Designing Effective Revegetation Strategies for Restoration Projects on the Lower Columbia River

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Despite the many well-documented successes of restoration projects along the lower Columbia River, re-establishment of native vegetation is often given relatively little attention in project design and implementation. An increasing interest in multi-species management and cohesive ecological approaches makes this a good time to develop and share learned best practices.

This presentation will outline some challenges and solutions to revegetating common habitat types found on the lower Columbia River. Desired future conditions, local climate and hydrology, regulatory requirements, and available resources lead to varying approaches, but common modes for revegetation failure include insufficient planting densities, poor species selection, drought, flooding, browse, and insufficient site preparation and post-planting maintenance. Anticipating each of these challenges in advance and designing a replanting (if needed) and maintenance plan to address them, along with a healthy dose of adaptive management, can mean the difference between project success and failure.

Frequently, restoration planting approaches often follow a prescribed approach with a focus on overstory canopy development in narrow riparian corridors, which, even when successful, often does not result in diverse, multi-layered plant communities that support important ecological processes, and are vulnerable to disturbance and invasion by nonnative species. We give an example of one such project, Lower Elochoman II, and contrast it with the nearby Nelson Creek (Lower Elochoman III) restoration project, where a dense “edge to edge” comprehensive approach is currently underway.

Uncertainties associated with climate change also underscores the need for comprehensive restoration approaches that reintroduce diverse plant communities to project sites, as some species inevitably thrive and others decline under changing conditions.

Other topics overviewed will include timing strategies for weed control, species and reference site selection, construction approaches that increase success rates for native plant establishment, and how to harness tools from forestry and agriculture to reduce costs and increase project success.

Describing and Assessing a Basin-scale Mitigation Program: The Northwest Power and Conservation Council's Fish and Wildlife Program

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The Northwest Power and Conservation Council (Council) was formed in 1981 following passage by Congress of the Pacific Northwest Electric Power Planning and Conservation Act (Act) in 1980. The Council, an interstate compact between Washington, Oregon, Idaho, and Montana, was directed through the Act to adopt a program to "protect, mitigate and enhance" fish and wildlife affected by the hydroelectric facilities while assuring the region a reliable and efficient power supply. Fish and Wildlife Programs are developed and amended from recommendations for measures or objectives. Programs are implemented as projects funded directly by Bonneville Power Administration (BPA), as projects implemented by federal agencies and reimbursed by BPA, and as actions required of federal action agencies.

The first Fish and Wildlife Program was completed in 1982, with subsequent versions developed approximately every five years. The scope and investment in this Program make it one of the largest fish and wildlife mitigation efforts in the nation and a major part of the tapestry of mitigation efforts in the Columbia Basin. The collective efforts over the last 40 years represent a significant investment of time and money, and the work has been implemented for a long enough time that we can now begin to ask questions about how this Program has been applied, and what influence it has had on mitigation and restoration of fish and wildlife across the basin, over time. We are interested in looking at the Program as a whole, rather than evaluating individual actions or local-scale efforts.

There are inherent challenges in describing the performance of a program that covers such a large geography and timeframe. For example, because the Columbia Basin is large and is diverse with respect to hydrology, climate, geology, geography, species, and habitat types, development of the hydropower system has created unique effects in different regions of the basin and for different species. Specific effects vary depending on location, dam type, dam operations, and the duration of time since the dam was constructed. As such, appropriate actions to achieve protection, mitigation, and enhancement vary throughout the basin. Similarly, Fish and Wildlife Programs have been influenced by the conditions, events, and context of the times in which they were developed. As called for in the Act, the Programs have been developed based on best available scientific knowledge, thus implicitly incorporating adaptive management.

In this presentation we will describe our process to develop an approach for evaluating basin-scale performance of the Program. We will provide conceptual models for how we are organizing information into a consistent format to allow for considering program implementation over time and space. We will also discuss concepts for how to consider different species, populations and biological processes that are the subject of the mitigation program.

Blue Carbon Research to Establish Baseline Conditions and Inform Restoration Planning in the Pacific Northwest

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Since 2016, we have been collecting data on carbon dynamics in 34 natural and disturbed coastal wetlands from northern California to Washington, including nine sites in the Columbia River Estuary (CRE). These ecosystems are carbon hotspots due to their high productivity, high sedimentation rates, and low decomposition rates. Quantification of carbon sequestration and fluxes is needed to inform conservation and restoration decision making and to forecast potential climate change effects on carbon dynamics. We found that carbon stocks increased along the elevation gradient, with tidal spruce swamps storing carbon at one of the highest levels in the world, comparable to tropical mangroves. We are also compiling a database of west-coast carbon stocks to compare data regionally and identify data gaps. Recently, we measured greenhouse gas (CO_2/CH_4/N_2O) fluxes over a 1-year period and across gradients of environmental drivers to evaluate the effect of inundation, salinity, and season. Preliminary findings indicate complex patterns of methane consumption and production, with higher methane fluxes when temperature and groundwater levels were high and salinity was low. Nitrous oxide fluxes in tidal wetlands were lower than dry pasture sites. Next steps include developing net ecosystem carbon budgets, development of a regional blue carbon calculator, and application of results to restoration and climate-change forecast modeling to understand potential future carbon dynamics and inform management decisions in coastal wetland ecosystems.

Development of Site Evaluation Cards:
Preliminary Findings Based on Restoration Project Revisits in Fall 2022

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This presentation will concern the Site Evaluation Cards (SECs) resulting from activities undertaken during fall 2022 as part of the Expert Regional Technical Group's (ERTG's) project review process to revisit selected restoration projects constructed for the Columbia Estuary Ecosystem Restoration Program (CEERP). The goal of the SECs is to document and assess the results of constructed projects, leading to improved project design, monitoring, and assessments of future projects, thereby increasing the effectiveness of the program. Revisiting restoration projects constructed under CEERP is an important element of the program's adaptive management process because the revisits allow the ERTG, sponsors, and all interested parties to better assess project outcomes and apply the lessons learned to future projects. Since the ERTG evaluates projects in the proposal/design phase, learning what resulted on-the-ground based on pre- and post-construction observations and monitoring data helps "close the loop." During fall 2022, sponsors prepared Revisit Templates and made presentations to the ERTG and Steering Committee for 18 projects. Applying this essential information, the ERTG drafted SECs, highlighting: How does the project's outcome compare to what the ERTG expected (better, comparable, worse)? How do scores for Certainty of Success, Access, and Capacity and resulting project benefit units compare between pre- and post-construction? What is the project's overall performance to date relative to the sponsor's original vision for the project (performance exceeded, met, or underperformed)? Since development of SECs is new to the ERTG process, regional outreach, review, and feedback are imperative.

Modeled future wetland habitat impacts of an M9 Cascadia earthquake on the Columbia River Estuary

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M9 megathrust earthquakes have profoundly altered wetlands in the Lower Columbia River and Estuary (LCRE) during the Holocene. The last major earthquake occurred in 1700 and resulted in instant conversion of spruce forested wetland to tidal flats throughout the Pacific Northwest and took decades to centuries to recover. In this presentation, we use numerical simulations to explore how a future, near-instantaneous subsidence of up to 2 meters after an M9 may impact wetland habitats and tidal hydrodynamics. Three different scenarios are evaluated: 1) M9 subsidence alone; 2) M9 subsidence and infrastructure failure; and 3) M9 subsidence, infrastructure failure, and a main-channel liquefaction event near Sauvie Island.

Overall, we find that >90% of wetland habitats will shift to lower-elevation habitat types, with an overall loss of ~29% of intertidal habitat area. Low water datums from Cathlamet Bay to the mouth will be lowered as a result of the reduction in land surface elevation in all scenarios. Tidal shifts caused by the lowered bed are reduced in the infrastructure failure scenario due to modulation of the tides by an enhanced floodplain area. The liquefaction scenario results in shallowing of the adjacent tidal river, causing a wave reflection, which results in local amplification of tidal range downstream and damping of tidal range upstream.

Comparison of a dynamic (land-subsidence + hydrodynamic model) versus a bathtub (land-subsidence only) model resulted in significant differences in the estimates of lowered habitat areas. For example, the dynamic model predicted 67% of sandflats convert to subtidal in Cathlamet Bay, while the bathtub model resulted in a prediction of 91%. These results demonstrate the importance of incorporating hydrodynamic models into estimates of habitat change from natural disasters.

Tidal-Hydrological Dynamics of Water Temperature across Freshwater Forested Wetlands

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Tidal freshwater forests were once extensive across temperate coastlines, but land use change and logging resulted in the loss and fragmentation of these forests to as little as 5% of their historical range in the Pacific Northwest. This loss, along with climate change, has made it more challenging to estimate their historical and potential ecosystem functions and services. To study the effects of tidal forests on water temperature and the potential for forested wetlands to act as climate refugia for aquatic biota, we measured water temperature for two years along channels within five wetlands on Grays Bay and the Grays River, on the Washington side of the Lower Columbia River. The sites included three intact Sitka spruce tidal forests (Secret River, Crooked Creek, and Seal Slough), a recently reconnected and restored formerly diked pasture (Kandoll Farm), and an emergent marsh on the lower Secret River channel. We assessed temperature differences and spatial rates of change at multiple points in the channels within sites, and the differences between the sites on Grays Bay versus its tributary Grays River. We also evaluated how water surface elevation and tidal range influenced the mean, 7 day average daily maximum (7DADmax) and range of temperatures within each site.

The tidal forest near Grays Bay reduced water temperatures by up to 2.7°C (median) and 2.0°C (7DADmax) relative to the emergent marsh and the mainstem, with most cooling occurring during the warm, low-flow months of July through September. Generally consistent, cooling temperature gradients were seen in the Grays Bay forests, with average decreases of -0.16°C and -0.07°C per each 100m distance from the channel mouth into the forest. Gradients in all forest sites were less consistent (more well-mixed) during the freshet. The sites on the Grays River tributary had 7DADmax temperatures that were lower than Grays Bay sites by 1.5°C to 3.1°C during summer, but less cooling effect within the sites; we hypothesize an effect of site size on cooling effect because tributary sites were considerably smaller than those adjacent to Grays Bay. The Grays River site temperatures were driven more by input from the cooler Grays River than by internal effects. In contrast, the Grays Bay sites had upland watersheds that enhanced the forest cooling effects when water levels were low in the tidal frame. The restoring site, with grass and shrub cover, had the least effect on temperature. The emergent marsh on Grays Bay was warmer and more variable than all the forest sites. In summer and fall, the forest sites were also cooler than the mainstem Columbia River. Hydrology and tides affected sites differently: high tidal ranges reduced or reversed the cooling effects in Crooked Creek and Seal Slough, while Secret River and Kandoll Farm had less cooling when water elevation was high. In conclusion, tidal and riverine hydrology and landscape factors mediate temperatures in tidal forests, which can provide important temperature refugia for cold-water

aquatic biota including salmon. Our results emphasize the need for informed preservation, restoration, and adaptive management of tidal forests in riparian zones.

Scaling Up to Implement Complex, High-Risk, Climate-Resilient Floodplain Restoration

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The dire prospects for many imperiled salmonid runs combined with the increasing need for climate resilient infrastructure necessitates increasing the scale and magnitude of floodplain restoration; however, these larger, more impactful projects inherently have greater social and technical risks and complexities. The Steigerwald Reconnection Project is a $32 million effort spanning nine years and 1,000 acres of Columbia River floodplain that successfully navigated those complexities and offers a number of lessons learned that may benefit similar efforts in the future. This talk will summarize the project, which involved 10 landowners, 9 real estate acquisitions, 1.6 miles of setback levee, and 1.7 million cubic yards of earthwork. It also will share lessons learned, including details of the project's risk management strategy, an innovative approach to procurement that netted a reputable contractor whose bid not only was ~25% below the engineer's estimate (and two competing bids) but who also identified a fatal flaw in the project's multi-year phasing, and tips for reducing the carbon footprint of future projects. We also will share a post-mortem on the project budget and why you have to expect a little Type 3 fun on projects of this scale.

