2018 Columbia River Estuary Conference:
Promoting Resiliency under Shifting Environmental Conditions

April 10 – 12, 2018
Liberty Theatre, Astoria, Oregon

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- Jennifer Morace, U.S. Geologic Survey, Oregon Water Science Center
- Joe Needoba, Oregon Health and Science University
- Patty O'Toole, Northwest Power and Conservation Council
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Thanks to the many sponsors, we are able to put on the 2018 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:

Financial assistance is provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, through a grant to the Department of Land Conservation and Development.

An Introduction to Our Keynote Speakers

Mary Hunsicker
Research Ecologist, Estuarine and Ocean Ecology Program
NOAA, Northwest Fisheries Science Center, National Marine Fisheries Service

Mary Hunsicker joined NOAA Fisheries in 2015 as a Research Ecologist. Prior to this position, she was a postdoctoral fellow at the University of California Santa Barbara's National Center for Ecological Analysis and Synthesis. She also conducted postdoctoral research at Oregon State University's College of Earth, Ocean, and Atmospheric Sciences. Mary received her Ph.D. in Aquatic and Fisheries Sciences from the University of Washington. In addition, she holds an M.S. in Marine and Environmental Sciences from Stony Brook University and a B.S. in Biology from Lafayette College.

Mary's research interests focus on the structure and functioning of marine ecosystems and the potential impacts of climate and human activities on ecosystem components. Most recently, she has been using synthetic and analytical approaches to 1) identify nonlinearites and thresholds in relationships between climate drivers and human stressors and ecological responses, 2) test the utility of early warning indicators to reliably detect abrupt shifts in marine ecosystems, and 3) determine the influence of environmental variables on species distributions and interactions. Mary's work provides insights into the population dynamics of fishes and invertebrates and ocean ecosystem processes that benefit both management and conservation efforts.

John Shurts
General Counsel
Northwest Power and Conservation Council

John Shurts is the Northwest Power and Conservation Council's General Counsel. His undergraduate degree in history is from The Colorado College, with a law degree from Lewis and Clark Law School in Portland and a Ph.D. in American History at the University of Oregon, with an emphasis on environmental and legal history. His dissertation on the origin and development of Indian reserved water rights has been published by the University of Oklahoma Press as *Indian Reserved Water Rights: The Winters Doctrine in its Social and Legal Context, 1880s-1930s*. John is also an adjunct professor at both the University of Portland and Portland State University and has been an adjunct at both the law school and the undergraduate campus of Lewis and Clark College and in the history department of the University of Oregon, teaching courses in water resources law and policy, energy law, natural resources law, environmental and natural resources policy, and environmental and world history. He regularly briefs delegations and study tours from different parts of the world on Columbia River and U.S. water, energy, and fish and wildlife issues, including most recently from the Nile basin, the Mekong basin, Vietnam, the Ukraine, South Asia, and north Africa.

In 2004 – 2005, John worked in southern Vietnam on a U.S.A.I.D. canal restoration project. And in 2008, he served as a member of the Anadromous Fish Independent Review Panel organized by the Bureau of Reclamation and the U.S. Fish and Wildlife Service for a comprehensive review of the Central Valley Project's Anadromous Fish Restoration Program in California. John also speaks and consults separately from his Council work on Indian reserved water rights issues.

Agenda

2018 Columbia River Estuary Conference:
Promoting Resiliency under Shifting Environmental Conditions

April 10, 2018

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

Session 1: Update on Ocean Conditions and Ecological Impacts
Session Moderator: Curtis Roegner, NOAA National Marine Fisheries Service

9:30 AM **Keynote Address—Nonlinearity and Early Detection of Abrupt Change in Northeast Pacific Marine Ecosystems**
Mary Hunsicker, NOAA National Marine Fisheries Service

10:00 AM **The Blob, El Niño, La Niñas, and North Pacific Marine Ecosystems**
Laurie A. Weitkamp

10:20 AM **Effects of Warming Ocean Conditions on Feeding Ecology of Small Pelagic Fishes in the Northern California Current**
Mary Hunsicker, Richard Brodeur, Ashley Hann, Todd Miller, and Yi Gong

10:40 AM **Break**

11:00 AM **Growth and Survival of Coho Salmon Smolts in the NE California Current 2000 – 2017**
Brian Beckman, Cheryl Morgan, and Meredith Journey

11:20 AM **Ocean Conditions and Run Size Forecasts for Natural Coho Salmon in Washington Tributaries of the Lower Columbia River**
Mara Zimmerman

11:40 AM **Ocean Acidification and Hypoxia Monitoring Network**
Charlotte Regula Whitefield

12:00 PM **Question and Answer Period**

12:10 PM **Lunch** (on your own)

Session 2: Adapting to Shifting Ecosystem Conditions—Predicting Sea Level Rise and Flood Risk
Session Moderator: Lynne Krasnow, NOAA National Marine Fisheries Service

1:30 PM **Observations and Simulations to Characterize a Changing Estuary: The Good, the Bad, and the Uncertain**
António M. Baptista

1:50 PM **Sea-Level Rise in the Columbia River Estuary, Past, Present, and Future**
Stefan A Talke, David A Jay, and Lumas Helaire

2:10 PM **Modeling Flood Risk in the Portland, OR Metro Area**
Lumas Helaire, Stefan A Talke, and Heejun Chang

2:30 PM **Sea Level Rise: Implications for Water Level Management**
Mojgan Rostaminia and Gary Wolff

2:50 PM **Break**

Session 3: Adapting to Shifting Ecosystem Conditions—Integrating Shifting Conditions into Restoration and Management
Session Moderator: Amy Horstman, U.S. Fish and Wildlife Service

3:10 PM **Approaches for Integrating Transitioning Ecosystem Conditions into the Conservation Reserve System for the Lower Columbia River**
Catherine Corbett

3:30 PM **Identifying Geographic Priorities for Coastal Wetland Conservation Funding in a Changing Climate**
Chris Swenson

3:50 PM **Finding Conservation Opportunities and Constraints along Estuary Margins in an Era of Sea Level Rise**
Brian Fulfrost and David Thomson

4:10 PM **Enhancing Blue Carbon Sequestration and Resilience to Sea Level Rise with Tidal Marsh Restoration**
Katrina L. Poppe, John M. Rybczyk, Logan Parr, Analissa Merrill, and Sage Pollack

4:30 PM **Soil Carbon Accumulation and Ecosystem Drivers in Youngs Bay and Tillamook Bay, Oregon, USA**
Laura S. Brophy, Erin K. Peck, Robert A. Wheatcroft, Laura A. Brown, and Michael J. Ewald

4:50 PM **Incorporating Future Climate Predictions into Today's Ecosystem Restoration Design**
Caitlin Alcott and Matt Cox

5:10 PM **Question and Answer Period**

5:30 PM – 7:30 PM **Poster Session** (McTavish Room upstairs)

Agenda

2018 Columbia River Estuary Conference:
Promoting Resiliency under Shifting Environmental Conditions

April 11, 2018

8:00 AM **Registration**

8:20 AM **Welcome**
Catherine Corbett, Chair, Steering Committee

Session 3: Adapting to Shifting Ecosystem Conditions—Integrating Shifting Conditions into Restoration and Management (continued)
Session Moderator: Jason Karnezis, Bonneville Power Administration

8:30 AM **Developing a Framework for Incorporating Climate Change and Building Resiliency into Restoration Planning Case Study—Lower Columbia River Estuary**
Keith Duffy, Ethan Rosenthal, and Sandra Conveny

8:50 AM **Enhancing Cold Water Refuges at Small Tributaries in the Lower Columbia River**
Chris Collins, Keith Marcoe, Catherine Corbett, Mike Burke, and Matt Keefer

9:10 AM **Enhancement of Cold Water Refuges in the Lower Columbia River Gorge**
Keith Marcoe, Chris Collins, Paul Kolp, Catherine Corbett, and Mike Burke

9:30 AM **Examining the Functions and Forms of Restored Channel Outlets in Floodplains of the Lower Columbia River Estuary**
Curtis Loeb and Jeremy Lowe

9:50 AM **Tidal River Dynamics at a Junction: Portland-Vancouver Harbor**
David A Jay, Lumas Helaire, and Stefan A. Talke

10:10 AM **Break**

Session 4: Assessment of Restoration and Management
Session Moderator: Siena Lopez-Johnston, Bonneville Power Administration

10:30 AM **Quantifying Habitat Connectivity in the Lower Columbia River and Estuary**
Amy B. Borde, Shon A. Zimmerman, Gary E. Johnson, Heida L. Diefenderfer, and André M. Coleman

10:50 AM **Wetland Restoration Trajectories and Long-Term Ecosystem Monitoring: A Tidal Wetland Story**
Sarah Kidd and Matthew Schwartz

11:10 AM **Is it Working? – Quantifying Restoration Successes at the Physical Processes Level**
Matthew Schwartz and Sarah Kidd

11:30 AM **Management Trade-Offs Between Reed Canarygrass Control, Amphibian Habitat, and Salmon Habitat in Multnomah Channel Natural Area**
Regan A. McNatt, Brian Cannon, Susan A. Hinton, Luke D. Whitman, Rachael Klopfenstein, Thomas A. Friesen, and Daniel L. Bottom

11:50 PM **Question and Answer Period**

12:00 PM **Lunch** (on your own)

Session 5: New Understanding of the Lower Columbia River Ecology
Session Moderator: Mike Turaski, U.S. Army Corps of Engineers

1:20 PM **Indirect Benefits of Habitat Restoration on Juvenile Salmon: Results from the Landscape-Scale Action Effectiveness Study**
Laurie Weitkamp, Meredith Journey, Brian Beckman, Angie Munguia, Don Van Doornik, Jessica Miller, and Kym Jacobson

1:40 PM **Investigating the Diet of Juvenile Chinook Salmon in the Lower Columbia River Using Stable Isotopes**
Tawnya D. Peterson and Joseph Needoba

2:00 PM **Making Connections to Habitats: Feeding Ecology of Juvenile Salmonids During Emigration in the Lower Columbia River and Estuary**
Angie Munguia, Jessica A. Miller, Laurie A. Weitkamp, and Donald M. Van Doornik

2:20 PM **Direct Benefits of Habitat Restoration on Juvenile Salmon: Site-Scale Evaluation**
Nichole Sather, Regan McNatt, Adam Martin-Schwarze, Kailan Mackereth, Heidi Stewart, Susan Hinton, and Gary Johnson

2:40 PM **Growth of Yearling Chinook Salmon and Steelhead Smolts in the Columbia River Estuary 2016 – 2017**
Brian Beckman, Meredith Journey, Laurie Weitkamp, Don Van Doornik, and Kym Jacobson

3:00 PM **Break**

Session 5: New Understanding of the Lower Columbia River Ecology (continued)
Session Moderator: Nicole Czarnomski, Washington Department of Fish and Wildlife

3:20 PM **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, David Teel, Matthew Nesbit, Samuel Rambo, Jesse Lamb, Louis Tullos, Kinsey Frick, April Cameron, Mark Sorel, David Huff, and Rich Zabel

3:40 PM **You Are What You Eat: A Study of Age Demographic Changes in Eulachon Smelt**
Laura Lloyd

4:00 PM **The Cyanobacterial Neurotoxin, L-β-methylamino-N-alanine (BMAA), as an Emerging Public Health Concern in the Columbia River Watershed**
Stuart W. Dyer, Tawnya D. Peterson, and Joseph A. Needoba

4:20 PM **Pharmaceuticals and Personal Care Products Measured in Water and Suspended Solids in the Columbia River Estuary**
Elena Nilsen, Jennifer Morace, and Tawnya Peterson

4:40 PM **Mapping Contaminants in the Columbia River Basin—What Can We Learn**
Mary Lou Soscia, *Jennifer Morace*, Leslie Bach, and members of the Mapping Subgroup of the Columbia River Toxics Reduction Working Group

5:00 PM **Question and Answer Period**

5:10 PM **Adjourn**

Agenda

2018 Columbia River Estuary Conference:
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April 12, 2018

8:00 AM **Registration**

8:20 AM **Welcome**
Catherine Corbett, Chair, Steering Committee

Session 6: Results of Restoration—Are We Having an Effect?
Session Moderator: Patty O'Toole, Northwest Power and Conservation Council

8:30 AM **Keynote Address—Just What the Hell is Going On?: The Latest in Columbia River Fish and Wildlife and Energy Policy and Law**
John Shurts, Northwest Power and Conservation Council

9:00 AM **An Overview of the 2018 Synthesis Memorandum for the Columbia Estuary Ecosystem Restoration Program**
Gary E. Johnson and Kurt L. Fresh

9:20 AM **The State of the Sandy: Bolstering Resiliency in a Decade of Post-Dam Restoration**
Steve Wise and Katherine Cory

9:40 AM **Restoring Resilience to Tillamook Bay: Incorporating Climate Change in the Restoration Design and Construction at the Kilchis Estuary Preserve, Tillamook County, Oregon**
Dick Vander Schaaf, Curtis Loeb, and Hunter White

10:00 AM **Habitat Restoration Using Dredged Material Placement within the Lower Columbia River at Woodland Islands, WA**
Hans R. Moritz, Matt Fraver, Logan Negherbon, Mike Turaski, Ann Hodgson, Valerie Ringold, and Louis Landre

10:20 AM **Break**

Session 7: New Tools for Assessing and Evaluating Restoration Impacts
Session Moderator: Rudy Salakory, Cowlitz Indian Tribe

10:40 AM **Use of Drones and Hyperspectral Imagery to Remotely Sense Vegetation Patterns at Wetland Restoration Sites**
Curtis Roegner, Amy Borde, Andre Coleman, Robert Erdt, Joe Aga, George Pierce, and Carla Cole

11:00 AM **Juvenile Salmon Movement/Passage Through a Tidal Free-Flowing River Junction Emerge from Swim Orientations Based on their Recent Past Flow Field Experience**
R. Andrew Goodwin, Yong Lai, Noah Adams, Russell W. Perry, David L. Smith, Aaron Blake, Jon R. Burau, Paul Stumpner, Ryan Reeves, and Jacob McQuirk

11:20 AM **OFAIM and Fortune in Oregon's Floodplains: Oregon Floodplain Impact Mitigation Tool**
Rowyn Cooper-Caroselli, Marjorie Wolfe, and Polly Gibson

11:40 AM **Elevation is the Surrogate for Everything: A Short Story of Translational Ecology, Multi-Species Floodplain Restoration Design and a Biological Risk-Reduction Habitat Model**
Kelley Jorgensen and Chris Watson

12:00 PM **Question and Answer Period**

12:10 PM **Closing Remarks**
Madeline Ishikawa

12:20 PM **Adjourn**

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The park and bookstore hours are from 9-5:00 daily

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We work with the public to ensure an affordable and reliable energy system while enhancing fish and wildlife in the Columbia River Basin.

