specific mound designs.

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Monitoring Microbes in the Columbia River Estuary Using an Autonomous Robotic Sampler Integrated with an Observation and Prediction System

**Lydie Herfort*, Charles Seaton, Michael Wilkin, Peter Zuber, António M. Baptista, and Holly M. Simon

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Our understanding of the impacts of environmental change on microbial communities would be improved by the acquisition of samples in the precise moments that conditions change and the ability to subsequently monitor the responses of microbial populations to the change. Our approach to this problem involved embedding a robotic microbial sampler (Environmental Sample Processor) within the operations of an interdisciplinary observation and prediction system (SATURN; www.stccmop.org/saturn) for the Columbia River estuary. The Columbia River estuary provided an ideal testbed for the challenge of capturing transient fluctuations in physical, biogeochemical and microbiological parameters in an extremely dynamic environment. The estuary is characterized by fast-changing water masses with large freshwater and oceanic influences, high but fluctuating suspended particulate matter concentrations, strong currents and short flushing times. Water samples of microbiologically-relevant transient events were collected autonomously, either adaptively (i.e., sampling was initiated based on sensor data meeting user-defined parameters) or at predetermined times, and the abundance of specific microorganisms was determined by molecular analysis. Environmental parameters, assessed from SATURN physical-biogeochemical sensors and model predictions, provided context to these results. This allowed the effective characterization of (1) the impact of wind-driven coastal upwelling on ammonia-oxidizing archaea in the estuary (especially those associated with estuarine turbidity maxima); and (2) temporal dynamics of the red water bloom-forming ciliate, *Mesodinium major*, and its cryptophyte prey, *Teleaulax amphioxeia*. Changes in the populations of these organisms can be linked to changing environmental conditions (e.g., brought about by upwelling episodes for the archaea, and lowering of the river discharge for the ciliate), making them good candidates for this monitoring study.

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Long term Changes to River Flow Observed in Historic Tide Data (1853-2015) at Astoria, OR

**Drew Mahedy*, Stefan Talke, David Jay, and Sam Hawkinson

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

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. Recent recovery of tide data at Astoria, OR from analog tabulations and tide rolls show that the M2 tidal amplitude has increased by nearly 10% from 1855 to the present. Moreover, peak river discharge during the spring freshet has decreased by an average of 40% since 1878. Based on tidal theory, the interaction between tides and river discharge is determined by quadratic bed friction. We estimate spring freshet conditions in the two decades (1853-1876) preceding the start of U.S. Geological Survey observed flows based on long-term regressions of tidal property (TP) ratios. These TP ratios include the M2 admittance, which is the tidal amplitude relative to the astronomical forcing, and $M4/M2^2$, which represents frictionally produced asymmetry in the tide wave. Historic flow measurements are calibrated using water level measurements from Portland, OR in 1876 and validated using rating curve estimates of discharge at The Dalles, OR. Initial results reproduce large spring freshets and flood events in 1859, 1861, 1862, 1866, and 1876, and demonstrate how seasonal flooding was a common event. Compared to historic norms, the Columbia River estuary is in a condition of permanent drought; the low-flow year of 1869, an extreme outlier in the 19^{th} century, has become the new norm.

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Lower Columbia River Thermal Refugia Study: Results Summary for 2014-2015 Columbia River Gorge Stream Temperature Monitoring

**Keith Marcoe*, Matt Schwartz

Lower Columbia Estuary Partnership, Portland, OR

**Presenting author* (email: kmarcoe@estuarypartnership.org)

The lower Columbia River serves as rearing habitat and a migration corridor for multiple endangered and threatened salmonid species. There is growing concern that Columbia River temperatures during the summer months, which have been increasing for several decades, may be inducing thermal stress on populations of these fish that utilize the river during these months. Streams and tributaries entering the lower Columbia are typically cooler than the Columbia itself, and as such can provide refuge for these migrating fish from warmer Columbia River waters. As part of a multi-year study to document cold water inputs to the lower Columbia River, we monitored summertime thermal and discharge characteristics of the 15 primary tributary complexes that enter the Columbia River in the lower Columbia River Gorge (below Bonneville Dam) during 2014 and 2015. Based on these results, we assessed the potential of these streams for serving as 'thermal refugia' zones to migrating adult and juvenile salmonids, under current climatic conditions. Five of the fifteen tributaries were seen to have cold water 'plumes' at their respective confluences with the Columbia River, which may offer thermal refuge directly or provide thermal cues to fish to seek cooler water upstream. Even for streams where plumes were not observed to form, evidence of suitable refugia was noted. Based on our criteria, twelve of these tributaries had adequate flow and cold enough temperatures to offer thermal refuge in floodplain or higher gradient reaches.