A Challenge to the Lower Columbia River Community - Weaving Climate Mitigation into our Conservation and Restoration Programs

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The Intergovernmental Panel on Climate Change (IPCC) repeatedly has warned that we will exceed the goal of limiting global warming to less than 1.5°C above pre-industrial levels if we do not aggressively reduce greenhouse gas emissions. A recent Stanford study predicts that the world is on track to exceed this cap between 2030-2035 and that there is an 80% chance of exceeding 2 degrees Celsius by 2050 (Diffenbaugh and Barnes 2023). Amongst other actions, the IPCC recommends that we protect and aggressively restore ecosystems as nature-based solutions for carbon sequestration and storage in addition to other ecosystem services e.g., flood protection, soil retention and erosion control, and nutrient cycling.

Oregon and Washington both have quantifiable targets for reducing greenhouse gas emissions that include nature-based solutions. Washington's Climate Commitment Act (CCA) goal is to reduce greenhouse gas emissions by 95% by 2050, while Oregon's Climate Action Plan (CAP) is to reduce emissions by 45% below 1990 levels by 1935 and by at least 80% by 2050.

- Washington's CCA implements a cap-and-invest program by setting an emissions cap that lowers over time to meet the goal and using a market-based system that could link to similar programs in California and Quebec.
- Oregon's CAP directs ODEQ to cap and reduce emissions from large stationary sources and major fossil fuel emitters. It focuses on reducing carbon in transportation sector (roughly 40% of GHG emissions), increasing energy efficiency of buildings, investing in renewable energy, and integrating nature-based solutions for carbon sequestration and storage on Oregon's natural and working lands.

We challenge the lower Columbia River community to weave climate mitigation (in addition to adaptation!) into our conservation and restoration programs via multiple opportunities: 1) by implementing our habitat coverage targets (no net loss of native habitats from 2009; recover 40% of historic coverage of priority habitats by river reach by 2050 (restore 22,480 acres)); 2) by reducing our emissions footprint in our restoration projects by explicitly using less intensive, more passive restoration techniques that require less earth-turning, heavy machinery; 3) by calculating the carbon emissions from constructing our restoration projects and offsetting these through increasing our native plant establishment efforts; 4) by assessing and inventorying the carbon storage opportunities available through restoration and land acquisition projects and implementation of regenerative agricultural practices; and 5) tracking loss of native habitats and concomitant GHG emissions as a result of land conversions to development and urbanization.

Thermal Refuge Enhancement at the Horsetail/Oneonta Creek - Columbia River Confluence

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During the past century, a combination of factors has degraded Columbia River water quality, including its thermal regime. Currently, summer migrating adult and juvenile salmonids using the Columbia River are exposed to mainstem temperatures that average well above thresholds for optimal survival and are expected to increase further with climate change. Numerous studies have documented adult summer migrants seeking refuge in cooler embayments at mid-Columbia tributary confluences for periods of weeks to months during July, August, and September. A large spatial gap of nearly sixty miles exists in the upper estuary (upstream of the Lewis River confluence) where no thermal refuge is presently available. Human infrastructure and removal of large wood loading has simplified a once complex shoreline, and many tributary confluence habitats in this zone lie behind highway and railroad embankments, cut off or only marginally connected to complex floodplain habitats. A prior study by the Lower Columbia Estuary Partnership evaluated the potential for creating thermal refuge zones at smaller confluences within this gap area through the enhancement of existing physical features, essentially replicating conditions seen at some of the larger mid-Columbia refuges. High resolution hydrodynamic and water quality modeling identified the confluence with Horsetail/Oneonta Creeks as one of three potential confluence zones capable of providing suitable refuge conditions for migrating salmonids. Based on depth, temperature, and size criteria that we established from existing literature and field observations of similar mid-Columbia refuge zones, this confluence has been selected for a potential pilot project to establish a thermal refuge zone for migrating salmon, through enhancement of the existing site. Here, we present results of the feasibility assessment to date, including a review of the predicted physical performance of the modeled embayment, sedimentation risk analysis, alternatives considered, and the associated regulatory, land ownership, and implementation challenges. While full reconnection of the entire floodplain is no longer feasible, we envision the project as a way to reconnect migrating fish to a portion of the cold-water refuge and complex edge habitat lost due to modern highway and railway construction. If successfully implemented in the future, this project may serve as a model for implementing a climate change adaptation strategy that would help summer-migrating salmon populations continue navigating the mainstem Columbia River in the coming decades.

Estuaries as microbial bioreactors: relationships between organic matter, bacterial productivity, and microbial diversity in the Columbia River Estuary

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Estuaries function as "bioreactors" for fluvial materials in which microbial, biogeochemical, and ecological processes transform organic matter and nutrients prior to export to coastal oceans. The impact of these bioreactors is linked to the bioavailability and residence time of fluvial material, and to the activity and diversity of microbial communities. In the Columbia River Estuary, water residence time is short (approximately 2 d), but particle residence time is extended by estuarine turbidity maxima (ETM). To investigate relationships between organic matter, microbial activity, and microbial diversity, samples were collected in spring and fall 2012 and summer 2013, and ETM particles were fractionated by settling velocity using an Owen-style settling column. The composition of suspended particulate matter shifted seasonally following the river phytoplankton bloom in spring with decreasing organic content, increasing C/N ratio, and an increasing contribution of autochthonous particulate organic matter (POM) produced in four shallow lateral bays. Heterotrophic bacterial production responded to seasonal changes in POM and correlated most strongly with estimates of labile particulate nitrogen during any particular season, and with the riverine flux of chlorophyll a (Chl a) across all seasons. Microbial communities associated with ETM particles were diverse and seasonally variable, consisting of a mixture of taxa dispersed from river and ocean as well as taxa that were uniquely estuarine. These results demonstrate that microbial diversity and heterotrophic activity in the Columbia River estuary are influenced by particulate organic matter lability, and by the degree to which estuarine turbidity maxima retain and concentrate river organic matter.

Lower Columbia River Suspended Sediment Modeling and Real-Time Data Network

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A USGS sediment-monitoring program has enabled the development of functional surrogate models to provide estimates of real-time continuous suspended-sediment data at four sites on the Lower Columbia River (LCR) basin since 2016. Time series of suspended-sediment data are produced at the Columbia River near Vancouver, Washington, the Willamette River near Portland, Oregon, the Columbia River at Port Westward near Quincy, Oregon, and the Cowlitz River near Castle Rock, Washington. The surrogate suspended-sediment models will inform development of a sediment budget for the LCR to support planning efforts for dredged material placement and enable informed regional sediment management. The presentation will provide an overview of the sediment data collection program, analysis and modeling results which will allow for development of a proof-of-concept phase to yield a precise sediment flux estimate at each of the sites above.

Visualizing and Analyzing 10 years of Wetland Habitat Monitoring Data in Tableau

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Since 2008, the Estuary Partnership's Ecosystem Management Program and Action Effectiveness Monitoring Program have collectively tracked the status and trends of both natural and restored wetlands throughout the Lower Columbia River Estuary. Tracking the status and trends across the lower Columbia River, understanding the critical metrics, and visualizing and disseminating information in an easy-to-understand method are all critical to inform future restoration design and improve monitoring across the watershed. With millions of water surface elevation and temperature data points, tens of thousands of vegetation plots and soil statistics, and thousands of sediment accretion measurements, software more specialized than Excel is required to analyze the data on an estuary-wide scale, especially when each data point is georeferenced. We experimented with R, Exploratory, and several other software programs before ultimately deciding on Tableau due to the ease of use and power of the software. We utilized Tableau for basic data management and QA/QC, as well as exploring data, conducting analyses, and disseminating results to project partners. Dashboards allow near-instant feedback to partners and explicitly allow one to investigate and explore how sites have developed post-restoration, without additional analysis or input. In this talk, we will outline the steps we took to transform the data from Excel into a Tableau-ready format and the initial QA/QC processes, including the drawbacks of the simple text file solution we chose. Additionally, we will discuss the exploration processes, dashboard creation, and the ease of expanding the dataset. In the future, we will be combining these datasets with drone imagery and vegetation models to further inform restoration. This overview of data storage and visualization as well as preliminary meta-analyses of the lower Columbia River, will provide the audience with an example of a novel technique that can be utilized for their own data and time issues to aid ongoing restoration and adaptive management efforts.

Lessons Learned for the Columbia from Puget Sound Estuary Restoration

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Theories in island biogeography and conservation biology support restoring several large habitat patches that are connected in the Lower Columbia River Estuary (LCRE) compared to restoring many more small and disconnected habitat patches. This presentation will leverage lessons learned from designing and constructing large estuary restoration projects over the last 10 years in the Puget Sound and will highlight the design and analysis elements that led to a trajectory for mature marsh evolution. Using case studies of 4 tidal projects totaling more than 700 restored acres (and 100's more if measured as connected acres), we will attempt to provide valuable lessons for future tidal restoration in the LCRE. Projects range in location from major river deltas like the Stillaguamish and Snohomish to estuaries along the Straights of Juan de Fuca and Admiralty Inlet. How can we design and implement these 200+ acre projects in our estuaries more efficiently and more adaptively? How can we leverage marsh science to effectively design, sequence, and construct?

Predicting near-future juvenile salmon response to water management and engineered structures across diverse tidal river conditions

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The decisions of volitional, freely moving fish frequently dictate the success of multi-million dollar engineered structures and management actions. In waterways supporting the needs of human society, structures and other management actions are often used to facilitate the safe travel and growth of fish for improved survival. In other cases, structures are used to facilitate the capture or limit the spread of invasive species. The design of waterways management and infrastructure for fish typically involves some form of build-and-test. The ability to predict fish response to infrastructure and management actions during the design phase has the potential to save time and money as well as living resources. Research in decision-making, perception, and fish-flow interaction dates back more than a century. A numerical model simulating a reduced form of animal cognition and perception, using algorithms dating back (in some cases) more than a century, can reproduce fish movement patterns observed in tidal river environments. For the past 25 years, the U.S. Army Corps of Engineers, Research and Development Center (ERDC), has been working on a management tool that can hindcast and predict near-future fish response to infrastructure designs and management actions. Development of the tool – a Eulerian-Lagrangian-agent Method (ELAM) - has leveraged over $65 million dollars' worth of river and fish movement data. The model is not perfect, and limitations will be discussed. However, the ELAM model has achieved unique success in predicting near-future 3-D/2-D fish movement, guidance, and entrainment, and also has accurately predicted patterns prior to the availability of field data in some cases. Further, the ELAM has performed well on out-of-sample data where the future condition is different from the calibration conditions. The model does not attempt to represent the true cognitive architecture of fish; rather, the decision-support tool attempts to leverage researched non-linear relationships between stimuli, perception, and action to make predictions of what fish will do at the scale of river infrastructure and water operations management. Central to model performance is the notion that fish are attuned to more than one environmental signal and more than one timescale. Emerging theoretical developments suggest the potential exists for inverting downstream-moving behavior rules to describe upstream-moving fishes. Fish movement depends on the species, but work unifying past data into a common framework—and advanced by a growing community of ELAM users—facilitates value-added benefits to existing data, the ability to understand fish behavior more quickly, and the ability to better incorporate animal behavior into the fast-paced nature of engineering design projects.