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- More than 400,000 acres of habitat secured for wildlife; 44,000 stream miles protected from new hydropower
- Improved fish survival at dams

The heart of the Council's mission is to preserve the benefits of the Columbia River for future generations. See more at nwcouncil.org.


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Session 1: Update on Ocean Conditions and Ecological Impacts

Nonlinearity and Early Detection of Abrupt Change in Northeast Pacific Marine Ecosystems

Mary Hunsicker

NOAA, Northwest Fisheries Science Center, Newport, OR.

Presenting author (email: mary.hunsicker@noaa.gov)

There is a growing trend within both scientific and management communities to improve our ability to forecast and respond to abrupt shifts in marine ecosystems. This trend is evident in the increasing amount of work dedicated to understanding the mechanisms of ecosystem shifts and identifying ecological thresholds. Here I present an overview of our efforts to characterize stressor-response relationships in marine ecosystems and to develop an ecological framework to define ecosystem-based thresholds for both human and environmental pressures. In addition, I will present results from our efforts to develop 1) state indices to reduce the time required to detect abrupt community-level changes in Northeast Pacific ecosystems and 2) early warning indices to track changes in the relative likelihood of a sudden ecological shift. The ultimate goal of this work is to develop reference points based on how the indices have performed in the past to enable scientists and managers to distinguish normal variability from changes signaling a major shift.

The Blob, El Niño, La Niñas, and North Pacific Marine Ecosystems

Laurie A. Weitkamp

National Marine Fisheries Service, Northwest Fisheries Science Center, Newport, OR.

Presenting author (email: laurie.weitkamp@noaa.gov)

Since early 2014, the Warm Blob and a strong El Niño resulted in a strong and prolonged marine heat wave across the North Pacific Ocean. This warm water was associated with dramatic alternations in the distribution and abundance of marine organisms locally in the Pacific Northwest and across the North Pacific, with impacts at trophic levels ranging from diatoms to sea birds and marine mammals. This talk will provide highlights of ecosystems changes that were observed since 2014, which consist of species range extensions, human health concerns from persistent harmful algal blooms, economic impacts (both positive and negative) from variation in commercial species abundances, and both population-level and ecosystem-wide impacts from huge increases and decreases in the abundances of numerous species. Unusual ocean conditions have also affected salmon populations, with extreme adult returns (both high and low) reported from Alaska to California. Although conditions at the equator have cooled with two La Niñas, the biological response to the marine heat wave is expected to continue into the future as species that were impacted at early life stages reach maturity. These changes provide a glimpse of the types of changes to marine ecosystems that will likely occur in the future and provide a timely "heads up" about how both research and fishery interests might prepare for the next big perturbation.

Effects of Warming Ocean Conditions on Feeding Ecology of Small Pelagic Fishes in the Northern California Current

Mary Hunsicker[1], Richard Brodeur[1], Ashley Hann[1], Todd Miller[2], and Yi Gong[3,4]

[1]NOAA, Northwest Fisheries Science Center, Newport, OR.
[2]NOAA, Alaska Fisheries Science Center, Juneau, AK
[3]Hatfield Marine Science Center, Oregon State University, Newport, OR
[4]Shanghai Ocean University, Shanghai, China

**Presenting author* (email: mary.hunsicker@noaa.gov)

Forage fish play a central role in the transfer of energy from lower to higher trophic levels. Ocean conditions may influence this energy pathway in the Northern California Current (NCC) ecosystem, and we may expect it to differ between warm and cold periods in the northeast Pacific Ocean. The recent marine heatwave in the NCC provides a unique opportunity to better understand the connection between ocean conditions and forage fish feeding habits and the potential consequences for predators that depend on them for sustenance. Here we present findings from stomach content and stable isotope analyses to examine food sources and trophic levels of multiple forage fishes (northern anchovy, sardine, mackerel, herring and smelts) off the Washington and Oregon coasts. Analyses were applied to fish and prey samples collected in May and June during years warm years (2015, 2016) and compared to neutral (2000, 2002) and cold (2011, 2012) years. Results of the analyses indicate that fish feeding habits varied significantly between cold and warm periods. For instance, euphausiids, decapods, and copepods were the main prey items of the fishes for most years, while gelatinous zooplankton were consumed in much higher quantities in warm years compared to cold years. This shift in prey availability was also seen in plankton and trawl surveys in recent years and suggests that changing ocean conditions are likely to affect the type and quality of prey available to forage fish and other ecosystem components.

Growth and Survival of Coho Salmon Smolts in the NE California Current 2000 – 2017

Brian Beckman[1], Cheryl Morgan[2], and Meredith Journey[3]

[1]National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA
[2]CIMRS, Oregon State University, Newport, OR
[3]Lynker Tech, Seattle, WA

**Presenting author* (email: brian.beckman@noaa.gov)

Coho salmon have a relatively simple marine life history, juveniles enter the ocean in the spring at 1.5 years of age and adults return to freshwater in the fall after 18 months of marine rearing at age 3. As such, it is relatively easy to identify years in which differences in ocean conditions may have led to variation in marine survival of these fish. A long-standing hypothesis suggests that variation in marine survival of coho salmon is related to marine growth of juveniles soon after ocean entry. We have tested this hypothesis by measuring growth of juvenile salmon in June, soon after ocean entry, in an ocean survey conducted off the Oregon/Washington Coast since 2000 (2000 – 2017). In this presentation we report on juvenile abundance, juvenile growth and adult coho salmon returns over this time period. In addition, we examine relationships between these salmon metrics and common ocean indices, including temperature, up-welling, sea level height, PDO and NPGO. We report on a disruption of previous relationships between PDO, growth and survival of coho salmon in the years 2014 – 2015. In particular, we found abundant food resources and high growth of juvenile salmon during and after the blob, an unexpected result during periods of warm ocean temperatures.

Ocean Conditions and Run Size Forecasts for Natural Coho Salmon in Washington Tributaries of the Lower Columbia River

Mara S. Zimmerman

Washington Department of Fish and Wildlife, Fish Ecology and Life Cycle Monitoring Unit

Presenting author (email: mara.zimmerman@dfw.wa.gov)

The Washington Department of Fish and Wildlife Science Division produces annual forecasts of wild coho salmon for 24 management units in western Washington, including the Lower Columbia River (LCR). These forecasts are based on estimated smolt production and predicted marine survival. In the LCR management unit, a limited time series is available to develop these forecasts. During this time frame, freshwater production of LCR coho salmon has varied 2-fold (331K to 724K smolts over 10 years) whereas marine survival has varied 12-fold (0.9 to 11.5% over 17 years). Variables explored as potential predictors of marine survival include the Oregon Production Index sibling regression, local conditions in the Columbia River, and regional conditions of the California Current during the year of ocean entry. The Oregon Production Index sibling regression used for hatchery coho salmon in the Columbia River has not been a good predictor of natural coho salmon marine survival. Columbia River flows have also not been a consistent predictor of marine survival. The forecast may benefit from additional Columbia River variables if suitable time series become available. Environmental indicators of marine conditions, including the NOAA ocean ecosystem indicators, have been useful predictors of marine survival and are used in the LCR natural coho salmon forecasts. The model currently selected for forecasting includes temperature (from the Newport Hydrographic Line) and the length of physical upwelling in the three months following ocean entry.

Ocean Acidification and Hypoxia Monitoring Network

**Charlotte Regula-Whitfield*, Caren Braby, Daniel Sund, and Jack Barth

Oregon Department of Fish and Wildlife

**Presenting author* (email: charlotte.m.regulawhitefield@state.or.us)

In 2007, Oregon was one of the first places in the world to observe direct impacts of Ocean Acidification and Hypoxia (OAH). Since then, throughout our coastline OAH events are continuing to intensify and there are now clear signs that they are undermining the rich ocean and estuarine ecosystems' food webs. Oregon's iconic fisheries and the coastal communities that depend on them are at risk. The emergence of OAH represents new challenges for the translation of emerging scientific understanding into ocean policies. In response to growing concerns, in 2017 the passage of Oregon Senate Bill 1039 created the Oregon Coordinating Council on OAH to provide guidance and recommendations to the State on how to respond to this issue. The OAH Council consists of State agencies, academic experts, stakeholders, and Tribal interests, who will collaboratively advise and develop recommendations for the State on the implementation of actions to support the sustainability of Oregon's ocean and estuaries as OAH intensifies. The work of Oregon's OAH Council will become part of this regional strategy, through the creation of Oregon's OAH Action Plan. Here, we will discuss Oregon's OAH Council efforts moving forward and our goals to incorporate regional scientific data and collaborations from the Columbia River Estuary into the development of regional responses to global change challenges.

Session 2: Adapting to Shifting Ecosystem Conditions—Predicting Sea Level Rise and Flood Risk

Observations and Simulations to Characterize a Changing Estuary: The Good, the Bad, and the Uncertain

António M. Baptista

Oregon Health & Science University, 3181 SW Sam Jackson Park Rd., Portland, OR

Presenting author (email: baptista@ohsu.edu)

The Columbia River estuary is naturally highly variable, and is also subject to frequent change from local actions such as hydropower management, navigation improvements and ecosystem restoration. Identifying amidst these shifting conditions the fingerprints of climate change is challenging. It requires diverse efforts, with distinctive tools, frequent cross-fertilization and stringent checks and balances. It also requires the benefit of transdisciplinary expertise, time, and resources.

SATURN (http://www.stccmop.org/saturn) integrates observations, simulations and analysis, with the type of long-term perspective that adds distinctive value in support of those engaged in estuarine and climate science as well as in policy-making, management and operation of the Columbia River. Twenty years have passed since the deployment of the first sensor of the observation network, and over a quarter century since the first simulation. In the intervening time, many researchers and institutions have contributed to a growing body of interdisciplinary data and to an increasingly robust predictive capability—much of which translated into a healthy mix of peer-reviewed publications and guidance for stakeholders.

The first part of the presentation will offer a retrospective on SATURN: What have been the drivers? What has been done. What has been learned. Successes, failures and uncertainties. What the system has (and has not) added to better characterizing and steering an estuary in permanent evolution. As appropriate, climate change—including revised estimates of sea level rise impacts—will provide loose context.

Leveraging this historical perspective, the presentation will also introduce and catalyze discussion on the options ahead for the future of SATURN. As a regional infrastructure, its continuity and priorities are dependent on the collective will, and on how our data and models fit into the fabric of the many ongoing regional efforts addressing salmon recovery, hydropower management, ecosystem restoration, navigation improvements, resilience under climate change, and so much more.

Sea-Level Rise in the Columbia River Estuary, Past, Present, and Future

*_Stefan A Talke_, David A Jay, and Lumas Helaire

Civil and Environmental Engineering, Portland State University, Portland OR 97201

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

Using archival tide data, we analyze sea-level trends in the Columbia River Estuary since 1853. Extensive archival work has allowed us to estimate the historical datum in Astoria (1853-1876) and correct for an up to 0.06m bias in early Tongue Point tide measurements from between 1925-1950. Additional, but temporally sparse, records have been found from the Fort Stevens region (1905-present), Altoona (1941-present), Fort Canby, and Young's Bay, allowing for a spatial representation of changes. Results show that the biggest signal, historically, has been vertical land motion (VLM): the rate of change between Fort Stevens and Astoria, though separated by less than 10 miles, is approximately 0.2 m/century. Further landward, upstream of about Longview, VLM is negative. Our results suggest that both our present GPS system and tide-gauge monitoring system inadequately assess the strong spatial variations in relative sea-level that occur due to the complex VLM in the estuarine region.