Future components of this study include monitoring Gorge streams that were not surveyed in the current year, documenting 'non-stream' cold water inputs such as groundwater, outfalls, etc., documenting cold water sources downstream of the Columbia River Gorge, and assessing potential impacts due to climate change. As Columbia River temperatures continue to warm, the importance of cold water sources that can be utilized by fish, i.e. thermal refugia, will likely continue to increase. Gaining a better understanding of the extent and quality of these sources is fundamental to understanding how these endangered stocks currently utilize the lower Columbia River corridor during warm water periods, how this use may be impacted by a changing climate, and what management actions can be taken to restore and protect these cold water areas.

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Trestle Bay Habitat Restoration Project

*_Gail Saldana_ and Justin Saydell

US Army Corps of Engineers and the Columbia River Estuary Study Taskforce

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Trestle Bay is a jetty lagoon feature that was formed as a result of sediment accretion along the ocean side of the MCR South Jetty during initial construction of the jetty between 1885 and 1895. 628 acres of intertidal and shallow subtidal habitat are largely enclosed by the 8,800-ft portion of the South Jetty Root that bisects the bay. The permeable jetty structure provides full exchange of tidal water volume over the complete tidal cycle through relatively large circuitous pathways between the jetty rocks. It is believed that lack of light, water velocities and length of pathways are a deterrent for juvenile salmonids and other fish species from passing back-and-forth through the permeable rock jetty.

The Trestle Bay Section 1135 Project (constructed in August 1995) lowered a 500-ft segment of the jetty providing more efficient ebb and flood tide and partial fish access into the enclosed bay. This lowered jetty segment provided a solitary access/egress point for the entire 628 acres of enclosed habitat. Salmon and Steelhead juveniles typically enter shallow embayments like Trestle Bay during flood tide and exit before ebb tide, which provides the juvenile fish with two ~6-hour windows per day to get into the bay, forage, and exit before the ebb tide.

Pre- and post-project biological monitoring data for the Section 1135 Project suggest that fish access could be further improved by opening up additional targeted segments of the relic jetty root. Pre- and post-project sediment monitoring data also suggest that flushing of nutrients and detrital material from the enclosed bay could be further improved by such actions.

The recent restoration effort (completed in February 2016) created seven additional spatially distributed openings in the relic jetty root. Lowering segments of the relic jetty root down to adjacent grade will provide open access through the entire water column; and additional openings through the jetty will distribute flow quantities through a larger composite cross sectional area, thereby reducing maximum entry and exit velocities during mid-tides. Additional openings would also increase the export/exchange of intertidal inputs, which are an important component of the estuarine food web.

The constructed project will provide improved foraging and rearing conditions and increased duration for juvenile salmonids and other fish species access/egress to important shallow-water and intertidal habitat. Improved access, opportunity and ecological function are expected to benefit several threatened and endangered species including: fall and spring/summer Chinook salmon (_Oncorhynchus tshawytscha_), chum salmon (_Oncorhynchus keta_), Snake River sockeye salmon (_Oncorhynchus nerka_), steelhead trout (_Oncorhynchus mykiss_), coho salmon (_Oncorhynchus kisutch_) and coastal cutthroat trout (_Oncorhynchus clarki_).Candidate species such as Coho salmon _Oncorhynchus kisutch_) also are expected to benefit from improved access, opportunity and ecological function of the bay.

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Local Atmospheric Effects in the Columbia River Estuary: Can We Simulate Them, and Do They Matter?