The Past, Present, and Future of the CMOP Observatory at the Columbia River Inter-Tribal Fish Commission (CRITFC)

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The Coastal Margin Observation and Prediction (CMOP) program includes a long-running observation network of buoys and fixed stations in the Columbia River estuary and plume. In 2020, CRITFC assumed stewardship of CMOP (previously an NSF Science and Technology Center hosted at the Oregon Health & Science University) in order to complement and benefit CRITFC efforts to protect and restore anadromous fish populations of the Columbia Basin. CMOP currently maintains one multi-depth ocean buoy in the Columbia River plume, two multi-depth dock-based stations in the lower estuary, and six buoys/fixed stations within the estuary, including locations in the mainstem and lateral bays. Instruments at these stations continuously measure water properties including temperature, salinity, turbidity, dissolved oxygen, nitrate, fluorescence, and photosynthetic efficiency. With >20 years of physical observations and >10 years of biogeochemical observations, this observatory supports crucial time series datasets that can be used to assess the long-term changes and drivers of physical and biogeochemical conditions in the Columbia River estuary. Here, we present an overview of current data collection efforts and long-term trends, with a special focus on a 12-year time-series analysis at the Point Adams station in Hammond, Oregon. This is a dynamic location that observes both ocean and river conditions depending on the tide and river discharge, and these measurements demonstrate repeatable patterns in water temperature and dissolved oxygen that cause physiological stress to salmon. We also discuss the future directions of the CMOP observatory, including the upcoming installation of a continuous ocean acidification analysis system and efforts to establish an environmental DNA collection program to enable the monitoring of fish and microbial populations within the lower estuary.

Multispectral UAV Data for Wetland Plant Community Mapping: Predicting and Evaluating Restoration Impacts

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The focus of this research is to highlight the effectiveness of integrating UAV (Unmanned Aerial Vehicle) multispectral data into our standard approach to wetland monitoring and restoration planning. The goal of this approach is to integrate multiple aspects of wetland recovery, including 1) native and non-native plant community development and 2) changes in salmonid habitat opportunity into a sitewide assessment of ecological condition. The utilization of UAV multispectral data collection provides an opportunity to capture ongoing changes in wetland plant community conditions and topography. When these data are combined with site hydrology (water depth and temperature), they can provide an integrated approach for evaluating wetland habitat conditions over time and predicting changes from restoration actions and climate change. In addition to monitoring site hydrologic conditions, wetland plant community composition data determines habitat quality and provides essential organic inputs to the juvenile salmonid food web. Post-restoration shifts in wetland plant communities primarily reflect changes in site hydrology and, as a result, defines the structure and function of restored habitats. We utilize the UAV to obtain Near Infrared (NIR) and RGB sensor data to generate multispectral composite orthomosaic and digital surface models (DSM) of site elevations. Through an integrated multispectral data processing and modeling approach using Pix4D, R, and ArcGIS software, these UAV data are combined with traditional field plant surveys to produce sitewide vegetation maps. This approach allows for a more accurate and cost-effective assessment of existing habitat conditions, including the extent of dominant native and non-native emergent vegetation such as wapato (*Sagittaria latifolia*) and reed canarygrass (*Phalaris arundinacea*). Maps made from these integrated aerial and ground surveys can be combined with salmon habitat opportunity assessments and used to assess and model potential restoration impacts, track post-restoration changes at sites, and identify areas or locations that may benefit from further adaptive restoration actions.

Action Plan for Restoring Chum Salmon Resulting from Outreach and Studies of the Youngs Bay and Big Creek Watersheds

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The NCWA spearheaded a collaboration to examine the historical presence, current situation, and future potential of chum salmon (*Oncorhynchus keta*) in the Youngs Bay and Big Creek watersheds of the Lower Columbia River region through a technical assistance grant and a stakeholder engagement grant awarded by Oregon Watershed Enhancement Board. The resulting understandings of the area's history, issues within the watersheds for chum, current restoration techniques to address these issues, and plans to put them to use will be presented.

Oregon's Coordinating Council on Ocean Acidification and Hypoxia: Increasing Knowledge, Awareness, and Action on Ocean Change

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2021 was the most extreme season on record for hypoxia, or low-oxygen, yet changing ocean conditions have been recognized in Oregon for over two decades. In the early 2000s, seasonal hypoxia was first documented in Oregon's nearshore waters and was associated with presumptive crab mortality. Then, in 2006, the Oregon oyster industry suffered catastrophic loss of oyster juveniles due to what was later identified as ocean acidification. Since then, Ocean Acidification and Hypoxia (OAH) events have been documented by increasingly robust research and monitoring programs across the west coast, that show OAH seasons disrupting and undermining the rich ocean and estuarine ecosystems in a variety of ways including species distribution, physiology, forage, and productivity. The impacts of OAH are anticipated to have far-reaching consequences, for both Oregon's ocean ecosystem and the economy. In recognition of these changes and the need to address them, the Oregon legislature established the Oregon Coordinating Council on OAH in 2017 to develop recommendations on steps the state can take to understand, adapt to, and mitigate OAH vulnerabilities. The Governor-adopted Oregon OAH Action Plan (2019-2025) outlines the state's roadmap for OAH Actions, and the Oregon OAH Council is working to make progress on roadmap. This presentation will highlight the progress made as well as the remaining needs for the 6-year action plan. Early planning has started for Oregon's next OAH Action Plan (2025-2031), which will result from a public process that is anticipated to kick-off in 2024.

Revegetation and Carbon Sequestration on a Large Columbia River Floodplain

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The Steigerwald Reconnection Project reconnected 965 acres of historic Columbia River floodplain. In the process, the project not only re-established the site's historic hydrology (both from the Columbia River and Gibbons Creek) to hundreds of acres of degraded wetland, it also created over 100 acres of new wetland and is in the process of re-establishing 250 acres of native riparian forest. Some of this reforestation not only is critical to meeting the project's climate resiliency goals but also to protecting flood control infrastructure, such as the new setback levees. Revegetation of the wetland and riparian habitats over the large project footprint was an immense challenge that was adaptively managed throughout construction and will continue to be in the years to come. This presentation will share the project team's strategy for managing the revegetation process, adapting to all manner of extreme weather conditions, modifying the planting list to account for climate change, and mitigating challenging soil conditions for planting. The presentation also will detail the project's effort to expand the site's wapato (*Sagittaria latifolia*) and black cottonwood (*Populus trichocarpa)* footprints and how the riparian plantings will, over time, sequester 100% of project emissions (including those associated with burning 429,000 gallons of diesel fuel and pouring nearly 1,100 cubic yards of concrete).

Columbia Estuary Ecosystem Restoration Program: Documenting Performance and Leveraging Opportunities for Programmatic Reporting and Accountability

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The Columbia Estuary Ecosystem Restoration Program (CEERP) has been undertaking restoration, monitoring, and research activities aimed at understanding and improving habitat for listed salmonids in the lower Columbia River and estuary for nearly two decades. The collective knowledge gains from studies, projects, and ongoing research and monitoring enable the CEERP program managers (i.e., USACE, BPA, and NMFS) to assess how well the program is meeting its stated objectives, as well as helping to inform new priorities and fill potential gaps in understanding. Over the last year, CEERP managers have made a concerted effort to survey project sponsors, researchers, monitoring practitioners, and the Expert Regional Technical Group (ERTG), both formally and informally, to better understand critical uncertainties. Managers are also working to secure the support required to effectively meet short and long-term goals at project and programmatic scales. This presentation will provide an update on CEERP restoration outcomes to date, discuss priority uncertainties that could be focal points for new research, summarize new initiatives within CEERP to streamline data sharing, and highlight key findings from recent project revisits that give a window into the continuum of restoration outcomes and adaptive management. In sum, CEERP is continually striving to improve program assessment, reporting, and accountability.

Restoration incorporating living shorelines, Stage 0 alluvial fans, and other design measures for climate adaptability on a 1,000 acre floodplain of the Lower Columbia River

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The Lower Columbia Estuary Partnership, Port of Camas-Washougal, U.S. Fish and Wildlife Service, Bonneville Power Administration, and others have partnered to reconnect 965 acres of historic Columbia River floodplain and reduce flood risks at the Steigerwald Lake National Wildlife Refuge located southeast of Washougal in Clark County, Washington. Restoration and reconnection of the floodplain presented numerous technical challenges, including ensuring no adverse impacts to WA State Route 14 and designing a levee and floodwall to meet strict regulatory, flood risk reduction, and habitat objectives. Reconnection was particularly challenging given anticipated changes in climate (higher winter flows and higher summer stream temperatures) and future increases in watershed development. Three distinct measures were developed to improve resiliency to climate risk and uncertainty. (1) A vegetated wind-wave overbuild berm was designed in lieu of riprap to protect the levee from extreme winds and associated wave erosion that is anticipated to increase in the future. The berm also accommodates transitioning wetland and riparian habitats up the topographic slope due to changing river stages. (2) When analyzing site hydrology and hydraulics, the design also incorporated peak flows scaled to account for anticipated future development and higher intensity winter storms, as predicted by climate models. Consequently, site infrastructure including the west setback levee is designed for Gibbons Creek discharges that are 20% larger than current peaks. (3) Finally, the design targeted full floodplain connectivity (Stage Zero condition) in restoring Gibbons Creek's 80-acre alluvial fan while also ensuring functionality of instream habitat at the base of the alluvial fan. Maximizing hyporheic exchange to cool water temperatures along with wood structures for initial floodplain roughness and cover habitat for juvenile salmonids in turn maximizes thermal refuge for salmonids throughout the warm summer months. These three climate resiliency design measures were based on several simple yet often underestimated concepts including space, scale, imprecision, and redundancy, and the focus of the presentation will be on how these ideas can be applied even in constrained environments to yield high functioning floodplain habitat.

Columbia River Sediment Loads: Evaluating Historical Changes and Observing the Response of Lower Columbia Wetlands

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Trends in sediment supply in the Columbia River and long-term changes in the sediment budget have important implications for wetland restoration, salmon recovery, the management of infrastructure and navigation, and coastal erosion in the 165-km littoral cell from Point Grenville, Washington to Tillamook Head, Oregon. The Lower Columbia River Estuary (LCRE) appears always to have been a system with a relatively low sediment supply compared to, for example, the nearby Fraser River and other estuaries. Given sea level rise (SLR), extensive sediment removal, and sediment trapping behind dams, it is vital to define historical and present sediment inputs. Using data from as early as the 1880s, we have developed historical (pre-1940), mid-20th century (1940-1980) and modern (post-1980) sediment rating curves for seven locations on the Columbia River and twenty-eight major tributaries. These statistical relationships model the influence of river discharge on the total suspended load (coarse plus fine material) and the total load of fine sediment (<0.0625 mm grain size). Since the 1880s, these relationships have shifted in response to changes in river discharge, land use, and river channel modifications. Estimates of current sediment loads show that the Columbia River system has lost most of its sediment supply compared to historical conditions—reductions are as much as 9 million metric tons annually in the lower Columbia River below Bonneville Dam. The coarse load has been reduced by about 75% and the fine load by 70%. The greatest changes have occurred since 1980 and may reflect the success of post-1972 water quality regulations. Tributary loads show smaller decreases, underlining their importance for maintaining future sediment supply to the estuary. In addition, the timing of peak sediment supply to the estuary occurs earlier in the season than historically, in response to comparable shifts in peak flows. Overall, sediment delivery to the Lower Columbia River (LCR) and its flanking wetlands has substantially decreased over 140 years of development. These sediment load estimates, drawing on heretofore undigitized datasets and synthesizing all known data, form a relatively complete picture of the Columbia River Basin from the British Columbia to Astoria, but the role of rare events, e.g., large winter floods, volcanic eruptions, and landslides, remains uncertain.

How have LCRE wetlands responded to the above historical changes? Long-term accretion measurements indicate that several LCR wetland sites are still accreting. Here we also introduce the Sediment Sentinel System, a network of turbidity and velocity sensors co-located with Sediment Elevation Table monitoring sites, that is designed to investigate impacts of this basin-scale shift on tidal wetlands. The specific purpose is to reconcile estimates of decreasing

sediment supply with observed long-term accretion, and to identify the sediment transport pathways that are currently maintaining LCR wetlands. Understanding historical trends and current pathways is critical as climate change, SLR, and reservoir operations continue to exert pressure on critical wetland habitats and future restoration efforts.