Nonetheless, a coherent signal with other west-coast gauges indicates that sea-level rise along the Eastern Pacific affects the estuary as well, and suggests that future sea-level rise of up to 1.4m (NRC, 2012) will also affect the estuary, but in a spatially variable way. Changes to river flow have caused a minor, but statistically significant change in both the seasonal and annual cycle of water level in the estuary; upstream of the Astoria, the fluvial imprint becomes increasingly important and changes to river flow dominate changes to sea-level. In the future, numerical modeling results suggests that changes to sea-level will cause water levels to increase all the way to the Portland Metro area, but that the effect of sea-level rise will slowly damp out the further one gets from the coast. Finally, a major subduction zone earthquake at some (unknown) time in the future would drop coastal lands dramatically, with smaller changes in Portland and other inland areas.

Modeling Flood Risk in the Portland, OR Metro Area

Lumas Helaire[1], Stefan A Talke[1], and Heejun Chang[2]

[1]Civil and Environmental Engineering, Portland State University, Portland OR
[2]Department of Geography, Portland State University, Portland OR

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

The Portland, OR metro area periodically experiences winter flood events (Dec – Feb) due to storm events of relatively short duration (<7 days). When these rain events are combined with excessive snowmelt such as the February 1996 event, there is the potential for extensive flooding and property damage. An analysis of water levels in Portland shows a complex relationship, with water levels dependent on discharge from the Columbia River and Willamette River, and the tidal range at Astoria, OR. We have developed a Delft3D numerical model of the Lower Columbia River (LCR) to help us better understand flood impacts. The model contains inputs from Columbia River and five of the major tributaries (Sandy, Washougal, Willamette, Lewis and Cowlitz) and estimates of ungauged discharge. LCR discharge records indicate that in winter floods scenarios, the peak water level at Portland is highly dependent on upstream discharge from the Columbia River at Bonneville, and discharge from smaller tributaries. An analysis of discharge over the past 100 years shows that during these flood events, tributaries such as the Sandy River, which normally are too small to be considered as a significant contribution to water levels in the LCR, can spike to over 2 kCMS during winter floods. An analysis of the February 1996 event shows that the extreme water levels resulted from a large amount of Columbia River discharge coinciding with record Willamette River event. Future scenarios involve the incorporation of 0.5m - 1.4m of sea level rise along with a 10-20% increase in discharge from future climate projections. We will also examine the effect of coastal tidal range on upstream water levels. The model water levels and inundation projections will help planners understand and mitigate the effects of projected sea level rise and climate related increases in discharge.

Sea Level Rise: Implications for Water Level Management

**Mojgan Rostaminia* and Gary Wolff

Otak, Inc., Portland, OR

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The Columbia River estuary, the transitional zone between continental land and the ocean, is home to a variety of aquatic species. Climate change in general and sea level rise in particular will impact the estuarine environment in ways that should be accounted for in the design of resilient restoration and mitigation plans. As such, managers and decision-makers stand to benefit from quantifying the estuarine response to sea level change. The Center for Coastal margin Observation & Prediction (CMOP) at OHSU has recently updated its numerical simulations of sea level rise impacts on the estuary. The simulations cover a range of seven possible future scenarios developed by NOAA, 2017. We used those model outputs to evaluate the changes in water depth for the entire estuary. We then downscaled the outputs to evaluate the sea level rise impacts on water level management at Smith and Bybee Lakes, where the water levels are managed for a variety of purposes, including the simulation of spring freshet floodplain functions, control of invasive species, and habitat for migratory waterfowl. Our analysis suggests that sea level rise could lead to substantial changes in water depth, which would alter the estuarine dynamics and ecosystem. Factors of uncertainty in the analysis are discussed, as are their implications on water level management strategies.

Session 3: Adapting to Shifting Ecosystem Conditions—Integrating Shifting Conditions into Restoration and Management

Approaches for Integrating Transitioning Ecosystem Conditions into the Conservation Reserve System for the Lower Columbia River

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Since the late 1800's, the lower Columbia River ecosystem has lost 114,050 acres, approximately 50%, of its native historic habitat to largely urban or industrial development and agriculture. Over 23,195 acres have been restored or protected since 2000, a significant effort from regional partners to reverse the trajectory of degradation in the lower river. Areas within the lower Columbia River that have been acquired and restored for conservation purposes function as a *de facto* reserve network. Several years ago, regional partners wanted to ensure efforts to assemble our reserve network would protect common species from becoming imperiled at a minimum, and optimally provide an ample land base for the recovery of imperiled species (e.g., red-legged frogs, Columbia White-tailed deer, salmon, and steelhead). As a result, we established native habitat coverage targets, using generalized conservation biology approaches, that describe the quantity, the types, and priority locations for recovery of native habitat to meet the overall goal of *historic* habitat diversity. The targets are: 1) no net loss of native habitats as of the 2009 baseline, 2) recovery of 30% of historic extent for priority habitats by 2040, and 3) recovery of 40% (i.e., 22,480 acres) of historic extent for priority habitats by 2050. We employed the first of three overarching conservation biology approaches for identifying areas and quantities of habitat for a reserve network: 1) representation of all habitats, vegetation types, or species within a network of reserves, 2) protection of special elements, such as rare species hotspots or critical watersheds, and 3) meeting the needs of focal species, especially those that are area-dependent and sensitive to human activities. We hope to collaborate with others and use existing data to employ the other two approaches in the future.

Nonetheless, our habitat coverage targets focus on recovering the *historic* habitat template when ample recent conservation biology research has justifiably concluded that the past no longer serves as a guide for maintaining native biodiversity in the future with transitioning climate and ecosystem conditions. A commonly used framework for conceptualizing approaches used to adapt to changing climate conditions is the continuum of resistance, resilience, and transformation: resistance referring to actions promoting persistence and maintenance of current or historic conditions; resilience referring to actions improving the capacity to return to a desired condition after a disturbance; and transformation referring to actions that enable or facilitate the transition of ecosystems to new functional states. Additionally, protecting biodiversity and native species will require a shift from place-based strategies that maintain integrity of local reserves within fixed boundaries to dynamic approaches that foster the ability of species to move across landscapes so they can persist. This presentation will provide an overview of a number of proposed conservation biology approaches, such as protecting land facets and bioclimatic modeling, for integrating shifting climate and ecosystem conditions into conservation reserve network management. Much of the recent research has been focused on terrestrial ecosystems, and as a result, will require us to collaboratively brainstorm how best to adapt the techniques (and develop new ones) for application in our lower Columbia reserve network.

Identifying Geographic Priorities for Coastal Wetland Conservation Funding in a Changing Climate

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Grant managers in state and federal agencies, non-profits, and other funding entities are interested in targeting their wetland protection and restoration grants to areas that will continue to provide conservation benefits under a variety of sea level rise scenarios. An early model constructed to provide this information for the Columbia River Estuary will be presented. Pros and cons of this approach and suggestions for fine-tuning future efforts will be discussed.

Finding Conservation Opportunities and Constraints Along Estuary Margins in an Era of Sea Level Rise

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Finding the best locations for optimizing conservation of habitats requires mapping the distribution and extent of habitats, ranking their likely value to conservation, and modeling how projected climate variability could change them. One habitat type that managers in San Francisco Bay value for bird and related fauna populations is found along the upper estuarine margin, which is subject to infrequent flooding. These so-called upland transitional habitats can provide critical functions both to their own flora and the fauna of adjacent habitats. Their conservation and restoration can provide landscape connectivity, which appears to contribute to overall ecological productivity, as well as potential accommodation space for marsh migration during rapid sea level rise. I present our methods from San Francisco Bay as an example of a mapping approach to prioritizing floodplain projects in the lower Columbia estuary. Prior to our work in California, the distribution and status of upper marsh habitats were poorly understood, nor were potential conservation opportunities easily identified. Initially focused on the needs of obligate fauna, we set out to better describe these habitats, develop a way to combine high resolution Lidar with tidal gauges to predict the location within their elevation range (relative to the tides), and then use a set of GIS based metrics to rank their relative utility to estuarine conservation. We also projected the future distributions of these habitats under two sea level rise (SLR) scenarios (61cm and 167cm) to better inform long term planning and to improve the resilience of restoration efforts. In SF Bay, land managers are using our "bay margin" Decision Support System (DSS) to predict the baseline condition of these habitats, find restoration opportunities and assess constraints, and to inform long term restoration planning and site design under different SLR scenarios. The maps can also help evaluate habitat connectivity or prepare assisted migration scenarios for constraints imposed by the landscape, both now and into the future. Modeling the distributions of these habitats under different SLR scenarios in the lower Columbia estuary would likely enhance the potential of restoration efforts and infrastructure plans not only to be more resilient over time but also identify opportunities to reconnect these tidally influenced habitats to floodplains.

Enhancing Blue Carbon Sequestration and Resilience to Sea Level Rise with Tidal Marsh Restoration

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Recent attention has focused on exploring the carbon storage and sequestration potential of tidal wetlands to mitigate greenhouse gas emissions. In 2015, a methodology was approved allowing coastal wetland restoration projects to earn carbon credits. Efforts are now underway to improve our estimates of the carbon sequestration potential of various coastal wetland habitats, as well as to develop tools to make these data more accessible. Although blue carbon financing is still in its early stages, it has the potential to provide restoration funding opportunities while also giving funders a chance to be part of an exciting climate change mitigation solution. This talk will provide an overview of "blue carbon" – what it is and how it works – followed by an example of a blue carbon assessment in Puget Sound, Washington, as the implications may be relevant to marshes in the Columbia River estuary. The Stillaguamish River discharges into the Port Susan Bay Preserve which contains a 60-hectare tidal marsh restoration site that was reintroduced to the tidal regime in 2012 from its previous use as diked and drained farmland. We hypothesized that the restoration project would not only maximize carbon storage in a former tidal wetland but also, through the accumulation of organic and mineral matter, enhance this system's resilience to rising sea levels, and this was supported by our results. We report here on carbon stocks, accretion and elevation change rates, and carbon sequestration rates from 13 sites across the estuary, within and outside of the restoration area. Carbon stocks were partitioned into three components as recommended by the IPCC: aboveground biomass, belowground biomass, and sediment carbon. Mean sediment carbon stocks in the upper 30 cm of sediment within the restoration area (5.60 kg C/m^2) were somewhat lower than those measured in the adjacent natural marsh (7.60 kg C/m^2). However, mean elevation change, as measured by SETs, were substantially higher in the restoration area (3.10 cm/yr) than in the natural marsh sites (0.93 cm/yr). As a result, carbon accumulation rates were also higher in the restoration area (576 g $C/m^2/yr$) compared to the natural marsh sites (226 g $C/m^2/yr$).

Soil Carbon Accumulation and Ecosystem Drivers in Youngs Bay and Tillamook Bay, Oregon, USA

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During 2015-2016, we measured soil carbon stocks, soil carbon accumulation, and sediment accretion at diked restoration sites and least-disturbed emergent and scrub-shrub tidal wetland reference sites in Youngs Bay, Columbia River estuary (Wallooskee-Youngs site and reference sites) and the Tillamook Bay estuary (Southern Flow Corridor site and reference sites) of Oregon, USA. To help interpret the results and provide a baseline for restoration effectiveness monitoring, we also measured ecosystem drivers at carbon core locations; monitored plant community composition; and quantified channel density (Youngs Bay reference sites only) using LIDAR analysis. Ecosystem driver measurements included water level, salinity and temperature of channel water; groundwater level; and ground water salinity (using conductivity dataloggers at Youngs Bay, and soil porewater grab samples at Tillamook Bay). Soil carbon accumulation rates were calculated using soil carbon density data along with sediment accumulation rates, determined by analyzing radioisotope levels (210Pb and 137Cs) in the cores. Mean sediment accretion rates at least-disturbed reference sites (2.6 mm/yr at Youngs Bay, 2.2 mm/yr at Tillamook Bay) were similar to or greater than current estimates of the rate of sea level rise. Low marsh sites showed much higher sediment accretion rates (10 to >18 mm/yr), indicating that these tidal wetlands have some capacity to equilibrate with accelerated future sea level rise. Carbon accumulation rates varied with elevation and ranged from 44 to >420 g Corg/m2/yr, similar to or higher than recently published global averages. Soil carbon losses due to diking were estimated at 490 tons/ha and 200 tons/ha for the Youngs Bay and Tillamook Bay restoration sites respectively; these were volumetric estimates using diked site subsidence and reference site soil carbon content. It is expected that after restoration, these sites will accumulate an equal or greater quantity of carbon, helping to mitigate climate change. This study was part of a larger, ongoing OSU investigation of soil carbon accumulation across several estuaries on the Oregon coast. The results of these studies help fill the large "blue carbon" data gap in Pacific Northwest tidal wetlands; provide insight into the impact of human modifications to our estuarine landscapes; and shed light on the potential climate change resilience of Pacific Northwest estuarine ecosystems.

