**NWFSC Watershed Program Open House**

**NOAA Western Regional Center**

**7600 Sand Point Way NE Seattle, WA**

**November 6, 2019**

**https://www.nwfsc.noaa.gov/research/divisions/fe/wpg/index.cfm**

9:00-9:05 Welcome – Kevin Werner, Science and Research Director, Northwest Fisheries Science Center

9:05-9:10 Overview of Watershed Program research – Rich Zabel, Fish Ecology Division Director, Northwest Fisheries Science Center

## Session 1 – Puget Sound

**Moderated by David Price – NOAA Regional Office**

9:10-9:30 **Ecosystem response to the Elwha River dam removals - an update** – George Pess (George.Pess@noaa.gov), Mike McHenry (Lower Elwha Klallam Tribe), Sam Brenkman (National Park Service), Joe Anderson (Washington Department of Fish and Wildlife), Keith Denton (KPD Consulting), Todd Bennett, Steve Corbett, John McMillan (Trout Unlimited), Sarah Morley, Martin Liermann, Roger Peters (USFWS), Jeff Duda (USGS), Andrew Ritchie (USGS), Amy East (USGS), and Chris Tonra (Ohio State University)

Worldwide stream and watershed restoration efforts cost billions annually. These projects are typically local-scale activities that do not have a measurable effect on ecosystem function or services. One ecosystem restoration technique that can have a large-scale effect is dam removal. This single action allows for the re-connection of ecosystem processes such as upstream and downstream organism movement, the rapid transformation from lentic to lotic conditions in former reservoirs, rapid shifts in community structure and food webs, and accelerated habitat creation through sediment deposition. We present results from the Elwha River, where the largest dam removal ever undertaken resulted in measureable ecosystem changes. The release and subsequent downstream transport of tens of millions of metric tonnes of sediment from former reservoirs has resulted in the transformation and rebuilding of estuarine and riverine habitats. The resumption of free passage for aquatic organisms has re-established anadromous fishes to areas that have been void of such species for 100 years, prompting rapid increase in salmonid life history diversity particularly to bull trout and steelhead. Short-term changes due to large changes in sediment supply resulted reductions in Chinook salmon productivity but has recently rebounded. Benthic invertebrate response to dam removal and the changes in sediment supply were immediate and of large magnitude, but similar to salmonids has rebounded since the majority of sediment has passed. Following dam removal, marine derived nutrients increased, entered foods webs and altered the migration patterns and fecundity of an aquatic songbird. Our results demonstrate the critical importance of maintaining longitudinal connectivity for maintaining watershed processes and ecosystem services.

9:30-9:50 **Puget Sound Partnership's Common Indicators Metrics and NOAA's Salmon Habitat Status and Trends Monitoring Program** – Jason Hall (Cramer Fish Sciences, Jason.Hall@fishsciences.net), Alex Stefankiv (NOAA Affiliate, A.I.S., Inc.), Britta Timpane-Padgham (NOAA Affiliate, A.I.S., Inc.), Timothy J. Beechie, George R. Pess, Leska Fore (Puget Sound Partnership), and Jen Burke (Puget Sound Partnership)

The Salmon Habitat Status and Trends Monitoring Program (SHSTMP) was developed by NOAA's Watershed Program to support NMFS status reviews of Endangered Species Act (ESA) listed Puget Sound salmon populations. The protocols and data products being developed by the SHSTMP are currently being applied to other regions (e.g., Oregon and Washington coast watersheds) as well as directly supporting other Puget Sound salmon recovery programs. The Puget Sound Partnership (Partnership) is one such regional salmon recovery program that has integrated SHSTMP data products and protocols into regional salmon recovery evaluations and planning. The Partnership uses a framework of Common Indicators to track and report regional progress toward the implementation of the Puget Sound Salmon Recovery Plan. The SHSTMP and the Partnership have worked towards integrating data products and protocols from the SHSTMP into the Partnership's Common Indicators framework, and components of the SHSTMP large river delta and floodplain protocols and datasets have already been integrated and adopted into the Partnership's salmon recovery reporting and evaluation. Conversely, the SHSTMP has adopted a shoreline armor dataset being developed by the Partnership. In addition, the SHSTMP has supported workshops and collaborative development of additional Common Indicator protocols and components to support regional salmon recovery. Most recently, the SHSTMP has worked with the Partnership to develop protocols for tracking and reporting habitat status for pocket estuaries, marine riparian, and freshwater riparian Common Indicator metrics. Such collaborations and coordination are important for regional salmon recovery as it supports the development of consistent status and trends monitoring protocols and metrics while also leveraging existing efforts to support continued development of tools to support regional salmon recovery evaluations.