Connections with the Nearshore Ocean at the Mouth of the Columbia River

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The Mouth of the Columbia River (MCR) is host to a confrontation between Titans of Nature, a spectacle that must be fought twice each day but never won: Ocean tide versus River flow, life-forces that sustain ecology within the Columbia River and beyond. The MCR is also a regionally critical coastal inlet, facilitating more than $25 billion in navigation commerce to world markets. To enable deep draft navigation through the MCR, the U.S. Army Corps of Engineers removes 3-4 million cubic yards of sand from the MCR navigation channel each year. The sustainability of the MCR inlet is dependent on how we beneficially use this dredged material to maintain the inlet's morphology without harming ecology. A leading theme for this presentation will summarize results from several collaborative investigations that have produced actionable science enabling the Corps of Engineers to place 90% of the sand dredged at MCR in a manner that is beneficial for sustaining the inlet's morphology. The presentation's second theme will illustrate how the MCR's continued evolution has beset emerging vulnerabilities for multiple locations within the inlet. To appreciate the presentation results, some background is provided. Before the ocean inlet at MCR was improved for navigation during 1885-1939, passage through the MCR was considered to be one of the most dangerous bar crossings in the world and was known as the graveyard of the Pacific. Famous mariners would lament "that the terrors of the bar of the Columbia are one of the most fearful sights that can possibly meet the eye of the sailor." Although the MCR is now an engineered inlet, it is not tranquil nor static, and the spectacle between ocean and river goes on. The dynamism of nearshore ocean waters at MCR continues to exert an evolving influence on morphology, both on the ocean side and estuary side of the inlet. This dynamism drives sediment transport within the MCR inlet, eroding sediment from tidal shoals and spits and depositing sand within the federal navigation channel. Through collaborative efforts between MCR stakeholders, regulatory interests, researchers, and the U.S. Army Corps of Engineers, the nearshore ocean of MCR has revealed some of the secrets regarding sediment transport at the MCR. Results improve our use of dredged material to sustain the inlet's morphology and benthic ecology, and address emerging vulnerabilities. Essential tenets for successful collaboration at the MCR are: Learn by doing and do no harm. Our work is not done. This presentation will share insights exemplified by the following questions.

- Where does the sand at MCR go? — Visualizing sediment transport pathways using a sediment tracer.

- What’s happening down there? — Evaluating dredged material placement on nearshore benthos.
- Do things really change that much? — Assessing decades of morphology change of the MCR inlet.
- Castles on the sand? — Sustaining an engineered inlet by maintaining morphology.
- Feeding the beast? — Augmenting the sediment budget using sand dredged from the MCR.

Status and Trends from a Decade of Time Series Water Quality Monitoring in the Mainstem and Intertidal Wetlands of the Columbia River Estuary

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The Lower Columbia River Estuary (LCRE) encompasses fluvial freshwater and brackish tidal wetlands interconnected by the Columbia River across the ~230 km region between the Bonneville Dam and the Pacific Ocean. The region is highly productive and known for its importance to anadromous fish, including endangered salmon and lamprey. Despite its central role in the environmental and economic well-being of the Pacific Northwest, the LCRE wetland system has traditionally been relatively lacking in basic water quality measurements and time series monitoring. This is partially due to the challenges of monitoring over a large geographical extent, but also to the challenges of monitoring the dynamic nature of the LCRE wetlands, which are characterized by intermittent flooding at time scales ranging from daily tidal inundation to seasonal flooding caused by upstream dam management, episodic events, and the annual spring freshet.

Over the last decade, the Ecosystem Monitoring Program coordinated by the Lower Columbia Estuary Partnership has been monitoring habitat and ecosystem conditions at undisturbed wetland sites that span the LCRE. One component of the monitoring is high resolution, in situ measurements of basic water quality parameters including temperature, conductivity/salinity, dissolved oxygen, pH, chlorophyll a fluorescence, and turbidity. Here we present an analysis of the dataset including status and trends over the last decade associated with: inter-annual variability, mainstem river conditions, extreme events, and human activities. The results of this work can be used to evaluate ongoing wetland restoration projects and to plan for future large-scale changes to both hydrologic and climate conditions.

Growth, size, and survival: The impact of growth in the early ocean and lower Columbia River estuary on early ocean survival of Interior Columbia River Spring Chinook salmon

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Early ocean residence is a critical period in the life history of juvenile Pacific salmon. During the transition from freshwater to the marine environment individuals are exposed to a suite of new prey, predators, and habitats and must physiologically adapt to salt water. During this period size and growth of individuals is thought to play an important role regulating population abundance. This is because size can impact both susceptibility to predators and the availability of prey. This study examined the impacts of size and growth, in freshwater and in the nearshore ocean (within three weeks of ocean entry), on survival of Interior Columbia River Spring Chinook salmon. We used a multidisciplinary approach consisting of otolith chemical and structural analyses, hormonal measures of growth, genetic stock identification techniques, and parentage-based tagging to examine the impacts that size and growth have on individual survival and cohort strength. We first examined how growth in the Columbia River impacted survival through the early ocean period on an intra annual scale over two years of poor survival (2016 and 2017). Second, we examined how size and growth during the period of early ocean residence explained variation in cohort strength on inter-annual scales over a longer time (2007, 2008, 2011, 2015-2019). This period experienced significant ecosystem disturbance in the form of marine heatwaves in 2015-2016 and 2019. On intra-annual scales we found no evidence for size selection, although we found that individuals that grew faster in freshwater were more likely to survive the early ocean period in the lower survival year (2016) than in the higher survival year (2017). Interannually, we found that the size and condition of individuals during the early ocean period explained a significant portion of the variation in cohort survival. Years in which fish were larger and in better condition correlated with higher cohort survival. Together, our results indicate that larger, faster growing fish have a survival advantage during the early ocean period. Management practices that promote growth of individuals prior to ocean entry and allow larger sizes to be attained in the ocean should be investigated as mechanisms to promote early ocean survival of Columbia River salmon.

New Solutions for Tide Gates, Fish Passage and Working Landscapes

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A contributing factor to the loss of tidal wetlands is dikes, levees, and tide gates that impede the historic function of low-lying coastal floodplains. In Oregon, stakeholders have awakened to the challenge and opportunity presented by tide gate infrastructure. Poor performing tide gates are required by law to be replaced or retrofitted to be fish passage compliant, but it is a considerable expense for landowners. Additionally, the scope and scale of Oregon's tide gate problem is poorly understood. As a result, the Oregon Tide Gate Partnership formed and is committed to seeking solutions that serve the needs of both people and nature. The Partnership is working to understand and increase awareness of the size, scope, and cost of Oregon's tide gate problem, and harnessing our scientific and technical expertise to pursue solutions. A tide gate inventory of the entire Oregon Coast and Columbia River was completed. In addition, The Nature Conservancy has developed a decision support tool that allows us to optimize among tide gates to help ensure we are focused on repair, retrofitting, or replacement of tide gates that maximize fish and wildlife benefits at the least cost. To help point private and public investments to the tide gate locations that will provide the greatest gains, TNC expanded the tool to include infrastructure, agricultural lands, and climate change scenarios. The results can be especially useful to project planners and decision makers in terms of evaluating the net gain in benefits, estimating return on investments, fundraising, and budgeting, and investigating spatial patterns.

Setback Levee Design, Construction, and Monitoring for the Steigerwald Reconnection Project

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The construction of setback levees for the Steigerwald Reconnection Project provided an effective method to maintain flood protection for existing residents, commercial properties, and infrastructure, but presented significant challenges. This presentation will discuss the geotechnical aspects for design and construction of large levees on soft, Columbia River alluvium. The design had to account for the seepage, strength, and settlement properties of the foundation materials and evaluate native soils and the existing levee embankment as the two sources available for levee fill construction. The project encountered several critical challenges during construction related embankment sequencing, rapid levee settlement, and typically short construction windows of the Pacific Northwest. This presentation will discuss how the design and construction teams used close coordination, test fill embankments, and instrumentation to resolve the issues to complete the project on time and within budget.

Update on Oregon Water Science Center Columbia River Basin contaminant studies

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Contaminant studies are crucial in understanding the presence and potential effects of toxic chemicals on aquatic ecosystems and human health. Several organizations, including the Oregon Water Science Center (ORWSC), have investigated the presence of contaminants in the Columbia River Basin, and determined that several contaminants of concern exist in multiple media types, e.g., sediments, water, and tissues of aquatic organisms. Previous contaminant studies focusing on the Columbia River Basin by ORWSC scientists have included: the Lower Columbia Estuary Partnership's Ecosystem Monitoring Program (2004-05) which focused on water and juvenile salmonids, Contaminants and Habitat Characterization (ConHab project, 2008-11), investigating legacy and emerging contaminants in largescale suckers (2014), and examining contaminants affecting larval Pacific lamprey (2015). ORWSC has continued its research in the Columbia River Basin by recently publishing an assessment of persistent chemicals of concern in white sturgeon (2022) in the Hanford Reach of the Columbia River. Investigations into contaminants are ongoing, with researchers examining PFAS, also known as "forever chemicals," within the Columbia Slough in Portland, Oregon. Tissues of fillet, liver, and blood were extracted from a variety of fishes, including largescale suckers, largemouth bass, carp, and goldfish at three separate reaches in the slough. The Columbia Slough is an important water body to examine because of its proximity to the Portland International Airport, Oregon Air National Guard, and historical fire training facilities, where firefighting foams that contain PFAS compounds were used and drain directly into the Columbia Slough through stormwater outfalls. Understanding the impact of PFAS contamination have helped inform decision makers to assess the potential risks of consuming fish from the Columbia Slough. Additionally, a separate ongoing investigation on contaminants is focusing on Pacific lamprey sampled in the Pacific Ocean and a major tributary of the Columbia River, the Deschutes River. Legacy and emerging chemicals of concern are being examined in tissues of Pacific lamprey to characterize the presence of these chemicals and compare to relevant human-health thresholds. This study will also explore any differences in contaminant concentrations between ocean-caught and returning adult Pacific lampreys. Results of the study will help identify potential differences in contaminant accumulation between the two groups and help decision makers identify the potential risks from human consumption of Pacific lamprey. Lastly, beginning this year ORWSC, along with the Lower Columbia Estuary Partnership, will repeat data collection efforts for toxic contaminants at 10 sites previously investigated almost 20 years ago. The primary objectives will be to track status and trends of toxic contaminants in the lower Columbia River, and then to publish the results of the data collected in technical and citizen-friendly educational formats.

The secret lives of European green crabs: Habitat utilization as revealed by acoustic telemetry

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The recent proliferation of highly invasive European green crab (EGC) in Pacific Northwest bays and estuaries has caused widespread alarm due to their well-established negative impacts on benthic fauna. The bivalve aquaculture industry may be especially vulnerable to crab predation. In Willapa Bay, at a hotspot at just north of Nahcotta, >26,000 EGC were manually trapped and removed in 2022. However, habitat preferences, tidal movements, and possible seasonal migration patterns of EGC are not fully understood for PNW crab populations. Animal telemetry can offer insights into crab behavior that may lead to more effective remedial actions, such as identifying spatial aggregations or temporal movement chokepoints. This can help resource managers develop a more targeted approach to removal efforts from high value habitats.
This pilot study was designed to test effectiveness of intertidal acoustic telemetry to compare the inter- and subtidal habitat use of EGC at Nahcotta in Willapa Bay. We deployed arrays of acoustic receivers (Vemco VR2AR) at intertidal and subtidal locations to establish an acoustically connected network, potentially allowing for fine-scale movements of EGC across the tidal gradient. One site was a bivalve aquaculture venture, the other an eelgrass-oyster-burrowing shrimp complex we recently mapped with imagery from uncrewed aerial vehicles. In addition to our receivers, transponder signals can be recorded on an existing green sturgeon receiver network spread throughout Willapa Bay.