Incorporating Future Climate Predictions into Today's Ecosystem Restoration Design

Caitlin Alcott and Matt Cox

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Climate scenarios exist for the Columbia River Basin and Pacific Ocean that provide a wide range of predicted impacts to the Columbia River Estuary. However, a majority of restoration project design does not incorporate these data in tangible ways. While current industry funding and policy efforts emphasize "resiliency" as a desired ecosystem function, many industry standards of practice rely on historical data sets and "resiliency" is not translated into quantitative project design criteria. Some steps are being taken in selected projects and regions to incorporate greater variability in hydrology, temperatures, storm events, salinity and species assemblages. Moving forward, additional work could be integrated to more explicitly incorporate anticipated climate changes and associated variability into projects. Identifying practical and defensible methods for considering future climate within restoration work can be a challenge, and this talk will describe our effort to do so. We will describe and discuss existing data, examples from other practitioners and potential applications to site level restoration modeling and design in the Columbia River estuary.

Developing a Framework for Incorporating Climate Change and Building Resiliency into Restoration Planning Case Study—Lower Columbia River Estuary

Keith Duffy[1], Ethan Rosenthal[2], and Sandra Conveny[3]

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This presentation describes a planning case study for how restoration practitioners working in the Lower Columbia River Estuary (LCRE) could incorporate future projected climate change into project planning and implementation. The US Army Corps of Engineers' (Corps) This study was begun in 2014 and is an extension of the Corps interest in building resiliency in light of changing climate. This study was intended to demonstrate a practical, project level, process for addressing climate change within the context of the Corps' planning and decision-making framework. This is a case study of a specific general ecosystem restoration project named Steamboat Slough, and considers how climate change can be more robustly incorporated into a typical LCRE restoration project. The pilot study used detailed climate change information and conceptual models of the estuary to determine potential alternative design features that might be implemented as part of the feasibility study phase for the Steamboat Slough project. The pilot study team then compared and contrasted the differences between the pilot project alternatives and the actual implemented alternatives.

Enhancing Cold Water Refuges at Small Tributaries in the Lower Columbia River

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During the past century, a combination of factors has degraded Columbia River water quality, including its thermal regime. Adult and juvenile salmonids migrate through the mainstem Columbia River (including the Columbia River estuary) during periods when temperatures average 18-22˚C and reach as high as 24˚C. The effects of these temperatures include physiological stress and higher susceptibility to predation. Despite data gaps, available evidence suggests that thermal refuges provide important benefits to returning adult salmonids and likely to outmigrating juvenile salmonids. This is particularly true for adult summer steelhead and both adult and subyearling Fall-run 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 refuge also presents a new habitat enhancement strategy for salmon recovery projects in the Columbia River estuary. We present a summary of physical characteristics that are anticipated to provide thermal refuge, examples of existing habitat enhancement techniques that help protect and restore thermal refuges, and the results of a feasibility study that developed and evaluated two new approaches to expanding the size of cold water plumes originating from small tributaries whose discharge currently is subsumed and diluted almost immediately upon entering the mainstem Columbia River.

Enhancement of Cold Water Refugia in the Lower Columbia River Gorge

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As a follow-up to our presentation on the importance of cold water refuges to migrating salmonids in the Columbia River (see Collins abstract), we present results of a feasibility study aimed at evaluating techniques for enhancing existing cold water plume formation at lower Columbia River Gorge tributary confluences. At up river confluence zones, such protected pockets of cold water have been demonstrated to be important to adult salmon and steelhead returning to their natal streams in summer, when peak mainstem temperatures now regularly exceed 21°C. Tributaries below Bonneville Dam, where we will be focusing, have been shown by us under previous US EPA grants to have temperatures lower than the mainstem by >2°C. However, due to their smaller relative flows and topographical characteristics, their outputs are typically subsumed and diluted upon entering the mainstem Columbia, thereby limiting cold water plume formation and potential detection by passing salmonids. This study utilizes high resolution, 3D hydrodynamic and water quality modeling to assess potential techniques that could be employed to increase the extent and retention of cold tributary water at 3 selected confluence zones, thereby making them more accessible to migrating adult and juvenile salmonids. Potential techniques include placement of diversion structures such as large wood to deflect mainstem river flows and encourage eddy formation, as well as modification of existing topography to create larger, isolated pockets of cold water.

Examining the Functions and Forms of Restored Channel Outlets in Floodplains of the Lower Columbia River Estuary

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Significant efforts have been made to guide restoration approaches for reconnecting and restoring floodplains within the Lower Columbia River Estuary. An important focus has been channel outlets or connections because they provide direct fish access, convey water/ sediment/ nutrients/ biota, and enable formation of new habitats upstream and downstream. Channel connection numbers/densities, cross sectional areas, depths, and wetted perimeters are among common channel metrics that are correlated to wetland area and tidal prism with varying degrees of success. Predicting appropriate channel densities has been particularly difficult, especially in the mid- and upper reaches of the estuary. Use of reference conditions, considered to be at least as effective as application of regression relationships, also has challenges because available geospatial data (aerial photographs, LiDAR topography, etc.) and associated desktop analyses are often not of a sufficient resolution; channels that provide important connectivity functions are often smaller than the data resolution scales (one meter or larger) and are consequently omitted. Other challenges include channels that are at or above the tidal range, providing temporarily varying connectivity and access. This presentation intends to shed light and build on restoration design challenge reports and other science-based studies. It draws primarily from observations and experience from recent restoration design and implementation experience. Applications span the estuary from Baker Bay to the Columbia River Gorge entrance, and discussion includes channel connection types that vary in size and relative tidal range position (subtidal, intertidal, supratidal). One focus is on the functions and benefits of "misfit" channels – those that are small or high in elevation, rather than primary or secondary connections. Hydraulic design calculations are used to compare allometry and other applied geomorphic methods for determining appropriate channel connection densities. Information provided will support project evaluations (explaining certainty of success/capacity/accessibility) and navigating fish passage and other regulatory requirements. The presentation is also directed towards restoration designers, who must evaluate potential project impacts such as erosion of nearby infrastructure, consider overly complicated designs, and assess the feasibility of constructing a high number of small channels.

Tidal River Dynamics at a Junction: Portland-Vancouver Harbor

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We use a combination of recovered archival data, wavelet tidal analysis, statistical models, and numerical modeling to show that flood heights, suspended sediment transport and probably bedstress in Portland-Vancouver Harbor are influenced by junction dynamics. We focus on the junction of the Willamette and Columbia Rivers (CR and WR), 163 km from the ocean. Here, the mixed, mostly semidiurnal tides (maximum amplitude ~0.5 m) are strongly modulated by seasonal variations in river stage of up to 6 m. Using water level and flow data from the 1870s to the present and two Delft3D vertically integrated model grids (ca. 1900 and contemporary), we investigate long-term changes in the system and two contemporary issues: a) the backwater dynamics of the junction that play a prominent role in flooding, and b) the effect of these backwater dynamics on sediment transport. Water level data have been recorded at or near the CR-WR junction since the early 1900s, with records being available for 1901-1915 (gaps), 1940-1942, and since 1991. Early in the 20th century, junction water levels at Kelley Pt showed a hysteresis relative to changing river flow in either river, such that the water level was higher on the falling arm of a freshet than on the rising arm, likely due to backwatering and flooding of wetlands. Interestingly, this hysteresis does not seem to have decreased, even though wetland flooding has been reduced. Also, US Geological Survey (USGS) suspended sediment transport data (1963 to date) show that the WR in Portland Harbor has a strong sediment transport hysteresis, with the highest transport on the rising arm of major floods. This is in part related to the sediment supply to the harbor, but there is also a local component—the shallower flow for any given flow level on the rising arm of the freshet likely erodes more sediment than the deeper flow on the falling arm.

Session 4: Assessment of Restoration and Management

Quantifying Habitat Connectivity in the Lower Columbia River and Estuary

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Habitat connectivity is a term used in many different ecological contexts. In the Lower Columbia River the term represents the connection of tidally influenced floodplain wetlands with the mainstem of the river as it pertains to the movement of water, flux of particulate organic material, export of prey, and access for juvenile salmonids to rearing and refuge habitat. In order to quantify connectivity overall and the effect of restoration and the reconnection of the floodplain to the river, we developed an index of habitat connectivity and used estuary-wide spatial datasets to calculate the index variables. The variables included change in connected wetland area, tidal channel edge length, the number of open and altered channel outlets, distance to the mainstem, potentially restorable (recoverable) area, contiguous habitat area surrounding connected wetlands, and unconnected natural upland and non-tidal wetland area. We evaluated the variables by river zone and during three time periods relevant to the Columbia Estuary Ecosystem Restoration Program (CEERP): 2004 (prior to most program restoration), 2010, and 2016. Our findings indicated that connectivity of the floodplain increased a measurable amount due to restoration and the amount of change varied by location in the river. The highest overall connectivity index value was in the Upper Tidal River zone (the Gorge) and the lowest was in the Middle Tidal River zone (the area surrounding Portland and Vancouver). However, the increase in connectivity attributable restoration was greatest in the Middle Tidal River. The Lower Tidal River (the area near Longview) had the second lowest overall connectivity index value and also the second lowest change in the index due to restoration. Overall, the approach quantified connectivity on an estuary-wide scale and provided a means of measuring the effect of restoration over three time periods. These data can be used by resource managers to help determine the effectiveness of the program and to determine target areas for future restoration actions.

Wetland Restoration Trajectories and Long-Term Ecosystem Monitoring: A Tidal Wetland Story

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Over the past century, humans have extensively diked and drained tidal wetlands in delta regions throughout the world. In an attempt to recover these lost habitats, large scale tidal reconnection restoration efforts are now common. It is, however, still unclear how long it takes after restoration occurs for reference wetland conditions to become established. Additionally, understanding the ecological trajectories of restored tidal wetland habitats is key to establishing quantifiable restoration objectives and timelines. The goal of this research is to use reference and restoration site data to evaluate the presence/absence of measurable gains in native wetland habitat conditions over time. Long-term tidal wetland data collected through the Lower Columbia River Ecosystem Monitoring Program and the Action Effectiveness Monitoring Program provide an opportunity to compare a range of reference wetland conditions to restoration site conditions throughout the lower Columbia. These data are critical for identifying if and when restoration goals have been met and for identifying what environmental conditions need to be present for successful restoration to occur.

Is it Working? –Quantifying Restoration Successes at the Physical Processes Level

**Matthew Schwartz* and Sarah Kidd

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Restoration actions are monitored at the site scale to determine if natural physical processes are beginning to reestablish desired habitat conditions that directly and indirectly support salmonids. It is common to collect water surface and water temperature data post-restoration, but how does this data relate to restoration success? We examined commonly collected metrics to understand the impact of restoration actions and developed an indicator that can be useful to putting physical process data into context for juvenile salmonids. We compared data collected at restoration sites to reference site data to examine if restoration projects approach similar conditions observed at reference locations.

Management Trade-Offs Between Reed Canarygrass Control, Amphibian Habitat, and Salmon Habitat in Multnomah Channel Natural Area

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Restoration projects in recent years have expanded to include floodplain wetlands and other off-channel habitats in the tidal freshwater reaches of the upper Columbia River estuary. An objective of many salmon restoration projects in the tidal-fluvial estuary is to control or eliminate invasive reed canarygrass. Control measures generally involve physical manipulations such as "scraping down" a site to remove reed canarygrass and lower site elevations, or installing water control structures to artificially retain water on the floodplain. Water control structures are also used to provide habitat for waterfowl and amphibians. However, the effectiveness of various measures to control reed canarygrass is often speculative, and in some cases, may be counter-productive for salmon recovery. For example, water control structures can impede the ability of migrating juveniles to freely access or exit floodplain habitats.

The Multnomah Channel Natural Area or Multnomah Channel Marsh (MCM) is a floodplain marsh managed by the regional governing body, Metro. The marsh is manipulated for amphibian populations and reed canarygrass control through two water control structures. In 2014 breaches were constructed in the barrier berm between the MCM and Multnomah Channel to improve juvenile salmon access to the floodplain during periods of high flow. From 2014-2016 we monitored fish communities within and adjacent to the MCM, examined the ability of juvenile salmon to pass the water control structures, and conducted captive-rearing growth studies in native vegetation and reed canarygrass.

The MCM is a productive habitat where we documented abundant prey resources that led to realized benefits in terms of salmon growth. However, the water control structures provided habitat for non-native predatory fish, fostered poor water quality, and impeded juvenile salmon migration. Future management of the MCM floodplain habitat will entail trade-offs between managing the area for amphibians and reed canarygrass control versus salmon habitat. Improving fish passage at the water control structures and active management of the structures coupled with real time water quality monitoring could benefit both amphibians and salmon.