Isabella Scroccaro, António M. Baptista, and Paul J. Turner

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Circulation modeling has become an important tool in understanding and managing the Columbia River estuary as a regional resource. That type of modeling has offered insights into ecosystem restoration and salmon recovery efforts, and in balancing ecological health, navigation improvements, and hydropower exploration.

River discharges, tides and coastal upwelling are all recognized as key drivers of the estuary's circulation, and therefore have been carefully accounted for in modeling efforts by CMOP and other groups. However, few modeling (or, more broadly, scientific or applied) studies have addressed the influence of local atmospheric forcing in detail. This is in part because local atmospheric forcing is perceived as secondary, and in part because available atmospheric observations and simulations have historically been spatially very coarse.
With the advent of high-resolution atmospheric modeling, it is timely to revisit the role of local atmospheric forcing. Here, we contrast the effects of third party (NOAA and University of Washington) forcing at resolutions ranging from 4/3km to 32km, on CMOP simulations of the estuarine circulation. We also contrast these results against ignoring atmospheric forcing within the estuary. Simulations are for three distinct periods: the year of 2014, and two separate ~30d periods in late 2015 and early 2016, including a major winter storm in 2015.

Results show that, while certainly secondary in general, local atmospheric forcing is at times significant for important estuarine features and metrics. This is particularly visible during the 2015 winter storm, where neglecting or coarsely representing local wind and atmospheric pressure can substantially alter water levels (by up to ~20cm) and salinity intrusion length (by over 5km), with implications that may extend to plume volume and shallow habitat. More generally, the effect of local forcing is important estuary-wide in winter months, through the wind and atmospheric pressure fields; and local solar radiation influences seasonal temperature trends.

Implications of these findings are discussed in the context of CMOP operational products (daily forecasts and simulation databases), as well as in the context of the scientific understanding of circulation, water retention and habitat in the estuary.

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Columbia River Endurance Stations: Eyes on the Warm Blob, and Beyond

**Charles Seaton*, Sarah Riseman, Michael Wilkin, Jo Goodman, Paul J. Turner, Joseph A. Needoba, and António M. Baptista

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An extensive network of interdisciplinary endurance stations has been established for the Columbia River estuary, as a part of a collaborative infrastructure (SATURN; Baptista et al. 2015) designed to help understand processes, variability and change in this important ecosystem. SATURN is a founding sub-system of the Northwest Association of Networked Ocean Observing System (NANOOS). Here, we review the network, introduce selected QA/QC procedures, and show examples of application of the data—with emphasis on a "Blob Watch" that offer insights into the influence on the Columbia River estuary of the 2015 Pacific Northwest Blob. Anchoring the observation network are long-term stations that capture system characteristics at the near-plume (SATURN-02), North (SATURN-01) and Navigation (SATURN-03) channels, as well as at the entrance of lateral bays (Baker Bay, SATURN-07; Youngs Bay, SATURN-09; Cathlamet Bay, SATURN-04) and upriver (Beaver Army, SATURN-05; Willamette River, SATURN-06 [now maintained by USGS]; and Vancouver, SATURN-08). Most of these stations measure scalar variables that include at least salinity, temperature, chlorophyll, turbidity, dissolved oxygen, and CDOM, with some stations also measuring additional scalar variables (including nitrate, Phycoerythrin, pH and pCO_2) and vertical profiles of velocity (SATURN-01 through 04). With the exception of SATURN-02 (which is seasonal), all stations are maintained year-round, as allowed by logistics and funding. All data is available (http://www.stccmop.org), both in real time and in an historical inventory. For the inventory, each variable is subject to customized QA/QC procedures, often involving a combination of deionized water measurements (at SATURN-03 and 04), vessel-based water sampling near stations, and correlations with other stations. Here we will describe the procedure used for nitrate in the lower estuary stations, with emphasis on SATURN-01, 03 and 04. Station data has been used to support a broad range of scientific analyses, model benchmarks, and management decisions. Web-based "Watches" have also been developed to keep customized "eyes" on processes of interest, including estuarine hypoxia and estuarine turbidity maxima. Here, we will introduce the "Blob Watch," designed to track the effects on the estuary of the unusually warm Pacific Ocean waters that are often referred as the "Warm Blob."