We tagged four groups of 10 European green crabs with V9-2x-BLU-1 transmitters during 13 October 2022. Treatments were released at high tide at inter- and subtidal locations. We also tagged two groups of 8 Dungeness crab and released them at the subtidal locations. At the time of writing, the experiment is ongoing. However, some preliminary data are available.

On 2 November 2022 data from several receivers from the green sturgeon receiver array were downloaded, and the detections provided to us. After 20 days post-release (dpr), 16 of 20 Dungeness crabs had moved from the Nahcotta site and were detected either north (10) or south (6) of our deployments. In contrast, only two of forty EGC were detected away from the deposition site (one each north and south). On 30 December 2022 we downloaded data from one intertidal receiver from each of the arrays. We detected 82.5% of the forty released EGC from these receivers (both sub- and intertidal releases). Four Dungeness deployed subtidally were also detected in the intertidal zone. Additionally, 5 tagged EGC crabs were reported from the eradication traps at the aquaculture site. Together, these preliminary data indicate a high degree of intertidal use and residency for EGC, in contrast to high mobility for Dungeness crab. This presentation will summarize movements and habitat preferences from the full experiment.

The Effects of Dredged Material Placement on Benthic Assemblages at Woodland Islands

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The U.S. Army Corps of Engineers (USACE) is considering the use of dredged material to augment and expand shallow water habitat in the lower Columbia River and estuary. The intended outcomes of using dredged material for habitat creation is to enhance rearing and foraging opportunities for juvenile salmon and to provide ecological benefits to other species reliant on shallow water habitats. While the results of these actions may yield benefits to species and ecosystems, the trajectory, magnitude, and outcome of responses are unknown. In 2020, the USACE placed ~200,000 CY of dredged material at the off-channel margins of Woodland Islands. To evaluate the effects of dredged material placement at Woodland Islands, PNNL implemented a Before-After-Control-Impact (BACI) study. Data were collected from April – July during the two years of before- and two years after-construction. The study included one impact site, Woodland Islands and two control sites, Martin Island and Bachelor Island. Benthic invertebrates, used as indicators of aquatic ecosystem health, were the primary focus of the BACI study. In addition, sediment characteristics – grain size and nutrients – were evaluated. We found the effect of spatial and temporal variation differed among the biological and environmental variables. Sediment characteristics at the impact site were intermediate to those at the two control locations; grain size and nutrients at the two control locations were either higher or lower than conditions at the impact site. After dredged material placement, sediment conditions at the impact site showed some similarities to conditions prior to placement, and the degree of similarity was dependent on temporal variation. The benthic assemblages at the off-channel sites were composed of more than 70 unique taxonomic groups, including many that are used by juvenile salmonids as prey resources. The benthic assemblage at the impact site was similar to the Martin Island control site before and after dredged material placement. However, patterns in invertebrate abundances varied by different taxonomic groups and across years. These results provide insights into the response of sediment characteristics and benthic assemblages at a dredged material placement site and help to understand the functional response of these projects and habitats.

The Columbia River Intertribal Fish Commission (CRITFC)'s CMOP program: modeling the Columbia River from watershed to the Pacific Basin

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In 2020, CRITFC assumed stewardship of the Coastal Margin Observation & Prediction (CMOP) program, previously an NSF Science & Technology Center led by Oregon Health & Science University. With CMOP, CRITFC added capabilities that support and expand efforts to protect and restore anadromous fish populations of the Columbia Basin, as they migrate into the estuary and coastal ocean. As an OHSU program, CMOP innovated modeling and observation of the estuary and near coast, to inform regional decisions on management and operation—on issues ranging from the deepening of the navigation channel and the renegotiation of the Columbia River Treaty, to coastal inundation from tsunamis and storm surges. CRITFC Is maintaining and expanding CMOP's observation and prediction infrastructure, to support Tribal and regional priorities, with an increased focus on salmon, steelhead, and lamprey protection and restoration. In a separate presentation (Gradoville et al.), we describe our observational program and illustrate the use of its data. Here, we offer an overview of CRITFC's expanded vision of CMOP as infrastructure at the service of Tribal and regional priorities—developed and maintained as long-term representation of the watershed-to-ocean continuum. Recent modeling advances will be used to illustrate our advancement and expansion strategy. Specifically, we will discuss the expansion of our modeling system to the Pacific Ocean basin, to enable tracking of salmon along its entire migration routes—a collaboration with NOAA-NOS. That effort required the use of an enhanced numerical circulation code (SCHISM), able to capture hydrodynamic processes from watersheds to deep ocean. With the benefit of SCHISM, we are now (a) integrating the effect of minor tributaries into our river-to-ocean models, (b) refining the spatial resolution of wetland representation (down to 1m scales), and (c) planning simulations of climate impacts that include and integrate sea level rise, changes of the Bonneville hydrograph due to dam operations and shifts in snowmelt patterns, and combined river and coastal flooding. With these advances and refinements, the Tribes and the region will have available more powerful tools to better support salmon habitat restoration efforts, climate resiliency planning, and coastal resilience under sea level rise.

Columbia River Estuary and Nearshore Data Products and Tools

**Kate Sherman*[1], Joe Bizzarro[2], Jamey Selleck[3], Joan Drinkwin[3], Van Hare[1], Dave Fox[4], Tanya Haddad[5], Andy Lanier[5], and Allison Bailey[6]

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The Pacific Marine and Estuarine Fish Habitat Partnership (PMEP) has developed a spatially explicit framework for comparing estuary and nearshore habitats along the West Coast, including the Columbia River estuary. This presentation will highlight data products and tools created by PMEP and Pacific States Marine Fisheries Commission (PSMFC) within the Columbia River estuary and nearshore environment. These data products include the extent of estuaries based on an elevation-based model, nearshore zones and regions based on bathymetry and management boundaries, and habitats classified using the Coastal and Marine Ecological Classification Standard (CMECS).

In the Columbia River estuary, four CMECS components were mapped using existing data resources to create spatial data for the CMECS aquatic, substrate, geoform and biotic components. In the nearshore off the coast of the Columbia River estuary, the biotic and substrate CMECS components are complete. The nearshore data is a companion to a recently completed report on the state of the Knowledge of Nearshore Habitats along the U.S. West Coast, which provides information on fish and invertebrate use of nearshore habitats mapped by PMEP.

These data provide baseline information for habitats within the Columbia River estuary and nearshore environment, which can be used at a local or regional scale. Since the data is part of a West Coast wide framework, local data can be considered with a broader perspective. These efforts to compile data also provided information on key data gaps in our understanding of habitats within the Columbia River estuary and nearshore.

For this effort, PSMFC and PMEP followed methods and guidance developed by the Oregon Coastal Management Program (OCMP), which has a state-wide framework within the Oregon Coastal Zone.

Shallow-Water Habitat in the Lower Columbia River and Estuary: A Highly Altered System

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This study investigates the magnitude and causes of long-term changes in shallow-water habitat area (SWHA) in the Lower Columbia River and Estuary (LCRE), 1928-2004. SWHA is the area inundated to a depth of 0.1-2m with velocity <0.3m/s. Juvenile salmonids make extensive use of SWHA during migration to the ocean as they adjust to saline conditions, providing access to food, refuge from higher-velocity flows, and cover from predation. Here we develop a physics-based regression model that evaluates higher high water (HHW) from the ocean to the head-of-tide in the LCRE as a function of river flow, tides, and coastal processes. Using modeled HHW to estimate maximum daily floodplain inundation, we hindcast daily SWHA, 1928-2004. A scenario-based attribution strategy is then used to determine the influence of six attribution factors on SWHA over the model period: levees, flow regulation, irrigation, navigational development, subsidence, and climate change.

The regression models indicated that loss of SWHA has been ~55% on an annual-average basis, but ~63% during the spring freshet. Isolation of large parts of the floodplain due to levee construction caused the largest decrease in SWHA (~54%). Climate change and navigational development are responsible for ~5% and ~4%, respectively, with high spatial variability. Flow regulation has caused a 5-16% loss of SWHA (depending on assumed degrees of subsidence) in parts of the estuary and tidal river. Irrigation impacts are small and uncertain.

Some attribution results are non-intuitive; for example, reducing a high flow event may increase SWHA in some reaches while decreasing it in others, because of the 2m SWHA limit. Furthermore, historical floodplain topography is uncertain due to variable subsidence, which introduces systematic uncertainty in results. Specifically, factors that have reduced flows (reservoirs, irrigation, and climate change) or riverbed slope (navigation) produce an increasing modeled effect as assumed historical floodplain elevations are increased to account for subsidence.

There are also important interactions between system alterations. Levees limit SWHA to the lowest parts of the floodplain; these areas were historically inundated too deeply to be SWHA during the freshet periods important to salmonids, but may be SWHA with modern, reduced flows. Overall, SWHA has moved downward in elevation and closer to the channel.

The single largest factor affecting SWHA in the LCRE is floodplain isolation. Thus, restoration of SWHA and its fish-habitat functions requires reconnection of isolated portions of the floodplain. Other attribution factors must, however, also be considered, particularly future changes in flow and climate as they relate to floodplain inundation and seasonality. Uncertainty in the degree of subsidence and infill in presently leveed areas must also be considered in selection of areas to be reconnected and/or potential addition or removal of fill, to ensure appropriate water depths for SWHA, particularly during the freshet season.

Wetland Reconnection and Habitat Restoration on South Bachelor Island: Working in Dredge Material on the Lower Columbia River

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The South Bachelor Island Wetland Reconnection and Habitat Restoration Project explored opportunities for restoration in dredged materials on the lower Columbia River. For more than 100 years, USACE Navigation Channel maintenance dredge material has been placed along the margins of the river. At South Bachelor Island (RkM 146) more than 1.5 million cubic yards of dredge sands have been deposited since the early 1930s. Shoreline wetlands and shallow water habitats were filled and largely converted to upland habitats. These lands are currently designated 'State Owned Aquatic Lands' (SOAL) and remain in Washington Department of Natural Resources (WADNR) ownership.

In 2019, in partnership with WADNR, Columbia River Estuary Study Taskforce, and U.S. Fish and Wildlife Service staff at the Ridgefield National Wildlife Refuge, approximately one hundred twenty-thousand (120,000) cubic yards of dredge material were excavated to form a channel reconnecting a remnant, hydrologically disconnected 20 acre open-water wetland feature to the Columbia River mainstem. Shallow water and tidal emergent marsh habitats were created, while sustaining existing habitats for terrestrial species. Excavated materials were placed onsite adjacent to the river shoreline to promote entrainment of materials and re-distribution to downstream shallow water areas. Fish sampling at the site indicates that juvenile salmonid use of restored wetlands is high. This project can be viewed as a case study of 'beneficial use' of dredge materials and lessons learned could be applied to other historic dredge disposal sites with potential for tidal wetland habitat restoration and creation.