Session 5: New Understanding of the Lower Columbia River Ecology

Indirect Benefits of Habitat Restoration on Juvenile Salmon: Results from the Landscape-Scale Action Effectiveness Study

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The Columbia River estuary is the site of one of the largest habitat restoration projects in the United States. This effort includes restoration of tidal inundation and other actions across thousands of acres of former wetland. This effort is undertaken, in large part, to ensure the continued existence of threatened and endangered populations of Pacific salmon. However, it is not clear whether habitat restoration in the Columbia River estuary is achieving expected biological and environmental benefits, especially to interior stocks of Chinook salmon and steelhead. With funding from the U.S. Army Corps of Engineers, in 2016 we began sampling juvenile salmon at multiple locations in the mainstem Columbia River and estuary to understand whether fast-moving salmon benefit indirectly (via exported prey) from tidal marsh habitat restoration. This talk will report the results of two years of field collections at the landscape scale, which complements a parallel study at the site (i.e., tidal marsh) scale and flux between the two. Despite very different river conditions in 2016 (lowish flows and warm water) and 2017 (extremely high flows, cold water), many patterns we observed for juvenile salmon in 2016 were replicated in 2017, such as stock composition and abundances. By contrast, spatial variation in salmon abundance across the estuary observed in 2016 differed in 2017. Using a suite of fish metrics, including fish size (length, weight, condition), insulin-like growth factor 1 (IGF-1), food habits (fullness and contents), and trophically-transmitted parasites, our results clearly show that interior stocks of juvenile salmon are feeding and growing as they move downstream and do indeed benefit from habitat restoration. While the study is designed to examine juvenile salmon ecology within the Columbia River estuary, it also increases our understanding of estuary-ocean coupling, as salmon leave estuarine environments for ocean waters.

Investigating the Diet of Juvenile Chinook Salmon in the Lower Columbia River Using Stable Isotopes

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The lower Columbia River historically supported large salmon runs, which have declined dramatically in recent decades. Changes in marsh habitats are thought to have led to a shift in the origin and type of organic material fueling the salmon food web. To better characterize the potential ecological effects of this shift, we determined the contribution of different sources of primary production to marsh invertebrates and to salmon in shallow off-channel habitats of the lower Columbia River estuary using a Bayesian stable isotope mixing model. Results showed that living and dead vascular plants are similar in their natural abundance stable isotope signatures, and that invertebrate prey such as chironomid larvae and amphipods have carbon isotope signatures closer to that of periphyton and phytoplankton (with the latter inferred from particulate organic matter measurements). Analysis of juvenile salmon muscle showed that amphipods and chironomids made up the largest portion of the salmon diet, in good agreement with stomach content analysis. Although the data show that preferred prey of juvenile salmonids assimilate organic matter from periphyton and phytoplankton, the degree to which a shift in the type of organic matter source fueling growth of these prey has influenced juvenile salmon populations, is unclear. This uncertainty limits our understanding of how resilient salmonid stocks might be to changing environmental conditions and their effects on critical food resources.

Making Connections to Habitats: Feeding Ecology of Juvenile Salmonids During Emigration in the Lower Columbia River and Estuary

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In the lower Columbia River and Estuary (LCRE), salmon recovery efforts have focused on wetland restoration. Although wetland residence by sub-yearlings has been well documented, it is less clear how important these habitats are for rapidly migrating species such as yearling Chinook salmon. Our ultimate goal was to determine if foraging habits changed as salmon moved through the LCRE, which extends from the lowermost mainstem dam (Bonneville) to the mouth of the estuary. As part of a collaborative effort to evaluate ecological benefits of restoration actions for threatened Chinook salmon in the Columbia River basin, we examined stomach fullness (relative indicator of feeding success), diet composition, and primary producers supporting salmon, along with stable isotope signatures ($\delta^{13}C$ & $\delta^{15}N$) of tissues (fin and muscle) with relatively fast turnover rates (7 –10 d). In 2016 and 2017, juvenile salmon were collected from three riverine sites using a tow net and at the mouth of the estuary using a purse seine. This presentation will focus on summarizing and comparing feeding habits of the Snake River Spring stock across both years. Initial results indicate, on average, salmon collected in 2017 had greater stomach fullness (2016 = 0.86 ± 0.43 SD; 2017 = 1.15 ± 0.53 SD) and higher richness of prey taxa (2016 = 4.25 ± 2.48 SD; 2017 = 6.25 ± 3.57 SD) in their diets compared to those collected in 2016, with the greatest stomach fullness and prey richness occurring at the most uppermost and lower middle estuary sites. Salmon consumed a greater biomass of insects in 2017 compared to 2016, with dipterans occurring in 60-100% of the diet samples across all sites. Further analysis of carbon sources of salmon tissues and stomach contents will provide additional insight on potential benefits and food web linkages to wetland habitats.

Direct Benefits of Habitat Restoration on Juvenile Salmon: Site-Scale Evaluation

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Research on the effectiveness of habitat restoration is a critical component of the adaptive management process for the Columbia Estuary Ecosystem Restoration Program. Implemented in 2015, the Action Effectiveness Monitoring and Research project, funded by the USACE, was designed as a collaborative research project to address direct and indirect ecological benefits of habitat restoration for juvenile salmon in the lower Columbia River and estuary (LCRE). Direct, site-scale benefits were studied at four paired restoration and reference locations within the upper estuary and lower tidal river reaches in the LCRE during April-July 2016 and 2017. Juvenile salmon from a diversity of stock groups, including interior basin stock groups, were present in both restored and reference wetlands. Stock specific use of wetland habitats by juvenile salmon and steelhead was verified with direct capture techniques as well as PIT detection arrays. Salmon prey resources were variable across all sites and through the spring/summer months. Diets of juvenile salmon, a measure of functional benefit derived from habitats, revealed spatial patterns relevant to location in the river as well as interannual differences. In addition to direct measures of prey resources and salmon diets, trophic relationships of juvenile salmon were evaluated in restored and reference locations through stable isotope analysis of prey resources found in wetlands and in the mainstem Columbia River. Collectively, these data provide new insight into the direct effects and functional response caused by restoration of tidal wetland habitats in the LCRE.

Growth of Yearling Chinook Salmon and Steelhead Smolts in the Columbia River Estuary 2016 – 2017

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Yearling Chinook salmon and steelhead smolts were collected from Rooster Rock, below Bonneville Dam, to the mouth of the Columbia River Estuary in April and May 2016 and 2017. Blood samples were collected from these fish to measure the hormone insulin-like growth factor 1 (IGF1), an indicator of recent growth. The primary goal of this work was to test to see if smolts displayed any evidence of growth due to recent feeding in the lower river and/or estuary. In steelhead we saw several patterns of growth by stock: low IGF1 levels throughout all sampling sites, moderate IGF1 levels at some sites and relatively high IGF1 levels at all sites. These data suggests that both individual and stock level variation in growth of steelhead smolts occurs in the lower river and estuary. Yearling Snake River spring Chinook salmon were the most abundant Chinook salmon collected. IGF1 levels of these fish were also variable, between individuals, sites and months. Again, these data suggest that variation in growth of yearling smolts occurs in the lower river and estuary. Together these data suggest that variation in migration pattern and feeding exists among yearling smolts such that variable growth rates occur in the lower river and estuary.

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, David Teel, Matthew Nesbit, Samuel Rambo, Jesse Lamb, Louis Tullos, Kinsey Frick, April Cameron, Mark Sorel, David Huff, and Rich Zabel

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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 2500 adult salmon within the CR estuary and measured their survival and transit time through the first 145 miles of freshwater. The results of our study indicate that pinniped predation on spring Chinook salmon is significant. They also indicate that fish arriving early in the run up to the peak (e.g. March-early April) experience higher mortality than those arriving to the river later (e.g. late April-May). Additionally, results from radio-telemetry studies conducted during 2016 and 2017 indicate that 35-50% of the mortality our study fish experienced occurred within the immediate vicinity of Bonneville Dam where less than 10% of the tagged sea lions were observed.

You Are What You Eat: A Study of Age Demographic Changes in Eulachon Smelt

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The eulachon smelt (Thaleichthys pacificus) is an anadromous forage fish with a long history of cyclical returns and occasional disappearances thought to be attributable to undesirable temperatures, chemical discharge, and other negative river conditions. In 1993, an overall decline in the commercial industry began to occur. The Columbia River eulachon harvest dropped from 500 metric tons to 233 metric tons, and by 2005 the total catch was less than 5 metric tons. [JCRMS, 2007] New regulations were put in place, but in April of 2010 the Southern Distinct Population Segment (DPS) of the eulachon was officially listed as threatened. In 2012, the focus of eulachon research turned to adult biological data collection. Lengths and weights were recorded on 1,890 returning spawners. Two hundred fish were examined for fecundity calculations and egg sizes, and 915 otolith pairs were extracted for ageing. The most dramatic information to emerge from this data collection was the dynamic nature of the age demographics. When linked to changes in ichthyoplankton and copepods, at both community and biomass levels, a pattern began to emerge; one that may lead to the discovery of what makes this fish so cyclical in its return history, and contribute to the answer of why the population is in decline.

The Cyanobacterial Neurotoxin, L-β-methylamino-N-alanine (BMAA), as an Emerging Public Health Concern in the Columbia River Watershed

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Cyanobacteria-dominated harmful algal blooms (HABs) are increasing in occurrence and are a threat to human and ecosystem health in freshwater lakes and rivers worldwide. In addition to the fiscal and environmental costs associated with bloom mitigation and management, there is mounting evidence that demonstrates that environmental exposure to the cyanotoxin BMAA poses a significant threat to public health. However, as critics of the BMAA/Guam-Parkinsonism Dementia (PD) hypothesis have fairly stated, before public health actions can or should be taken there is a need for better understanding of the endogenous role BMAA plays within the producing organisms, as well as enumeration of the species and environmental conditions that drive its production. Detection of BMAA in aquatic environments and the food web has been hindered by methodological challenges and in order to address the prior concerns there is a need for improved methods to provide accurate, low-level detection. Further, in order to assess the threat of BMAA in the environment, there is a need to identify the physiological and ecological roles the compound plays. Herein we give a brief overview of cyanobacterial physiology and metabolism, summarize the existing evidence for a link between prolonged BMAA exposure and the enrichment in PD seen in multiple geographically isolated regions, and present new data on the distribution and occurrence of cyanobacteria-dominated HABs within the lower Columbia River watershed.

Pharmaceuticals and Personal Care Products Measured in Water and Suspended Solids in the Columbia River Estuary

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Modern chemistry has produced many compounds that facilitate everyday life and improve health. Accumulation of synthetic chemicals in the natural environment is a measurable byproduct of these advances. These chemicals of emerging concern (CECs) include pharmaceuticals, fragrances, detergents, disinfectants, plasticizers, preservatives, and many others, and are ubiquitous in wastewater and agricultural and urban runoff. Many reconnaissance efforts in recent years have assessed the presence of CECs in water and sediment, but geographic coverage remains limited. The Columbia River is the fourth largest river by volume in the United States, and provides important hydroelectric power generation, anadromous fisheries, large recreational areas, scenic beauty, and valuable habitat for wildlife and fish. The Columbia River estuary, at the convergence of the Columbia River and Pacific Ocean, is one of the most biologically productive ecosystems in the world due to its rich nutrient profile. Despite its importance to threatened and endangered anadromous fish, and its documented CEC inputs, the estuary has rarely been sampled for these compounds. In this study, we sampled water and suspended solids at several locations within the estuary, and tested for a large suite of pharmaceuticals, personal care products, antibiotics, industrial compounds, and others. We compare results of sampling conducted in 2004 and in 2014, and during different seasons. We observed seasonal and temporal differences in detection patterns, and, despite extensive dilution in this large river, we found multiple compounds from each of the chemical classes tested. This effort confirms the presence of CECs in the estuary and the need for additional studies to understand routes of exposure, bioaccumulation pathways, and effects of these compounds on aquatic organisms and food webs.

Mapping Contaminants in the Columbia River Basin—What Can We Learn

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The Columbia River Toxics Reduction Working Group was established in 2005 by EPA and other federal agencies, states, tribes, and nonprofit partners to share information, coordinate activities, and develop strategies to identify and reduce contaminants in the Columbia River Basin. In early 2009, the State of the River report was written as a starting point for characterizing contaminants in the Columbia River Basin. It was followed in 2010 by the Columbia Basin Toxics Reduction Action Plan, which issued a call to action for governments, nonprofits, industries, and citizens to help reduce contaminants in the Columbia River basin.

One area of focus for the Working Group was to develop a map of contaminants across the basin to highlight data gaps, areas of concern, and locations where reduction efforts are underway or would be beneficial. Assembling and unifying data from different agencies, methods, and media from across the basin proved to be the largest hurdle for this effort. A mapping subgroup evaluated the different classes of contaminants and decided to work on a pilot effort focused on polycyclic aromatic hydrocarbons (PAHs). PAHs were selected because they are ubiquitous in the basin, have active non-point and point sources, have documented acute and chronic effects on aquatic organisms, and show linkages between air, land, and water.

The mapping group asked local data-collecting agencies to provide their PAH data using a standardized template and EPA interns organized the data and prepared them for mapping. With support from staff from the Northwest Power and Conservation Council (NPCC), the data were then used to create a story map that is hosted on NPCC's website (http://nwcouncil.maps.arcgis.com/apps/MapJournal/index.html?appid=99e5965fe1ac4dd38001e784d7c6aac6). This story map includes information on the effects of PAHs on native fish and wildlife, the potential sources of PAHs, and opportunities for reducing PAHs and their effects. The map provides a model for future work efforts and an example for mapping and displaying data and information on other contaminants that affect fish and wildlife in the Columbia River Basin. This presentation will share the story map and discuss how story maps can be used to provide education on contaminant issues across a broad spectrum of audiences and offer a tool for future decision making about implementation and monitoring of reduction efforts.