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Columbia Estuary Ecosystem Restoration Program: Restoration Design Challenge of Controlling Reed Canarygrass

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Reducing the extent of invasive reed canarygrass (RCG) in the extensive tidal freshwater region of the lower Columbia River and estuary (LCRE) is thought to facilitate establishment of native plant communities, improve food web dynamics, prevent floodplain armoring, facilitate passive channel formation, and avoid barriers to establishment of natural benthic communities. Concurrent research into reed canarygrass function is ongoing through BPA's Ecosystem Monitoring Program. The Restoration Design Challenges (RDC) study sought to address the lack of established best management practices to control reed canarygrass in tidal wetlands of the LCRE. The programmatic ecosystem-restoration objectives, particularly the focus on hydrologic connectivity for juvenile salmon, preclude the use of impoundment strategies for control. The study team conducted outreach to practitioners in the LCRE and in Puget Sound and outer coast regions, reviewed published literature on control methods and environmental factors, and completed field site review with data collection at two sites. Typically, restoration practitioners are lowering elevations to increase hydrologic impedance of RCG growth, or constructing elevated mounds and planting woody vegetation to control RCG. As a result, mid-elevations (non-woody high marsh) are being invaded by RCG, although some field sites show indications that native communities have the potential to compete. However, in general, there is practitioner resignation that RCG will persist in these habitats. Published literature regarding RCG control in tidal areas is sparse but indicates that with a strong understanding of site conditions there is a potential for control if wide scale, comprehensive (multi-factor) strategies are implemented with a commitment to maintenance. The potential role of soil nutrients was one factor identified in the literature review that had not previously been considered in the LCRE. The study provides a review of implications for restoration practice, an elevation table for RCG at river mile intervals for the LCRE, and recommendations for future study and field testing of control methods to improve restoration program performance.

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Columbia-Pacific Passage Habitat Restoration

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The Columbia-Pacific Passage Habitat Restoration Project is part of a multi-phase project sponsored by CREST involving three separate tributaries to the Columbia River estuary. The three sites are located within 5 miles of each other on the Columbia River shoreline in southwest Washington. The proposed sites of this large-scale restoration effort include Fort Columbia, which was restored in 2010 as part of phase I of the project, Megler Creek, which will be restored in the fall of 2016 as part of phase II, and Hungry Harbor, which will be completed during the third phase of the restoration strategy. Restoration is needed in this estuarine reach of the Columbia River because extensive historical alterations of the shoreline have eliminated the majority of off-channel foraging and rearing opportunities in this important migration corridor. Almost the entire 9 miles of lower river shoreline in Washington from Knappton Cove to the town of Chinook is heavily riprapped. Most of the historical estuarine tributaries that once served as off-channel habitat for migrating and spawning salmon have been disconnected from the Columbia mainstem by inappropriately sized and placed culverts. Fish presence studies conducted by NOAA on the Columbia River mainstem indicate that the North Channel is the primary route taken by outgoing juvenile salmonids in the Columbia River system. Therefore, reconnecting off-channel rearing habitat necessary for migrating salmonids along this widely used route is vitally important for improving salmonid survival for ESA listed fishes in the Estuary as well as fish utilizing Megler Creek.

Each phase of the project addresses a direct tributary to the Columbia River between river mile 8 and 14. Restoration actions consist of replacing dilapidated undersized perched corrugated metal culverts at the confluence of the creeks and the Columbia River with appropriately sized and placed concrete box culverts. The structure replacements aim to correct the existing fish passage barriers and improve access to upstream spawning habitat as well as improve off-channel rearing habitat by enhancing tidal connection to estuarine wetlands associated with the tributaries. The project is anticipated to restore habitat connectivity, eliminate the barrier to off-channel habitat, improve and expand off-channel habitat, improve nutrient exchange processes, increase availability of preferred habitat, and expand the macrodetrius-based food web.