Highlights from the 2022 IYS Pan-Pacific Winter High Seas Expedition

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During February-April 2022, a large scale, coordinated survey of Pacific salmon high seas habitats was conducted as a signature project of the International Year of the Salmon (IYS). An international fleet of five ships concurrently sampled the physical environment, pelagic ecosystems, and Pacific salmon across 2.5 million km^2 of the North Pacific Ocean using complementary methodologies. The overarching goal of this Pan-Pacific survey was to understand how increasingly extreme climate and associated physical environmental variability influence pelagic ecosystems, and the abundance, distribution, growth, and condition of Pacific salmon. The survey was focused on salmon ocean ecology during winter, a period hypothesized to be an important regulator of salmon survival. This talk provides highlights of the survey, with comparisons to similar surveys in the Gulf of Alaska in winters of 2019 and 2020. Across all ships, over 2,300 salmon were caught in winter 2022, representing all species of Pacific salmon and steelhead. In general, sockeye were found in larger numbers in the north, chum were widely distributed, and coho, chum, and pink salmon generally dominated in the southern parts of survey area. These salmon originated from around the Pacific Rim (including the Columbia River) and salmon from multiple regions were typically caught together. Other commonly caught taxa in surface trawls included myctophid fishes, gonatid squids, and jellyfish, but few potential predators were observed. While thousands of samples collected during surveys await processing, the preliminary results already provide new and exciting insights into salmon and the pelagic ecosystems that support them on the high seas.

Collaborative Analysis of Sediment Accretion Rate Data

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Sediment accretion in tidal wetlands is viewed as a means of mitigating the risk of sea level rise and changes to sediment supply and river flow that could impact restored wetlands. Generally, sites on the lower Columbia River and Estuary (LCRE) floodplain to be restored are behind dikes and have subsided in the absence of sediment supply. The Columbia Estuary Ecosystem Restoration Program (CEERP) aims to restore ecosystem processes, including inundation and sedimentation, and the assumption is that sediment accretion is a beneficial effect of the resumption of ecosystem processes natural on tidal river floodplains. For this analysis, involvement of those who collect Level 3 data in accordance with the Action Effectiveness Monitoring Research (AEMR) framework is central because it has been shown that localized, observational information is crucial to explaining sediment accretion rates. This talk will cover the development of a comprehensive, integrated data set and subsequent analysis of spatial patterns and temporal trends at multiple scales to address several research questions about current trends in sediment accretion and the factors that drive this process. We report the results of analyses of sediment accretion, hydrological features, and the relationship of these two by site type (reference vs. restoration), sediment stake elevation, river kilometer, river zone, and year. We will discuss new metrics and modeling approaches, including a functional data approach and features extracted from the water surface elevation curve. We discuss the key findings of this initial analysis, including greater accretion in restoration sites than reference sites in the lower estuary zone, increasing variability in accretion over time, and the changing association between accretion and water depth throughout the hydrological year. Work is continuing to resolve data gaps that are currently preventing complete statistical analysis and synthesis of CEERP data, and the most up-to-date results will be presented. We'll provide suggestions for future improvements and monitoring efforts. Additionally, others who have collected sediment stake data in the LCRE are invited to join this collaborative effort to analyze, synthesize, and evaluate results from restoration and reference sites.

Juvenile Chinook salmon diets at Environmental Monitoring Program sites in the lower Columbia estuary

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Since 2008, the Wetland Ecosystem Team at the University of Washington has studied spring and summer juvenile Chinook salmon diets at five sites in the lower Columbia estuary to inform patterns of foraging and recovery efforts. Juvenile Chinook salmon diets have followed a general spatial trend in which they consume predominantly dipterans and other wetland insects at the most upriver site (Franz Lake), incorporate cladocerans at Campbell Slough, transition to dipterans and amphipods at the middle sites (Whites Island and Welch Island), and consume primarily amphipods near the estuary mouth at Ilwaco Slough. In Chinook diets, amphipods, dipterans, and cladocerans have the highest index of relative importance, which is a metric that accounts for the frequency of the prey in the diet as well as prey counts and weights. Small salmon (30 - 59 mm), predominantly comprised of unmarked fish, have higher foraging performance—eating more prey and higher energy densities relative to body weight. Larger salmon have higher metabolic costs to compensate for larger body mass. Salmon are impacted by higher water temperatures, and juvenile Chinook are regularly exposed to water temperatures that exceed thresholds for salmon fitness.

Researching the presence of 6PPD-Q and Roadway Runoff Chemicals in Northwestern Clatsop County: River TALC

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A 2022 EPA Lower Columbia River Basin Toxics grant is funding the first research in Northwestern Oregon on the newly identified chemical, 6ppd-quinone, leached from car tires and linked to sudden coho death observed in the Puget Sound; the study will also test for other roadway associated toxins and search for new/unidentified chemicals present in samples. This project includes comprehensive local outreach and has helped stimulate interest in implementing an Environmental Science program at Clatsop Community College and revitalizing the college's Living Machine research/learning facility.

Implementing a Large Wood Estuarine Experimental Design at South Tongue Point Restoration

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Estuarine wetlands and floodplains are often credited as a source of enhanced productivity compared with main-channel habitat because of their enriched habitat complexity. In the lower Columbia River and Estuary (LCRE), work at select locations has been completed assessing the diets of juvenile Chinook salmonids and characterizing potential prey pools, to increase understanding of the relationship between salmonid foraging ecology and habitat capacity. However, the Expert Regional Technical Group of the Columbia Estuary Ecosystem Restoration Program (CEERP) has determined that little research has addressed whether large-wood retention contributes to productivity in estuaries, as has been assessed in non-tidal systems. Further outstanding questions concern differences between large wood structures such as size, complexity, decay, surface texture, tree species, and surface vegetation. Prey pools most commonly sampled in the LCRE are benthic, neuston, fallout, and emergence samples, but studies to date have not addressed the role of structures such as large wood as a medium for colonization within tidal environments. To address these data gaps and inform CEERP planners and managers, this large wood estuarine experimental design specifically focuses on the roles of large wood in tidal wetland channels of the LCRE relative to habitat functions of benefit to juvenile salmon (e.g., refuge, prey production).

In 2023, the large wood estuarine study design developed for CEERP in 2020, by three authors of this presentation, will be implemented in collaboration with CREST and Kilgren Water Resources during South Tongue Point restoration construction. Collaborative science and engineering during 2022 produced modifications between the 60% and 90% engineering plans to match the channel network design envisioned in the large wood study design. The overall design aim is to provide equivalent channel opportunities and conditions to juvenile salmon, with or without large wood placement. Forked channels will have three log jams placed on one fork and none on the other. Each fork will have similar length, elevation, geomorphology, and plant communities. The paired fork design will be replicated three times. The time horizon to complete monitoring for the large wood study is anticipated to be 4-5 years starting with construction.

Based on previously reported testing of large wood sampling methods, both wood scrape and benthic sampling techniques will be used starting in spring of 2024. Benthic and wood samples will be compared within treatment channels, and benthic samples will be compared across treatment and control channels. Partners will continue to closely collaborate to refine engineering plans, review changes necessitated during construction, and specify monitoring plans.

Lessons Learned for the Columbia Using Blasting to Excavate Tide Channels

**Dan Elefant, PE* and Sky Miller, PE

Environmental Science Associates

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This past summer 2022, the author and his colleagues worked with The Nature Conservancy (TNC) to test effectiveness of explosive blasting to excavate pilot tide channels. This presentation will present videos, photos, drone survey, permit process, and monitoring efforts such that other entities can learn from our experience.

Don't Look Up: Practical Methods for Incorporating Satellite Data in Monitoring Columbia River Ecosystems

**Austin Hudson*[1,4], Matthew Brand[2], Heida Diefenderfer[2], S.A. Talke[3], David Jay[4], Will Templeton[5], and Maggie McKeon[2]

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This community does extraordinary work preserving and restoring the ecological health of the Columbia River. Critical to an effective restoration program are informative and accessible data and data products that facilitate decision making and communication with the public. However, in-situ measurements and field data collection are time consuming, expensive, and often limited in temporal or spatial resolution. Spatial trends are often challenging to obtain from point-measurements, while temporal variability is challenging to obtain from airborne or boat-based surveys. The purpose of this presentation is to demystify satellite remote sensing products and highlight their potential utility for evaluating spatial patterns of turbidity, water temperature, plant cover, and potentially salinity, water level, and bathymetry. Satellite-based instruments collect a synoptic perspective of the river at monthly to daily time steps, and analysis of remote sensing products is able to characterize seasonal and decadal trends in various water quality parameters. Two barriers to utilizing satellite observations are that the data sets are BIG, and that the data sources and structures can be challenging to navigate. Condensing and analyzing satellite records, synthesizing them with ground-based point data and data from unmanned aerial vehicles, and communicating the results in a practical manner, also remains a challenge. Here we present examples of satellite measurements in the Columbia River along with tools for downloading and processing images.

New applications for Passive Integrated Transponder (PIT) interrogation in the lower Columbia River estuary

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Detection data collected from PIT-tagged salmonids *Oncorhynchus* spp in the lower Columbia River are vital for estimating survival through the Columbia River hydrosystem. For the last 22 years, the NOAA Pair Trawl has been the primary source of data collection in the estuary. The pair trawl operation samples between river kilometers 66 and 84 and annually detects about 2-3% of fish previously detected upstream of Bonneville Dam. While effective, this sampling method is intensive and involves two rotating shifts of seasonal employees working continuously during peak spring migration.

Development of alternative PIT interrogation methods have been ongoing in recent years, and as technology improves, more efficient detection systems may outperform the pair trawl. In 2011, an autonomous and stationary interrogation site ("PD7" in the PTAGIS database) was constructed along pile dike 43.30 near RKM 70 in the Columbia River to target detections of adult salmonids. To improve functionality at the site, utilize new transceiver technology, and increase the detection field of antennas, a new flexible cable antenna was developed. This led to the invention of a new towed system that replaced a net with flexible cable antennas, reducing the size of vessels needed to tow equipment and eliminating fish mortality. The towed flexible system performed comparably to the trawl in 2019, but needed better deployment and retrieval methods to become a safe and reliable sample method. In 2022, we reinforced components to handle the strain of a net reel.

In 2022, we installed a new pile dike interrogation site (site code "PD6" in PTAGIS) at Pile Dike 42.93 to target detections of PIT-tagged juvenile salmonids. From 29 April to 11 June, PD6 detected 3,076 juvenile salmonid detections, nearly a third of all trawl detections during the same period. In contrast, PD7 annually detected between 115 and 1,024 fish of varying species, runs, and age-classes. The stark difference in detection rates between the two pile dike sites highlight the importance of antenna placement in relation to river flow and fish migration corridors. While directly across the river from each other, PD7 is a spur dike oriented perpendicular to flow compared to PD6, a training dike oriented parallel to flow. The majority of juvenile detections at PD6 were among antennas installed perpendicular to the structure on the upstream side of the dike, suggesting juvenile salmonids were naturally funneled along the pile dike.

In 2023, we plan to install two additional pile dike arrays in the adjacent reaches to PD6 & PD7 and also operate a surface oriented towed flexible array. Our main objective is to find a combination of stationary and mobile detection methods that enhance detection rates in the lower Columbia River estuary while reducing costs and impacts to fish.

Quantifying Benefits of Mitigation-Funded Dam Removal in the Columbia River Basin

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The Habitat Equivalency Analysis (HEA) model is a tool used by NOAA under the Endangered Species Act, Magnuson Stevens Act, and the Damage Assessment, Remediation, and Restoration Program to answer questions of impact. This tool has been in use by NOAA's Restoration Center for over 25 years in the Puget Sound and allows for temporal impact and benefit assessments using an "ecological equivalency." Can this tool be used to quantify the benefits of dam removal to listed fish species in the Columbia River Basin? Recently several candidate dam removal projects have been determined eligible for private equity funding to develop mitigation credits because they are barriers to many miles of anadromous habitat, have willing landowners, and are within the vicinity of proposed impacts to anadromous habitat. What are the precedents for developing a similar HEA model for fish passage restoration? How can a similar process be applied to significant passage barriers in the Columbia? This lightning round presentation will provide preliminary concepts and updates to potentially developing a HEA model specific to dam removal in the Columbia River Basin.