U.S. Environmental Protection Agency, 2009, Columbia River basin—State of the river report for toxics: U.S. Environmental Protection Agency, EPA 910–R–08–004, https://www.epa.gov/columbiariver/2009-state-river-report-toxics

U.S. Environmental Protection Agency, 2010, Columbia River basin—Toxics reduction action plan: U.S. Environmental Protection Agency, https://www.epa.gov/columbiariver/columbia-river-toxics-reduction-action-plan

Session 6: Results of Restoration—Are We Having an Effect?

Just What the Hell is Going On?: The Latest in Columbia River Fish and Wildlife and Energy Policy and Law

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You can be excused if confused by recent developments in Columbia River fish and wildlife and energy policy:

- A federal court tossed out the last (2014) Federal Columbia River Power System Biological Opinion. A follow-on, court-ordered, jointly-agreed-to plan to increase spring spill to the gas caps is just about to start. Well, maybe not - an expedited appeal to the Ninth Circuit challenging the spill order will be argued and decided just days before the new spill regime is to begin - and just days before this conference.
- A giant Columbia River System Operations NEPA process is grinding along that - someday soon? - will begin examining alternatives for operating and configuring the system to benefit fish and wildlife while meeting all the other system obligations, too. To be completed in … wait, not until late 2021? What happens until then?
- One thing we know is that there will be a new FCRPS BiOp at the end of 2018. Well, unless there won't be - this is another issue now also being argued in court.
- The Council is just about to call for amendments to the big regional Columbia River Basin Fish and Wildlife Program. How does that fit in with the above?
- A NOAA "partnership" is digging into the question of what our regional objectives for Columbia River fish should be. Alas, separate from the BiOp, from the NEPA process, and from the Council's program amendment effort - but maybe these will all synch up?
- One week after the conference, the U.S. Supreme Court will hear arguments in the "culvert case" - with a ruling as soon as June that will roil - or not - everything we know about treaty fishing rights.
- At least Columbia River Treaty US/Canada renegotiations are starting up - yay! Only a mere five years after the regional recommendations. But will negotiations overseen by a new U.S. Administration have anything at all to do with the Columbia River Basin, or will the Treaty talks be driven by bi-national discord over NAFTA and other larger matters? Will "ecosystem function" get serious consideration as an addition to the Treaty, or will it get left behind in the dust of other concerns?
- The 10-year Columbia Fish Accord funding agreements between Bonneville and certain states and tribes will end later this year. Well, maybe not. Rumors tells us that roll-overs of the Accords are being negotiated or they are not, that a meeting of the minds and final deals are nearly imminent or that the parties are so far apart it will be impossible to bridge, and that funding for Columbia River fish and wildlife work under the Accords will stay relatively flat and that funding levels will take a hit.
- Does any of this matter if Bonneville's financial situation and its long-term competitiveness are as precarious as some say? What can we do about it if, as others say, the financial and competitiveness problems are mostly a result of matters we have little control over - massive changes in the energy industry in the last decade resulting in a west-wide wholesale power market awash in energy due to an overbuilding of wind and natural gas generation driven by state renewable energy portfolio standards and cheap natural gas from fracking.

Yikes! You get the point - it is a crazy moment in Columbia River energy and fish and wildlife law and policy. There is a lot going on, and not all of it links up coherently or consistently. Come listen to a snapshot summary of these many developments and some attempt (however laughable) to guess where all these matters go and whether and how they link - and what the implications are, if any, for your ongoing work in the estuary to improve habitat conditions and benefit fish and wildlife. The punch line is that there might not be much effect, at least in the near term - the big on-going regional effort at improving both system operations and tributary and estuary habitat to the benefit of fish and wildlife seems likely to continue even as the surface waters roil.

An Overview of the 2018 Synthesis Memorandum for the Columbia Estuary Ecosystem Restoration Program

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Periodic synthesis and evaluation of results from program implementation (~5 years) is a critical element of the Columbia Estuary Ecosystem Restoration Program's (CEERP's) adaptive management process because it informs adjustments to future program strategy and actions. Building off a previous synthesis report, the report incorporates new scientific findings, presents new summarizations, syntheses, and analyses, and uses the collective results to reevaluate program strategy and provide recommendations for future activities to advance the program. The report is organized around key management and scientific questions related to CEERP's main strategy to reconnect tidal floodplain habitats to the mainstem estuary.

Important findings include: 1) Fifty-eight restoration projects have restored 5,412 acres (2,190 ha) of tidal floodplain habitat, with 1,034 ha of additional connected wetland habitats in 2016 compared to 2004. There was an 11.6% relative increase connected wetlands from 2004 to 2016. There is at least 21,014 ha of "recoverable wetland" or 67.9% of the total area theoretically available for future restoration. 2) Based on action effectiveness monitoring data from 23 project sites collected in various years since 2004, restoration actions generally are having desired physical and biological effects by beginning reestablishment ecological processes, especially restored hydrologic connectivity. 3) The general paradigm that yearling-sized fish migrate rapidly through the estuary, feed little, and make little use of wetlands is not true; the estuary is not a pipe. This is evidenced by data showing yearling salmon feed in the mainstem and can inhabit tidal wetland channels. 4) Besides the overarching effect of flow regulation, limiting factors in the estuary continue to include sufficient habitat opportunity and capacity for juvenile salmon rearing and refuge, adverse water temperatures affecting habitat use and fish physiology, ecological impacts from non-native flora and fauna, intra- and inter-specific competition, and piscivorous and avian predation. 5) Evidence is growing that there are direct and indirect benefits of ecosystem restoration on juvenile salmon performance. 6) New data and analyses informing design of restoration projects are available for predicting plant community composition and density, reed canarygrass control, seed banks, mounds, channel network design, and large wood. 7) Climate change should be considered in restoration project design and CEERP strategy, despite uncertainty about the strength, timing, and duration of any changes. 8) Understanding the linkage between the ocean and estuary is critical to effect use of restoration resources in the estuary and the entire Columbia River basin. 8) A revisit of the evidence-based evaluation of CEERP substantiated the conclusion of the first EBE "…the restoration program is having a cumulative beneficial effect on juvenile salmon."

The report concludes with uncertainties, recommendations, and management implications. The overall intent is to provide managers, policy-makers, restoration sponsors, and others with a comprehensive, scientific understanding of the state of the science to inform program strategy and decision-making in the near and long terms.

The State of the Sandy: Bolstering Resiliency in a Decade of Post-Dam Restoration

**Steve Wise* and Katherine Cory

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Ten years after removal of Marmot dam from the Sandy River, a coordinated, science-based restoration campaign has begun to show results for federally listed salmonids and their habitat. Reconnecting floodplains, side channels, riparian zones, and other degraded habitat in priority sub-basins has expanded salmonid spawning and rearing reaches, with monitored biological responses indicating increased presence and productivity of threatened salmon and steelhead in restored areas. Completed by Sandy River Basin Partners in 2017, the *State of the Sandy** reviews restoration actions, wild fish populations, and socioeconomic conditions affecting watershed conditions. Results of the first decade of post-dam restoration also represent steps toward resiliency to predicted climate change, including storm intensity, snowpack and streamflow. The presentation will review findings in the *State of the Sandy*, as well as steps to conserve the Sandy's regional role as a wild salmon stronghold, a habitat corridor for a range of aquatic, terrestrial and avian species, and a free-flowing cold water refuge for the Lower Columbia River.

Full text of the State of the Sandy is available online:

http://sandyriver.org/wp-content/uploads/2017/10/State-of-the-Sandy-.pdf

Restoring Resilience to Tillamook Bay: Incorporating Climate Change in the Restoration Design and Construction at the Kilchis Estuary Preserve, Tillamook County, Oregon

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In 2015 The Nature Conservancy restored tidal wetlands on a former dairy farm located in the Kilchis River estuary in Tillamook County, Oregon. The objective of the restoration was to restore tidal flows to the former estuary wetlands through reconstructed tidal channels and sloughs and reconnect the river to the wetlands by the lowering of dikes. The restoration design and construction plans were developed with climate change data to inform a hydrodynamic model. The hydrodynamic model included flow data from the Kilchis River that borders the Preserve and tidal flow data from Hathaway Slough nearby. Climate change projections used in the model included sea level rise and precipitation changes. The model made predictions of hydrologic changes both on and off-site under various seasonal and climate change scenarios; it was also used in the selection of appropriate plant species for revegetation of the restored estuary habitats. Post-construction, a major flood in 2015 swept through the Tillamook Basin and affected the restoration site. We used this opportunity to conduct a second modeling effort to assess site changes and determine if the site performed as expected from a hydrological perspective.

Habitat Restoration Using Dredged Material Placement within the Lower Columbia River at Woodland Islands, WA

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This presentation introduces the concept of using sand dredged from the lower Columbia River federal navigation channel (FNC) to restore habitats spanning sub-tidal to riparian zones. With 6-8 million cubic yards of sand annually dredged from the 100-mile long LCR FNC, there is significant opportunity to beneficially use this sediment as a resource to restore shallow water and emergent habitat with the river. Targeted dredged material placement can also be used to increase resilience of existing in-water and riparian habitats affected by evolving hydraulic forcing and climate change effects. The proposed restoration action featured within this presentation involves targeted placement of 400,000 cubic yards of dredged sand at two adjacent locations within an embayment along the east side of Woodland Islands, WA, at RM 85-86. See figure below. The source for the dredged sand would be from the St Helens bar along the Oregon side of the FNC, within 1.5 miles of Woodland Islands. Habitat zones to be supported by the proposed terrain restoration include: intertidal sand flats (-5 to 0 ft NAVD), intertidal aquatic vegetation, (0 to 6 ft NAVD), emergent marsh or wetland fringe (6 to 10 ft NAVD), and scrub-shrub (10-14 ft NAVD). The proposed restoration features would be treated with post-placement grading and native willow plantings, creating a mosaic of elevations to encourage development of varying types of habitat to support fish (salmonids), amphibians, and targeted land-species (yellow warblers). A 2-dimensional hydraulic model (AdH) was used to identify and evaluate potential changes in river stage and current that could be realized in response to the proposed restoration activity, as compared to the existing condition. The AdH model was run for the time period of 1 APR – 14 JUL 1997 to simulate the hydraulic effects of both a high-flow freshet event having a 30-35 year return interval for Columbia River flow, and a "late summer" low flow season. The project features were emulated within AdH account for frictional and small-scale hydraulic aspects of the proposed project terrain modification. The potential for river current alteration within the project area (in response to restored terrain) was used as a surrogate to evaluate possible sediment transport effects associated with the project, based on exceedance of threshold river current magnitude for sand transport. Hydraulic "sheltering" effects due to the project were also evaluated using AdH model results.

The presentation will discuss the rational and trade-off challenges of providing restored habitat for multiple species spanning different hydraulic zones within a given restoration action. This presentation will also summarize the AdH hydraulic model results for Woodland Island habitat restoration, as a series of "Existing Condition" versus "Alternative Plan" comparisons, highlighting the expected circulation changes of the proposed restoration project.

Session 7: New Tools for Assessing and Evaluating Restoration Impacts

Use of Drones and Hyperspectral Imagery to Remotely Sense Vegetation Patterns at Wetland Restoration Sites

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Wetlands directly benefit endangered juvenile salmon by supporting diverse vegetation communities. Notably, insect prey that salmonids prefer is produced in wetland habitat. Restoration of degraded wetlands leads to vegetation and topographic changes that require comprehensive monitoring, but these monitoring surveys are expensive, time-consuming, and restricted in spatial and temporal cover. Our project aims to develop a comprehensive survey protocol for using remote sensing techniques employing hyperspectral imagery acquired from unmanned aerial systems (UAS, = drone). We have worked to develop flight data collection protocols, build a "spectral library" of diagnostic spectral signatures of ground-truthed plant and topographic objects (water, woody debris, detritus, ect), create analytical procedures to reduce computation time, and develop output metrics to quantify wetland restoration states and trajectories. These and other developing technologies will greatly enhance restoration science to benefit salmon recovery.