The project targets limiting factors for estuary and tributary habitats for anadromous fish. Rearing ocean-type juvenile salmon are closely associated with shallow water habitats in the estuary and lower mainstem. Presently, Megler Creek and Hungary Harbor are largely inaccessible to migrating juveniles. Targeted limiting factors include loss of habitat connectivity, blockages to off-channel/stream habitats, loss of side-channel or side-channel habitats, altered nutrient exchange processes, availability of preferred habitat (shallow water, peripheral habitats), and macrodetius-based food web. Tidal wetland habitat in addition to increased spawning access are projected to be restored – leading to higher nutrient transfer as well as increased productivity in the adjacent Columbia River nearshore environment.

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The Chinook Estuary: Intertidal Wetland Restoration in an Uncertain Hydrologic Future

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The 1500-acre Chinook Estuary in Pacific County, Washington (Columbia River Mile 5) has been a location of active wetland restoration in the midst of agricultural, ranching, rural residences and terrestrial wildlife management. Anthropogenic changes to the estuary began in the late 1800s, with the construction of a rail line through the estuary. Intensive wetland diking and draining to allow conversion to agricultural use, and intensive logging in surrounding uplands followed. Since the early 2000s, WDFW has been engaged in habitat restoration efforts on the 1050-acre WDFW Chinook Wildlife Area within estuary. Restoration actions have included land acquisition, filling of agricultural drainage ditches, excavation of legacy tidal channel blockages, re-establishment of native wetland plant species, and efforts to increase tidal flux between Baker Bay and the Chinook Estuary. In 2007, failing wooden tide gates were replaced by retractable tide gates near the Chinook Estuary-Baker Bay confluence to allow for increased tidal exchange between the two estuaries. Since 2007, these tide gates have been managed to maximize tidal flux, and since Fall 2015 they have been managed and operated by a local organization and select residents, creating opportunities for more responsive management and benefits for fish. WDFW lands within the estuary are surrounded by, and hydrologically connected to private lands and ongoing community engagement has been key to habitat restoration progress achieved to date. A series of public meetings have been held to solicit feedback and improve restoration plans. Biological research and monitoring, hydrologic modeling, and the installation of a telemetric flow, stage, and precipitation monitoring station on the Chinook River are tools used to continue community education and engagement. Concerns have been raised by private landowners regarding the effects of tide gate management and inundation in the estuary driven by precipitation events. Potential sea level rise and increased storm intensity driven by climate change will compound the need for continued monitoring, restoration and community engagement.

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Addressing Critical Data Gaps in the Life-History, biology, and Ecology of Threatened Eulachon (*Thaleicthys pacificus*) in the Lower Columbia River

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The population of eulachon *Thaleicthys pacificus* in the Columbia River is thought to be the largest in the world. Eulachon historically supported indigenous, commercial, and sport harvests, but were listed in 2010 as threatened under the U.S. Endangered Species Act. Despite the size and importance of the Columbia River population, critical uncertainties remain regarding adult spawning biomass estimates, run timing, migration behavior, sex ratios, and sex-specific size and weight. During January-March 2013, we used hydroacoustics and a trawl to sample eulachon in estuarine and tidal freshwater habitats of the Columbia River. Eulachon were present in the estuary on every sampling day. Acoustic data demonstrated that direct, fisheries-independent estimates of adult spawning biomass are possible for the Columbia River population. Direct eulachon mortality in the trawl was negligible (<0.001%). We observed sex ratios closer to 1:1 than previously reported and length-weight distributions that differed from comparable data collected in 1980-1981. The largest catches of eulachon occurred after a warming trend with reduced flow and turbidity when minimum estuary temperatures were above 5.5°C. Tributary spawning began after this warming period and continued for the next 2 weeks. Our observations support previous assertions that Eulachon hold in the estuary until warmer temperatures trigger upstream migration. Therefore, the estuary may serve as an important prespawning habitat and staging area. We believe recovery planning for Columbia River eulachon would benefit from updated, contemporary information on parameters related to adult spawners. Combined acoustic and trawl surveys could fill significant knowledge gaps for Columbia River eulachon and provide in-season information for fisheries managers, which has previously been unavailable.

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2016 Columbia River Estuary Conference:
Recent Anomalous Environmental Conditions –
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