Looking beyond the restoration site: Lessons from the Columbia River estuary

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The Columbia River estuary comprises one of the largest habitat restoration programs in the United States. Thousands of acres of former wetlands have been hydraulically reconnected to the mainstem, in part to benefit juvenile Pacific salmon and steelhead. We used a multi-pronged study to document direct and indirect benefits of estuarine restoration for juvenile salmon. Study elements measured: 1) prey production and direct salmon use in tidal wetlands; 2) export of prey from tidal wetlands; 3) consumption of wetland-produced prey by mainstem salmon; and, 4) PIT-tagged salmon using wetland habitats. Our results demonstrated that restored and reference tidal wetlands produced large quantities of invertebrate prey, which were readily consumed by subyearling Chinook salmon occupying wetlands (=direct benefits). Unexpectedly large quantities of wetland-produced prey (chiefly Chironomid insects) were also exported from wetlands during ebb tides. In the mainstem, juvenile salmon (mainly yearling Chinook and steelhead smolts) were actively feeding and growing; dominant prey included species originating from tidal wetlands (=indirect benefits). PIT tag arrays in tidal channels detected juvenile salmon from interior stock groups that may directly benefit from tidal prey production. Overall, our study found that restored tidal wetlands produced large quantities of insects and other invertebrate prey that were consumed by salmon within wetlands, but were also are exported to the mainstem where they fueled the growth of interior stocks of salmon. Our results highlight the need to look beyond the restoration site by considering the flux of material exported from productive wetlands. Our study indicates the “footprint” of benefits extend far beyond the restoration site itself, something that is overlooked in assessments of restoration benefits.

Surface Elevation Tables for Sediment Accretion Measurements and Sediment Stake Data Verification

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Estimating long-term accretion and erosion of floodplain wetlands relative to water surface elevations is vital to the selection of potential restoration locations for the Columbia Estuary Ecosystem Restoration Program (CEERP). With reliable data, CEERP managers can gauge the resilience of land surface elevation based on the position of a parcel and governing sedimentary processes. This is of increasing importance because of relative sea level rise (rSLR), reduced sediment supply from the basin to the estuary, and operational and climate-related changes to river flows. This presentation will discuss initial work, conducted since 2018, to address the following overarching research questions: have sediment accretion rates in lower Columbia River and Estuary (LCRE) floodplain wetlands decreased relative to historical evidence from deep sediment cores? How do rates compare to rSLR?

Virtually all data about sediment accretion rate at CEERP restoration and reference wetlands have been collected using a method that measures short-term accretion rates, which was termed “sediment stakes” (SS) in the original 2009 CEERP restoration monitoring protocols and is similar to “sediment pin” and “sedimentation erosion bar” methods. The SS method was selected in part for cost-efficiency and speed because at the outset of CEERP monitoring, those were important criteria to ensure all necessary environmental indicators could be monitored. For that reason, authors of the 2009 protocols (NOAA Tech. Memo. NMFS-NWFSC-97), including three authors of this presentation, did not recommend the surface elevation table (SET) method, although we discussed it in regional workshops focused on CEERP monitoring convened in June 2004 and February 2007. Because SETs are deeply anchored, they provide a more accurate means of measuring sediment accretion rates and make it possible to separate earth movement processes from surface accretion and erosion. It is typical at initial SET installation to also place 1-ft^2 feldspar on the sediment surface in three locations ~3 meters from the SET receiver, thereby providing two separate indicators of surficial sedimentary processes. Installation of SETs and feldspar allowed us to address two intermediate research questions, which will be reported on today: How do SS results for LCRE floodplain sediment accretion compare and contrast with SET and feldspar methods? What implications do comparative findings have regarding the utility of the larger and longer-term CEERP data set produced using sediment stakes?

We placed SETs at six sites to represent tidal river and estuarine system zones, including four bays and two islands with different hydrologic regimes and sediment supply conditions. At one site, three SETs were installed on an elevation gradient of low marsh, high marsh, and Sitka spruce forested wetland (swamp) communities. To assess the SS method, and ideally increase the level of confidence and improve uncertainty estimates for the existing data, four SETs were installed at current or former Ecosystem Monitoring Program long-term study sites where SSs have been in place for multiple years. Preliminary results of the comparison of these three sediment measurement methods will be presented for Baker Bay, Young’s Bay, Cathlamet Bay, Secret River, White’s Island, and Cunningham Lake.

Longitudinal Temperature Monitoring on Tributaries of the Lower Columbia River

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In 2016 the NCWA began monitoring stream temperatures at 9 sites in the Youngs Bay and Skipanon watersheds, adding 6 sites including 2 in the Ecola Creek watershed in 2017, and 7 sites within the Nicolai-Wikiup watershed in 2018 for a total of 22 sites with multi-year data as of the summer of 2022. More locations and parameters, including sites undergoing restoration and turbidity, have been added to our work as of 2022 with the hopes of adding water quantity/stream gauges as well as other relevant water quality factors in our area to our monitoring protocols going forward. Results, preliminary trends, and sites of concern will be highlighted.

Restoration of 1,000 acres of Lower Columbia River floodplain - Several big reasons why the project almost never happened

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After eight years of planning, design, and construction, the Steigerwald Reconnection Project in Washougal, Washington was finally completed in 2022. During development, the project received high levels of support from key stakeholders such as Port of Camas-Washougal and U.S. Fish and Wildlife Service due to the significant benefits of restoring approximately 1,000 acres of historic Columbia River floodplain, reconnecting Gibbons Creek to the historic river floodplain for the first time in over 50 years, and reducing overall flood risk. However, the project also overcame significant review agency challenges. Restoration required modifying two federally authorized Section 408 projects (the Camas-Washougal Levee System and the Gibbons Creek Realignment Project), which required demonstrating no hydraulic or other impacts to the functionality or purpose of either project. To address Section 408 requirements, technical analyses of Columbia River flood profiles and mobile bed sediment transport modeling in Gibbons Creek were conducted to ensure functionality of the replacement levee system under 50+ years of continuous simulations. In addition, the restoration proposed to remove the portion of the existing levee that protected a five-mile long segment of WSDOT State Route 14. WSDOT initially gave concurrence with the restoration, but later rescinded their support. Technical analysis and designs were again employed to address concerns; these included historical assessment of river flooding (1996, etc.), wind-wave assessment of erosion risks on the SR 14 embankment, as well as roadway improvements and an operable levee closure (closure structure) across the highway. This presentation details the analyses performed and how they were able to garner critical support to keep the project on track. The issues and corresponding technical assessments required for the Steigerwald Project may be helpful in understanding approaches for future large-scale restoration in the Lower Columbia River and elsewhere in the Columbia Basin such as levee setbacks, roadway infrastructure protection, fish passage, and expanded wetland habitats for juvenile salmonid rearing.

The Regional Coordination of Hopper Dredging Along the West Coast

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The Federal Navigation Channels are the hidden highways of the transportation world, but unlike their land counterparts, require regular maintenance to maintain depth. The maintenance of waterways is achieved through use of dredge plants, with the hopper dredge being best suited for the predominant environmental conditions, operating depths, haul distances, and channel conditions of the Columbia River and neighboring coastal ports and harbors. In previous years, West Coast U.S. Army Corps of Engineers (USACE) Districts with navigation missions have struggled to meet annual dredging requirements caused by funding restraints and an aging government hopper dredging fleet. Because dredging requirements remain steady, it is imperative they create an effective and feasible dredging plan every year. This year marks the tenth consecutive year of all West Coast Districts planning and coordinating their dredging needs, effectively strategizing resources to ensure the dredging mission is met.

The planning of the West Coast Hopper dredging schedule is a complex process involving coordination with 6 USACE districts across 16 annual projects, with the lower Columbia River and Mouth being the largest recurring maintenance projects on the West Coast. Portland District oversees the operation and maintenance of the only two government owned hopper dredges on the West Coast, the ESSAYONS and YAQUINA. Equitable use of the government hopper dredges is an important planning consideration because they are regional assets that must be shared amongst the districts.

During the repowering of the hopper dredge ESSAYONS in 2008, Portland District and San Francisco District rolled their projects into a single regional contract to cover the planned loss of government capability during the repowering. By writing a regional contract, Portland and San Francisco could split the large mobilization cost of the contract. In 2013, to deal with significantly reduced maintenance dredging budgets, and an increase in need caused by the request by Alaska District to have the ESSAYONS work at the Cook Inlet Navigation Channel, the districts once again developed a regional contract to optimize the use of the dredges and funding.

Since 2013, this coordination has evolved into an annual regional West Coast planning effort that involves 6 districts, across three divisions, with up to 23 projects. The planning scope looks at the next two years of upcoming work so project managers have better estimates for their annual budget submissions.

Annual coordination with the individual districts and project managers inform an optimization process that generates a set of recommended schedules. A report captures all constraints and discusses opportunities, such as pump ashore. This detailed analysis is critical to ensure that government funds are expended in a cost-effective manner.

Tracking Soil Dynamics to Understand Plant Community Development in Restored Tidal Wetlands

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Through monitoring soil conditions, this research aims to help us better understand the ecological mechanisms driving plant community development within tidally restored wetlands. Pre-restoration agricultural sites typically consist of well-drained soils with high oxygen concentrations. Reintroducing tidal flooding saturates the soil, creating an anaerobic wetland environment. In more saline sections of the estuary, this shift in soil oxygen levels is also accompanied by a shift in salinity. The restoration of these tidal wetland dynamics causes a cascade of biogeochemical and microbial reactions in the soil—ultimately affecting plant community establishment. In this study, we monitor these biogeochemical changes using in-situ soil ORP (oxygen reduction potential), pH, and salinity probes across multiple restoration and reference sites throughout the Lower Columbia River Estuary. These data provide insight into factors that drive the continued dominance and spread of reed canarygrass (*Phalaris arundinacea)*. In contrast to successful native plant communities, reed canarygrass (*Phalaris arundinacea)* was found to thrive primarily in soil with lower pH and salinity values, and higher ORP levels. The results and methods developed from these soil monitoring efforts can be used to guide continued native plant community restoration and adaptive management efforts throughout the estuary.

Tracing History: Morphological Changes of the Lower Columbia River

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Rivers are dynamic in every sense of the word. One aspect of change that can be easily overlooked, but has broad-reaching implications, is the morphological evolution of a river. Changes in morphology interact with ecosystem processes, civil infrastructure, recreation, navigation—virtually every stakeholder on the river. Gaining insight from morphological change is not difficult but requires us to pause and observe the world around us. A more challenging feat is effectively communicating such insights to the public. This poster presents a new look at historical and contemporary surveys along the Lower Columbia River to offer perspective of how much has changed under the water. Examples are illustrated with infographics that are readily accessible to experts and laypeople alike.

Relationship of Benthic Invertebrate Communities to Sediment Characteristics in the Columbia River Estuary

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The use of dredged material placement to provide beneficial outcomes for juvenile salmon is a new initiative in the lower Columbia River and estuary. While these projects are intended to enhance off-channel rearing and foraging habitat for juvenile salmonids through the creation of shallow-water habitat, the deposition of dredge material directly impacts the benthic invertebrate assemblages upon which juvenile salmonids rely upon as prey resources. Understanding the short- and long-term impact on invertebrate assemblages is further complicated by uncertainties regarding the effects of spatial and temporal influences, both natural and anthropogenic, on invertebrate community dynamics. Action effectiveness research at the Woodland Island dredge placement study site provided an opportunity to examine the relationships between benthic invertebrate communities and their environment at three sites in the Columbia River: Woodland, Martin, and Bachelor Islands. Paired invertebrate and sediment samples were collected using a petite Ponar sampler once a month from April - July from 2019 - 2022. The invertebrate samples were identified and enumerated while nutrients (e.g., percent total carbon, percent total nitrogen, phosphorus, ammonium) and grain size were quantified. Random Forest modeling was used to understand the environmental variables that best predicted the abundance of two key juvenile salmon prey items—*Chironomidae* and *Corophiidae*. Results indicate that *Chironomidae* abundance was negatively correlated with percentage of sand and positively correlated with available nutrients and water depths. Of the tested variables, the water depth, percent nitrogen, percent carbon, and ammonium concentration were important variables in predicting *Chironomid* abundance. Modeling of *Corophiidae* indicate that abundances were negatively correlated with nutrients and positively correlated with sand, but water depth had the strongest positive correlation and was also the most important predictor variable. Modeling of sediments indicated that high percentages of sand was negatively correlated with total nitrogen and total carbon as well as concentrations of ammonium and phosphorus. Spatial (site) and temporal (year, month) variables showed differing degrees of importance for both taxa. Increased understanding of sediment characteristics associated with benthic invertebrate communities will help to inform the functional response of habitat enhancement and restoration efforts. In addition, elucidating the relationships among benthic assemblages and environmental conditions along spatio-temporal gradients provides new opportunities to inform the Columbia Estuary Ecosystem Restoration Program.