Juvenile Salmon Movement/Passage Through a Tidal Free-Flowing River Junction Emerge from Swim Orientations Based on their Recent Past Flow Field Experience

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Managing fish movement is a challenge in waterways operated to help meet society's needs. Decades of work has not yet produced a reliable solution for directing fish swim paths in rivers to specific locations near infrastructure where individuals can be collected or passed for their continued safe travel. Pacific salmonids are a highly valued species economically, recreationally, and culturally. These species exhibit a strong propensity to move down- and up-stream in fast-moving currents during parts of their life cycle, an analogy shared by the many other organisms that must navigate highly-advective media in which they reside. Juvenile Pacific salmonids (salmon) confront what may seem to be a straightforward challenge: move downstream. Challenges include their swim speeds which are often slower than that of the surrounding water and, importantly, salmon must avoid predatory fish and birds. For humans, salmon have proved difficult to direct and collect in large river environments near infrastructure. The external and internal factors that underlie salmon orientation and speed are unknown. For engineering design and management purposes, salmon behavior has frequently been related to water speed, velocity gradient, acceleration, turbulence, and pressure. Most of what we know about fish hydraulic response stems from controlled laboratory experiments that can manage some of the possible external and internal factors that might influence movement. Here, we take a very different approach. We investigate salmon movement trajectory and passage patterns at the scale of a large, tidal free-flowing river environment. At this scale, we generate new explanations for observed salmon movement and passage patterns. Specifically, we focus on the experiences that a salmon encounters as it moves within a river flow field and then relate that to observed movements that reflect decision-making at the individual level over the course of space and time that it takes these fish to transit these environments. The behavioral repertoire described reproduces the predominate salmon movement and passage patterns at the Sacramento River and Georgiana Slough junction and also conceptually at Columbia and Snake River hydropower dams. In a way, our findings represent a nuanced, more complex middle ground between findings from prior analyses with much simpler data sets. The potential for engineering actions to influence salmon movement behavior becomes clearer from this analysis. Findings in this study provide a clue for how one might direct or guide individual salmon trajectories to specific locations within a river. While the results here stem from an analysis of salmon, other species that confront the common challenge of maneuvering downstream in water may have evolved similar variations of this strategy.

OFAIM and Fortune in Oregon's Floodplains: Oregon Floodplain Impact Mitigation Tool

**Rowyn Cooper-Caroselli*[1], Marjorie Wolfe[1], Polly Gibson[2], and Nicole Maness[2]

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Over time, most of Oregon's floodplains have been isolated and developed for human use with continual losses to critical habitat for many species. As a result, Oregon is facing the recent FEMA NMFS BiOP which will require stricter regulations for floodplain development to account for effects on ESA listed fish species. One of the key floodplain functions the BiOP intends to preserve is flood storage and attenuation. Computing changes in flood storage and attenuation (in terms of peak discharge, and flood wave speed) requires the development of a sophisticated hydraulic models which are expensive, data intensive and insensitive to many individual developments. Cumulative impacts to floodplain storage and attenuation are missed within our current regulatory context with devastating consequences. In addition, different types of impacts and mitigations affect storage and attenuation by different mechanisms and over different time scales. So how can Oregon communities effectively and consistently mitigate for development impacts on flood storage and attenuation? In cooperation with the Willamette Partnership, Wolf Water Resources is developing an impact mitigation assessment tool for floodplain projects. The tool assesses the general quality of impacts listed in the BiOP (fill, vegetation removal, impervious surface, and bank armoring) based on their physical size and location in the floodplain. This impact quality is then scaled to reflect the system context based on existing levels of degradation of three functional groups; channel complexity, floodplain connectivity, and floodplain complexity. Quality of mitigation is computed and scaled in the same manner and balanced with in kind impacts based on area. The imbalances are then compared to one another using the relative sensitivity of storage and attenuation to each impact category. This approach requires mitigation for impacts of any size and allows flexibility in the choice of that mitigation without sacrificing effectiveness. We need a better acronym for the tool, there is a prize for the person who comes up with the best one.

Elevation is the Surrogate for Everything: A Short Story of Translational Ecology, Multi-Species Floodplain Restoration Design and a Biological Risk-Reduction Habitat Model

**Kelley Jorgensen* and Chris Watson

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This presentation will include a story of translational ecology in action on a large-scale Lower Columbia River multi-species floodplain habitat restoration project. The talk will focus on a resulting habitat model that can be used to prioritize, select and design the most limiting types of fine-scale juvenile salmonid habitats in restoration projects in the Lower Columbia system.

Since 2014, Plas Newydd Conservation Program staff have collected intensive baseline data on over 1000 acres of diverse Lower Columbia floodplain habitats using a translational ecology approach. Translational ecology is a team and action driven applied science that uses inter- and trans-disciplinary methods that are better received by diverse stakeholders and inclusive of traditional and local ecological knowledge held by non-scientists including landowners, land managers, funders, and policy and decision-makers. Our team chose translational ecology as our research strategy because it is impact-driven, adaptive and iterative. Along the way, by incorporating non-scientists in the process and asking basic questions, we busted assumptions, broke stereotypes, unearthed new insights, and created bonds across traditional social boundaries. For everyone involved, this framework generated a profound appreciation for the complexity of both the social relationships AND the hydrology and biology that drives and constrains habitat-forming and -maintaining processes in the Columbia River estuary.

Plas Newydd LLC is the sponsor for the 876-acre Wapato Valley Mitigation and Conservation Bank (Wapato Valley), located at RM 87, at the confluence with the Lewis River (a cold-water refuge site). One goal of our design is to “unbuild” or remove man-made constraints added to the landscape over the last 175 years and restore processes to the extent possible, given the constraints of an ecosystem where nearly all the natural disturbance regimes (flood, fire, etc.) have been extinguished. The result is a floodplain restoration design that will benefit not only juvenile salmonids by restoring hundreds of acres of important cold-water fed, off-channel habitats, but also benefits multiple species (not just salmon) by restoring a diverse suite of upland, wetland and aquatic habitats. The presentation will include an overview of design goals, objectives and methods unique to this biodiversity-driven, ecosystem restoration program.

During our 3-year site characterization and design process, we developed a functional elevation-based habitat model for juvenile salmonids that is applicable for all tidal reaches of the Lower Columbia mainstem, tributaries, and off-channel areas. This model is at a finer scale to better address biological risk and mortality from threats such as predation, thermal exposure from lack of cold water off-channel refuge, and fish stranding from hydropeaking, drought, and vessel wakes, yet can be used with existing publicly available datasets, and refined with relatively common on-site data collected for most restoration design. Perhaps that 2-year flood elevation isn’t the most important thing to be calculating habitat benefits from. Our model addresses identification and restoration needs for low-flow refuge and tidal surge plain habitats throughout the Lower Columbia floodplain.

Translational Ecology in the Lower Columbia: Elevation and Hydrology in a Tidal Freshwater Riverine System as the Key to Achieve Rigorous Native Vegetation Performance Standards

Karen Adams, **Kelley Jorgensen*, and Chris Watson

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Translational Ecology takes an intentional approach in developing ecological research that is applied to improved environmental decision making. Wapato Valley Mitigation and Conservation Bank (Wapato Valley) is in the final stages of mitigation bank certification and will provide 4 credit types generated from restoration 876 acres of diverse floodplain habitats including wetlands, off-channel fish habitat, streaked horned lark and Oregon white oak habitats. The Wapato Valley design team has taken a translational ecology approach with an ecology-forward restoration design informed by 3+ years of intense field data collection. Design goals are to restore natural, self-sustaining processes to the extent possible, that will restore a diversity of floodplain, aquatic, wetland and upland habitat functions. Precise elevation and plant species data was collected from more than 3500 plots in low and high marsh habitats on site, providing us with information about the preferred elevation and hydrologic setting for a range of dominant species. A key finding from this data collection, consistent with recent research in the Lower Columbia River Estuary (LCRE), demonstrates the inextricable link between elevation and hydrology, which drives the predictable development of floodplain and wetland communities on our site. Wapato Valley developed a model using elevation as a surrogate for hydrology to develop restoration grading and planting plans. This model provides insights regarding optimal elevations for establishing a diversity of native wetland plant communities and controlling problematic invasive species including reed canary grass. This model is responsive to changes in water surface elevation, such as would be expected under current climate change predictions. As a result, the restoration design was developed to provide the proposed environmental benefits under a wide range of future hydrologic conditions, and still achieve the rigorous performance standards of native vegetation cover required for certified mitigation banks. The model has also allowed us to anticipate adaptations to be made in our future land management practices that would maximize the quality and persistence of these habitats for ecological function and wildlife habitat as the site evolves and habitat succession occurs.

Revised Estimates of Impacts of Sea Level Rise in the Columbia River Estuary

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Estimates of sea level rise impacts on the Columbia River estuary are presented that account for a new set of regional scenarios (NOAA 2017), conditions after a major Cascadia Zone Subduction earthquake, and the role of river discharges. These estimates use similar methodology, but correct and explain simulation errors of results we presented at CREC2016. Results suggest that impacts of sea level rise are large, but different in several aspects from those reported earlier. Sea level rise increases the estuary-shelf exchanges (as before), leading to extended salinity intrusion in the estuary (but not as much as before) and to larger plumes in the shelf (contrary to before). Changes in shallow water habitat are larger than previously reported. All these effects are significantly augmented in case of a seismic subsidence. Increases in salinity intrusion are exacerbated by smaller river discharges, while increases in plume volume are exacerbated by larger river discharges. The effects of river discharge on changes in shallow water habitat are complex and still under investigation.

Parasitism of Diatoms by Chytrid Fungi in Shallow, Off-Channel Habitats of the Columbia River

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Parasites play vital ecological roles, controlling population sizes, shaping food webs via energy redistribution, and driving genetic variation. Many species of freshwater diatom are parasitized by Chytridiomycota, or chytrid fungi. Chytrid fungi are uniflagellate, motile, lethal parasites that reproduce within zoosporangia; close relatives of chytrids that infect diatoms are known to parasitize amphibians and cyanobacteria. Chytrids provide a nutritious food source that is easily consumed by small crustacean grazers, unlike large, colonial diatoms. The Columbia River experiences diatom blooms each spring; these blooms are typically dominated by *Asterionella formosa*, a large, colonial pennate diatom that is susceptible to infection by chytrid fungi. In a time series of observations in the mainstem Columbia spanning four years (2010-2013), infections of *A. formosa* populations by chytrid fungi were observed throughout the year at a background level of ~10%, with peaks occurring after the peak in host abundance. In order to determine whether off-channel habitats show similar host-parasite dynamics, we enumerated host and parasite populations, as well as the intensity of infection in shallow, off-channel sites between 2014 and 2017. By calculating biovolumes of infected cells and relating biovolume to carbon content, we estimate the amount of carbon the chytrids would have redistributed from diatoms into smaller zoospores, which are easier for zooplankton to consume. Our findings confirmed that there is a stable population of chytrid parasites that infect diatom hosts, with higher percentage infection observed during bloom periods (up to ~80%). We conclude that the losses of diatom carbon to parasitism rival or exceed losses to grazing, making this process highly relevant to food webs of the lower Columbia River.

Net Ecosystem Metabolism in the Lower Columbia and Willamette Rivers

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One proposed consequence of building large dams on the Columbia River is "greening" of the river – that is, sediment trapped upstream leads to clearer water downstream, thus alleviating light limitation of photosynthesis and creating seasonal blooms of phytoplankton. Ecosystem responses associated with greening include changes to carbon and nutrient cycles, and alterations to the food web. Here, the aim is to use *in situ* oxygen sensors and weekly sampling-based incubation experiments to measure the rates of primary production, respiration, and net ecosystem metabolism (NEM) to describe the daily and seasonal patterns of primary production and aerobic respiration in the lower Columbia River and its main tributary the Willamette River. Our hypothesis is that greening of the Columbia River should lead to more positive NEM compared to the turbid Willamette River. We are comparing sampling-based measurements of NEM and nutrients at two different depths in both rivers, and measuring the availability of photosynthetically active radiation (PAR) in the water column. Initial data show higher levels of respiration at the end of summer 2017, and declining levels of both primary production and respiration through the fall and winter (generally <0.1 mg L^{-1} h^{-1}). The rates of biological activity are expected to rise again with the anticipated spring bloom of 2018. No apparent difference in metabolism exists between depths. Water column light measurements at both sites show the Willamette as having consistently less available PAR in the water column than the Columbia, supporting the proposed silt-trapping impact of the dams. A better understanding of present trophic dynamics of the Columbia system will allow more accurate predictions of how a warming climate – particularly through changes in precipitation and snowmelt – will impact the rivers.

Water Temperature Monitoring in Streams Tributary to Columbia River Estuary—
The North Coast Watershed Association Monitoring Network

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The watersheds of northern Clatsop County are drained by a network of small streams discharging to the lower Columbia River. Many of these streams and others in Clatsop County are 303d listed by Oregon Department of Environmental Quality (ODEQ) for water temperature and/or dissolved oxygen impairment. The ODEQ standard is 18^{o} C for maximum water temperature during summertime salmonid rearing and migration. Prior to 2016 little continuous water temperature data were being collected in a way useful to ODEQ for assessing water quality conditions in the watersheds or for establishing water temperature TMDLs during low flow months (Jun-Sep). In 2016, the North Coast Watershed Association (NCWA) received an Oregon Watershed Enhancement Board (OWEB) grant with matching funds from Oregon Department of Fish and Wildlife (ODFW) to fund the purchase of data loggers and peripheral equipment to continuously monitor water temperature through the low streamflow period at 15 sites in the Youngs Bay Watershed. NCWA monitoring follows stringent QA measures developed by ODEQ for ensuring the validity and accuracy of water temperature data. Selected sites provide wide geographic distribution but avoid tidal-effected reaches and focused on tributaries with large contributing areas while considering site access, stream site conditions, equipment security, and availability of historic or ancillary data. The network included sites on six stream systems, two with single monitoring locations and four with multiple locations, generally in the upper and lower parts of the watershed. Water temperatures are logged at 30 minute intervals using Hobo loggers manufactured by Onset, Inc. and the accuracy (0.2^{o} C) is confirmed by comparing to NIST traceable thermometers. Reliable data were obtained from 11 sites for between 90 and 139 days. The mean water temperature between June 10 and September 26, 2016 was 18.0^{o} C at the Carnahan Park site on the Skipanon River. Mean water temperatures at the other ten sites for their respective periods were all less than 18.0^{o} C. But water temperatures exceeded 18.0^{o} C for periods of time at nine of the eleven sites and exceeded 20.0^{o} C at five sites. The 2016 data confirm that high water temperatures are impairing water quality during summertime salmonid migration and rearing. The complete data with pertinent statistics and graphical display are available for viewing and download at http://www.clatsopwatersheds.org/temperature-monitoring/. Water temperature monitoring continued at selected sites in 2017 and funding has been secured to expand the network in 2018 by adding 8 monitoring sites on several streams in the Nicolai-Wickiup watershed.