From Concept to Operation: A New Nearshore Dredged Material Placement Site in the Pacific Ocean at the Columbia River Mouth, Southwest Washington

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The U.S. Army Corps of Engineers (Corps) maintains the 470-mile Columbia-Snake River navigation system, which extends from the entrance at the Pacific Ocean inland to Lewiston, Idaho. The Mouth of the Columbia River (MCR) federal navigation channel is the gateway to this system, and the Corps annually dredges ~3 million cubic yards (MCY) of clean sand from the 6-mile long entrance channel with trailing-suction hopper dredges (TSHDs). With federal, state, and local input, especially through the Lower Columbia Solutions Group (LCSG), the Corps and U.S. Environmental Protection Agency (EPA) jointly manage dredged material at the MCR, seeking to maximize the beneficial use of this valuable resource. Nearshore dredged material placement is prioritized to reduce chronic beach erosion north and south of the inlet. Prior to 2018, sand dredged from the MCR channel was placed in the Pacific Ocean at three dispersive nearshore sites and one offshore site. However, the capacity of the three nearshore sites was insufficient to accommodate the entire volume of sand dredged annually from the MCR federal navigation channel.

In coordination with our stakeholders, the littoral zone off North Head, near Long Beach, Washington was identified as an optimal location to place dredged material to address chronic beach erosion north of the Columbia River North Jetty. The LCSG identified data gaps, and from 2018-2020 we planned and executed several multiyear, interdisciplinary studies to improve our understanding of the marine and coastal environment around North Head and demonstrate the operational capabilities and constraints of the Government's TSHD, ESSAYONS. These investigations informed the configuration and utilization of a new nearshore site at the MCR: the North Head Site (NHS). The NHS became fully operational in 2021. The addition of the NHS to the Corps-EPA network of sites has increased our capacity for nearshore dredged material placement, helping to sustain the supply of sand in the Columbia River littoral zone. Long-term nearshore bathymetric monitoring and beach topographic surveys are planned along the Long Beach peninsula to track the shoreline response to dredged material placement at the NHS.

Design & Application of a New Submerged Diffuser for Targeted In-Water Placement of Dredged Material within the Lower Columbia Estuary

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During 2018-2021, Portland District (USACE) and the Port of Portland (PoP) collaborated to design and construct a new type of submerged diffuser to allow the Port of Portland's 30-inch cutter-head dredge (*Oregon*) to discharge dredged sediment at Lower Columbia River in-water placement sites in a more controlled and environmentally acceptable manner. This presentation will introduce the imperative for improving dredged material management within the Lower Columbia River and its estuary, mandating the need for improved control of dredged material placement within the river. The imperative for managing in-water dredged material placement within the LCR is clear when one considers that approximately 70% of the 6-8 million cubic yards of sand dredged from the 100-mile long LCR navigation channel is placed at in-water sites, where water depth is greater than 20 feet.

Prior to 2021, the cutter-head dredge *Oregon* utilized a simple discharge "diffuser" for subaqueous placement of dredged material at in-water placement sites. It was a crude instrument for trying to control the release of 40,000 gallons/minute (83 cfs) of dredged sand slurry. There was no energy dissipation, resulting in significant disturbance for the river bottom and highly uncertain disposition of placed dredged sediment. USACE and PoP needed a better "tool" to place dredged material within the Columbia River: one that manages energy dissipation, minimizes turbidity, enables shallow water placement (10-20 ft deep), allows controlled deposition of placed dredged material. Such a dredged material placement tool is required to enable us to build in-river habitat restoration features or feed the river's sediment budget while minimizing or avoiding adverse effect.

The presentation will quickly summarize the approach used to define operational requirements for the new submerged diffuser leading to its iterative design and eventual fabrication. Special features of the presentation illustrate how computational fluid dynamics (CFD) methods were used to refine the diffuser design, from a steeped configuration to a conical configuration. The presentation will also summarize results from the first operational use of the new submerged diffuse, applied within the lower estuary of the Columbia River during August-October 2021. The new diffuser's first deployment was for handling 400,000 cy of sand that dredged from a large cut-line shoal encroaching the LCR FNC (Federal Navigation Channel). The diffuser was used to place the dredged sand within an evolving tidal channel to re-direct river flow toward the river's thalweg, with the objective of stabilizing the river thalweg and reducing FNC shoaling. Operational lessons learned from the new diffuser's first deployment will be highlighted at the end of the presentation.

Regulatory, Landowner, and Real Estate Challenges to Removing Federally Authorized Levees to Reconnect 1,000 Acres of Floodplain Along the Columbia River

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The final approvals and permissions to remove and modify a federally authorized levee and multiple flood control structures in order to reconnect approximately 1,000 acres of floodplain were successfully acquired for the Steigerwald Reconnection Project. The feasibility of this complex restoration project was dependent on support from numerous stakeholders, project funders, and landowners. Due to the high-risk nature of the project, the project was subject to rigorous regulatory and permitting requirements and was reviewed with much scrutiny. Project progress depended on the coordination with numerous agencies to meet a specific approval sequence including USACE, National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Forest Service, Washington Department of Ecology, Washington Department of Fish and Wildlife, Clark County, and the City of Washougal. Active coordination with the Port of Camas Washougal, BNSF Railroad, WSDOT, and multiple private entities, resulted in adaptive design solutions where restoration and flood reduction features were altered to benefit landowners and secure eventual land easements from seven property owners. Direct collaboration with affected landowners led to the production of additional technical analyses and incorporation of additional project elements into the design through an iterative process that exemplified true project co-development. As a result, the regulatory, landowner, and real estate coordination efforts of this project rivaled the rigor of the technical and design requirements. Overall, these efforts led to a superior project design and implementation that is supported across multiple-stakeholder and regulatory groups.

Trends in Lower Columbia and Willamette River Water temperatures over the past 170 years

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Water temperature is a critical ecological indicator and is regulated as a pollutant when values exceed critical thresholds (e.g., 20 °C) However, no studies on the U.S. West Coast have assessed baseline pre-development temperatures during the 1800s, evaluated century-scale trends in riverine or estuarine water temperature, or investigated the cause of those changes. Here, we recover, digitize, and analyze archival temperature measurements from the 1850s forward to investigate how and why water temperatures in the lower Columbia River (CR) and the lower Willamette River (WR) are changing. To infill data gaps and explore changes, we develop regression models of daily historical Columbia and Willamette River water temperatures using time-lagged river flow and air temperature as the independent variables. Models were developed for three time periods (late-19th, mid-20th, and early 21st century), using modern and recently recovered archival measurements from the Columbia (1854–1876; 1938–present) and Willamette (1881-1890, 1941-present) rivers. Root-mean square errors are less than 1°C, comparable to hydrodynamic model results.

The overall trends for both river systems are remarkably similar, though some seasonal variability occurs. In the Columbia River (Bonneville Dam), annually averaged water temperatures have increased by 2.2 ±0.2°C since the 1850s, a rate of 1.3±0.1°C/century. Similarly, Willamette River (Portland) water temperatures have trended upwards at ~1.1 ^{o}C ±0.2°C century over the same period, with the largest shift in January/February (1.3 ^{o}C /century) and the smallest in May/June (~0.8 ^{o}C /century). For the Columbia, the largest increase of approximately 2.0 ±0.2°C/century occurs in the July–Dec time frame, while springtime trends (April–June) are statistically insignificant. In both cases, the modern system is warmer, but exhibits less short-term temperature variability. Both systems exhibit increased thermal memory, leading to larger fall temperatures (and mitigating against springtime warming). In the Willamette, managed release of water influences water temperatures in late summer, with an average reduction of 0.27 ^{o}C and 0.56 ^{o}C estimated for August and September. For both systems, the number of days that the river exceeds the ecologically important threshold of 20 ^{o}C has greatly increased (~20 and 50-days for the Willamette and Columbia, respectively). Moreover, cold water days below 2 ^{o}C have virtually disappeared in both rivers. In the Willamette since 1900, changes are primarily correlated with increases in air temperature (T_w increase of 0.81 ±0.25 ^{o}C) but also occur due to increased reservoir capacity, altered land use and river morphology, and other anthropogenic changes (0.34 ±0.12 ^{o}C). In the

Columbia, statistical experiments within our modeling framework suggest that increased water temperature is also driven by warming air temperatures (~29%), as well as altered river flow (~14%) and water resources management (~57%). In both systems, both climate change and anthropogenic modification are important factors in long term trends.

Improvement of Juvenile Salmon PIT Tag Detection Systems using Pile Dikes in the Lower Columbia River

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Since 1995, NOAA fisheries has operated a Passive Integrated Transponder (PIT) tag detection site in the Columbia River estuary near Jones Beach (75 river kilometers upstream from the river mouth). This site serves as the furthest downstream detection site on the mainstem, and the data it provides contributes to various studies throughout the basin.

In 2011, an autonomous PIT tag detection site (PD7) was established on a pile dike near the mouth of the Westport Slough. Due to the prevalence of fisherman moored to this pile dike structure during the adult salmon returns, this site was originally established with the intention of detecting adult Pacific salmon *Oncorhynchus* spp. Solar and electronics were mounted on the king pile (terminal pilings) of the structure and multiple antennas were deployed off of aluminum spurs downstream and transverse to the pile dike. In subsequent years, the orientation of these antennas relative to the pile dike were experimented with, and it was observed that this site may also have potential for detecting out-migrating juvenile salmon. Additionally, this site detected species such as white sturgeon (*Acipenser transmontanus*) and cutthroat trout (*O. clarkii*).

In 2022, we continued to experiment with antenna placement and upgraded equipment at PD7. We decided to deploy an additional site (PD6) across the river with the intention of targeting juvenile salmon detections using what we had learned at PD7. We used aluminum spur structures to deploy antennas on the upstream side of the dike. Our hypothesis was that juvenile salmon would be funneled towards the antennas by the current and would be less able to avoid the detection field of the antennas. Electronics were housed in Pelican cases retrofitted to a barge and solar was mounted on a nearby navigation marker.

During the 2022 season at PD6, we detected just under 1/3 of the 9.838 juvenile salmon detected by the long running Jones Beach pair trawl operation (operating since 1995 with several vessels and a large full time and seasonal crew). The success of PD6 prompted further interest and funding for the establishment of more autonomous pile dike detection sites. We are currently preparing for the reinstallation of PD6 and PD7 as well as two additional sites to be installed upstream and downstream.

Most of the pile dike structures in the Columbia River estuary were originally built by the U.S. Army Corps of Engineers in order to maintain shipping channels. These pile dikes are prevalent throughout the entire basin and could provide a low cost means of gathering fisheries data.

Furthermore, these data are uploaded to a local regional database (Ptagis) and are available for public use. Improvement of antennas, means of housing electronics, and understanding where to establish these sites could lead to advancements in our understanding of Columbia River fisheries and how we manage them.