Herbaceous Vegetation Monitoring of Tidal Restoration Projects at Lewis and Clark National Historical Park 2006 – 2016

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Through passive and active restoration of the Lewis and Clark River floodplain within the boundaries of Lewis and Clark National Historical Park, the National Park Service is contributing to the recovery of the Youngs Bay watershed and endangered salmon stocks. Herbaceous plant species have been monitored at three tidal wetland restoration sites in accordance with the standardized "Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary" (Roegner et al 2009). The data collected is stored within the *Oncor* geodatabase for sharing among partners. Multiple analyses have been performed using percent cover as a metric to measure the herbaceous species development and to determine the effects of various treatments on the plant community composition. The results from ten years of monitoring suggest that different site prep treatments, particularly excavation, have a significant and lasting effect on native plant diversity and abundance of reed canarygrass (*Phalaris arundinacea*).

Comparison of Salmon Habitat Opportunity and Capacity Between Restoration and Reference Sites on the Columbia River Estuary

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Environmental data has been collected from restoration sites in the Columbia River Estuary since 2016 to evaluate the direct effects of habitat restoration projects that are designed to benefit juvenile salmon in the lower Columbia River and estuary. Water elevation and temperature data was used to study the differences in habitat opportunity and capacity to support salmon at two restoration sites relative to their paired reference sites. To begin, the nature of the environmental differences at each site was assessed using standardized comparative plots and statistical tests of both the measured data and the differences between the data of each restoration-reference pair. The success of restoration efforts is then discussed in terms of temperature and water elevation thresholds required to support migratory salmon. This approach represents progress towards the development of practical methods to analyze environmental data in a way that is relevant to assessing biological response and informative to resource managers.

Increasing Resilience of West Sand Island in Order to Maintain Ecosystem Function and Reliable Navigation at the Mouth of the Columbia River

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West Sand Island is located in Baker Bay at the Mouth of the Columbia River (MCR) and hosts unique habitat types that are becoming increasingly rare on the west coast. Coastal infrastructure around the MCR inlet has helped maintain stability of the island, however, over the past several decades the west side of the island has experienced continual shoreline recession (~10ft/yr at certain locations). If West Sand Island continues to erode and beach dunes breach, the island would be inundated and valuable habitat could be lost. This study summarizes morphological changes and hydrodynamic characteristics of Baker Bay in order to provide guidance for inlet management strategies that stabilize West Sand Island while balancing ecological function and USACE's navigation mission. Current, salinity, and depth data are used to examine tidal circulation patterns that influence water quality and drive sediment transport in Baker Bay. Results highlight strengths and weaknesses of different approaches aimed at maintaining the Baker Bay morphology; which sustains hydraulic aspects of the Columbia River Estuary, ecosystem function, and navigation at the MCR. These insights will help optimize solutions to reduce island erosion that are resilient to future sea level rise. This effort is part of a nationwide initiative to sustainably balance USACE sediment-related project needs and natural system processes and to identify opportunities for beneficial uses of dredged sediment.

Multiple Species Habitat Restoration in the Lower Columbia River Estuary

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The convergence of the Willamette and the Columbia Rivers has resulted in a unique assemblage of floodplain habitats. The confluence of the big rivers is located in the lower Columbia River hydrogeomorphic Reach F, and includes Sauvie Island, a 24,000-acre floodplain island that is one of the largest islands in the United States. The northern 12,000 acres of the island is an Oregon Department of Fish and Wildlife area. The Sauvie Island Wildlife Area includes palimpsests topography containing scroll-bar formations, floodplain channels, sloughs, wetlands, and other geomorphic features. The northern region of the island also serves as juvenile salmonid rearing habitat for multiple runs of endangered salmonids and is home to numerous other priority species of amphibians, waterfowl, mammals, and reptiles. Reach F is a mecca for salmon and wildlife, but it is also bordered by the cities of Portland and Scappoose, Oregon, and Vancouver, Washington. The proximity of urban development to the wildlife area has resulted in land resource competition between many of the aquatic and terrestrial species. Since 2009, several salmonid habitat restoration projects have been implemented in the wildlife area, and throughout Reach F, targeting multiple species benefits, native plant diversity, and climate change resiliency, while also continuing management of the land for grazing by livestock and migratory waterfowl. Restoration elements included reconnecting salmonid rearing habitat, creating turtle nesting and basking habitat, removing levees and water control structures, and implementing beaver dam analog and wood habitat structures. This poster presentation discusses integrated solutions developed for multi-species restoration, such as maintaining the hydroperiod for wetland plant diversity and waterfowl, while removing water control structures to provide ingress/egress for juvenile salmonids. The challenges encountered and solutions developed have also improved the resiliency of reconnected and restored floodplain habitats by improving natural hydrologic redundancy, and providing topographically transitioning habitats that allow for changing water levels, enabling multiple species to thrive on a site. Ideas and concepts described in the poster can be used and built upon by planners, managers of local, state, and federal lands, regulatory review agencies, and restoration designers.

Designing for Fish, Wildlife, and Native Wetland Plants: Results from Habitat Restoration Projects at the Sauvie Island Wildlife Area

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The northern portion of Sauvie Island in Reach F of the Columbia River has been a focal area of restoration projects over the last five years (2013-current). A resulting landscape-scale mosaic of restored wetlands has been successfully created by focusing on a range habitat needs from fish and wildlife to native emergent wetland plants. Hundreds of acres of floodplain habitat have been opened up for juvenile salmonids while retaining and enhancing habitat features for migratory waterfowl, amphibians and emergent vegetation. Restoration features have included the removal of levees and water control structures, replacement of culverts with channel-spanning bridges, lowering marshplain elevations for the benefit of native emergent plants, and installing beaver dam analog structures and wood habitat. Lessons learned from these projects can be replicated on similar restoration concepts throughout the lower Columbia River estuary in order to meet a diversity of species needs. This presentation examines integrated approaches developed for multi-species restoration, specifically maintaining the hydro period for wetland plant diversity, waterfowl, and amphibians while removing water control structures in order to provide ingress/egress for salmonids. Challenges encountered and effective approaches will be described for the benefit of project managers, designers, land managers, and regulatory agencies.

Supporting Studies and Baseline Survey at the Proposed North Head Nearshore Dredged Material Placement Area in the Pacific Ocean, Pacific County, Washington

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The 110-mile, 43-ft deep Columbia River (CR) deep draft federal navigation channel, which extends from the Pacific Ocean to Portland, OR/Vancouver, WA, is maintained by the U.S. Army Corps of Engineers (Corps). Of the ~12 million cubic yards (Mcy) of sand dredged annually from the deep draft channel, approximately 3.5 Mcy is dredged from 6-mile entrance channel at the Mouth of the Columbia River (MCR). Maintenance of the MCR channel is critical to sustaining international waterborne commerce along the entirety of the Columbia-Snake River navigation system, which extends 470 river miles inland to Lewiston, ID. To accommodate the massive amount of sand dredged from the MCR, the Corps and the U.S. Environmental Protection Agency – Region 10 (EPA) jointly manage a network of three nearshore sites (Shallow Water Site [SWS], North Jetty Site [NJS], and the South Jetty Site [SJS]) and one offshore site (Deep Water Site [DWS] in the Pacific Ocean. The Corps and EPA prioritize the beneficial placement of dredged material at the nearshore sites over the DWS, because nearshore placement allows the sediment to remain in the active littoral zone. Maintaining sediment in the MCR littoral system feeds the adjacent beaches and provides added protection to infrastructure (such as the rubble-mound jetties at the entrance) and the Washington and Oregon coastlines during winter storms. In 2017, approximately 1.7 Mcy of the 3.5 Mcy dredged from the MCR was placed in the nearshore sites; the remaining 1.8 Mcy was disposed at the DWS, well outside the littoral zone. To increase the amount of dredged material placed in the MCR littoral system and minimize sediment losses, the Corps proposes to select a new nearshore site off the North Head, near Long Beach, WA – the North Head Site (NHS). This presentation highlights prior studies (sand tracer, sediment trend analysis, wave and current profiling) and the baseline survey activities (sediment physical, chemical, and biological characterization; epibenthic trawls; and commercial crab pot surveys) performed in the NHS study area to support the Corps' selection of a new nearshore dredged material placement site.

Estuarine Pathways of Juvenile Chinook Salmon in the Columbia River

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Understanding the extent to which juvenile salmon depend on estuarine habitats is important for conservation, management, and restoration efforts in the Columbia River. To address gaps in knowledge of juvenile Chinook estuarine residence time and patterns of migration, we developed an Individual Based Model (IBM). The model relies on pre-existing high-resolution simulations of 3D estuarine circulation and characterizations of estuarine habitat (some empirical and some derived from the circulation simulations). The IBM has three main modules: hydraulic transport, fish behavior, and bioenergetics. Hydraulic transport involves numerical tracking of passive particles along 3D simulated flows. Both advection and diffusion are accounted for, and the governing equations are formally derived and well established. Besides hydraulic transport, fish move in response to behavioral decisions. Multiple behaviors are explored in the model, including random walks, orientation to positive habitat indicators (e.g., an index of salmon habitat and vegetation cover), and event-based behaviors. The Wisconsin bioenergetics model is used to compute growth of individuals over time, providing an informative link between the individual's physical environment and its growth. We are currently using the model to explore and contrast estuarine pathways of stream-type and ocean-type juvenile Chinook. Preliminary results highlight differences in estuarine residence times, the extent of optimal habitat experienced, and growth. River discharge and tidal flows are major drivers of potential estuarine pathways, while water temperatures and optimal habitat experienced strongly influence growth. Field data are being compiled for model-data comparisons and to validate and enhance the model.

A Five-Year Snapshot of EPA-Funded Ocean Dredged Material Disposal Site Monitoring and Research at the Mouth of the Columbia River, Washington/Oregon

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Regional sediment management continues to occur in a collaborative and effective manner at the Mouth of Columbia River through the interagency and multi-stakeholder Lower Columbia Solutions Group. The US Army Corps of Engineers – Portland District (USACE) dredges annually up to 5 million cubic yards of sand from the 6-mile Mouth of Columbia River federal entrance channel to ensure safe navigation for mariners and transit to and from Oregon and Washington ports. The U.S. Environmental Protection Agency (EPA) and USACE co-manage a network of three nearshore sites and one offshore site in the Pacific Ocean to receive the Mouth of Columbia River dredged material. These sites are managed in accordance with the Marine Protection, Research, and Sanctuaries Act and the Clean Water Act with an emphasis by the agencies and the Lower Columbia Solutions Group on beneficial use of the dredged material. At the Mouth of Columbia River, placement of dredged material closer to shore allows for the material to provide coastal resiliency to coastlines and local communities by feeding beaches and protecting key infrastructure.

As a member of the Lower Columbia Solutions Group, the EPA has worked collaboratively to identify research opportunities and perform surveys that support the group's shared regional sediment management goals. Over the last 5 years, EPA has engaged in four research and monitoring efforts to assess the impacts of dredged material disposal on benthic and epibenthic communities. This work supports the USACE mission to maintain the Mouth of Columbia River federal entrance channel and ensures that the Mouth of Columbia River disposal site network is managed in compliance with the Marine Protection, Research, and Sanctuaries Act and the Clean Water Act.

This poster highlights EPA-funded research at the Mouth of Columbia River and focuses on the ocean surveys performed by EPA in 2014. EPA's 2014 survey confirmed that the benthic infaunal and epibenthic communities at the disposal sites are not negatively impacted by the USACE dredged material disposal operations. The EPA confirmed the quality of the dredged material and examined biodiversity and population density by performing sediment grabs, epibenthic trawls and crab pot surveys. These results are presented herein.

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 three proposed sites included in this large-scale restoration effort include Fort Columbia, which was restored in 2010 as part of phase I, Megler Creek, which was restored in the winter of 2016/17 as part of phase II, and Hungry Harbor, which is currently in the design process and will be constructed in 2019 as the third and final 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 both upriver and local stocks of ESA listed salmonids.

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, Hungry Harbor is the only one of the three Columbia- Pacific Passage Habitat Restoration sites that remains 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.