9:50-10:10 **Density-dependent habitat limitations for juvenile Chinook salmon in four large river deltas of Puget Sound** – Correigh Greene (Correigh.Greene@noaa.gov) and Joshua Chamberlin, Eric Beamer and W. Gregory Hood (Skagit River System Cooperative), Joseph Anderson (Washington Department of Fish and Wildlife), Chris Ellings and Sayre Hodgson (Nisqually Tribe), Matthew Pouley and Todd Zackey (Tulalip Tribes)

Efforts by people to restrain tidal inundation to promote agriculture and development has led to large amounts of tidal wetland habitat loss in large river deltas across the Pacific coast. These losses are one of multiple threats facing estuary-dependent species such as Chinook salmon, yet concomitant declines in these populations have raised questions about the extent to which juvenile Chinook salmon compete for limited estuary habitat and how estuary restoration will help recover populations. To examine the potential for habitat limitation, we used a cross-system approach to combine outmigrant and population density data in four large river deltas of Puget Sound. By adjusting of outmigration abundance to outmigrants/ha of delta channel, we were able to develop a statistical stock-recruit model that standardized outmigrations across all four estuaries. Our analysis revealed evidence for negative density dependence throughout the range of observed outmigration sizes. All systems approached predicted capacity levels some of the time each year, although the frequency with which this occurred varied greatly by large river delta. Furthermore, conditions in time and space were systematically associated with exceedance of capacity predicted by model. These conditions depended in part on hatchery releases, which have the potential to contribute to density-dependent relationships, particularly with respect to timing of releases. Systematic spatial variation also existed in the highest observed population densities (90th and 95th quantiles) within deltas, and these levels were not greatly influenced by densities of hatchery-origin migrants in tidal deltas. These findings have important implications for monitoring programs, estuary restoration, and hatchery management.

10:10-10:30 **Bioenergetic approaches to examining habitat-specific growth and productivity for Chinook salmon in estuarine systems** – Joshua Chamberlin (Joshua.Chamberlin@noaa.gov), Correigh Greene, Eric Beamer (Skagit River System Cooperative), Chris Ellings (Nisqually Tribe), and Todd Zackey (Tulalip Tribes)

Though many current estuarine landscapes represent only a fraction of their historical extent, these habitats still provide important rearing opportunities for juvenile salmon migrating from freshwater to marine environments. Large efforts to restore estuary capacity have been underway for some time in deltas throughout the northwest yet recent research suggests many of these systems still operate at or above capacity across varying levels of outmigration abundance and throughout the rearing period. Chinook salmon, in particular, rely heavily on estuaries for rearing growth during early life history and may reside from weeks to months prior to migration seaward. Given potential density dependent limitations across estuarine systems, it is unclear how potential growth of juvenile Chinook salmon may be affected during the estuary-rearing period. Our goal for this component was twofold: 1) to address habitat specific differences in growth, or growth potential, for multiple life history types of juvenile Chinook salmon and, 2) evaluate and quantify how well habitats can support individual growth and how foraging strategies may change when densities are above estimated capacity. We utilized a standard bioenergetics framework to evaluate growth throughout the rearing period for multiple life history types of Chinook salmon and compared growth potential among the primary habitat types. In addition, we assessed how increased densities within the estuary may influence growth opportunity and foraging strategies by estimating consumption demand and prey selectivity across varying levels of observe Chinook density among habitat types. Our results suggest habitat diversity is important for supporting growth opportunity to juvenile salmon in estuarine systems that operate at, or above, estimated capacity.

BREAK 10:30-10:45

## Session 2 – Salmon Response to Habitat Change

**Moderated by Eric Beamer – Skagit River System Cooperative**

10:45-11:05 **Modeling effects of habitat loss, climate change, and habitat restoration on three salmon species in the Chehalis River basin** – Tim Beechie (Tim.Beechie@noaa.gov), Colin Nicol (NOAA Affiliate, Ocean Associates, Inc.), Caleb Fogel (NOAA Affiliate, Ocean Associates, Inc.), Jeff Jorgensen (FE, NWFSC), Britta Timpane-Padgham (NOAA Affiliate, A.I.S., Inc.), Jason Hall (Cramer Fish Sciences), Joshua Chamberlin, Jamie Thompson (Seattle Public Utilities), and Gus Seixas (Skagit River System Cooperative)

To assist aquatic habitat restoration planning in the Chehalis River basin, we assessed habitat changes from historical (or natural potential) conditions to present, and used a salmonid life-cycle model to evaluate eight diagnostic scenarios to determine which types of habitat changes have had the greatest impacts on salmon populations. We also modeled three alternative restoration scenarios to evaluate potential improvements in salmon and steelhead populations in the future. The NOAA analysis uses three separate models to take raw GIS data and ultimately produce life cycle model results for each salmonid species under each diagnostic or restoration scenario: a spatial analysis that processes raw data to produce five habitat data layers, a habitat analysis that uses the habitat files to create diagnostic or restoration scenario input files for the life-cycle models (including historical and current life-stage capacities and productivities for each species), and the life cycle models that estimate equilibrium spawner abundance under each diagnostic or restoration scenario. The diagnostic results indicate that restoration of shade, wood, beaver ponds and floodplain habitat provide the greatest opportunities to increase spawner abundances for the three species currently modeled (coho, spring Chinook, and fall Chinook). Modeled restoration scenarios illustrate that restoration actions can significantly increase abundance of salmon populations to climate change in some cases. However, species currently at risk are more vulnerable to climate change even with restoration actions, whereas other species are less vulnerable to climate change and restoration actions will have greater positive benefits in the future.

11:05-11:25 **Importance of invertebrate drift for stream salmonids in a changing climate** – Peter Kiffney (Peter.Kiffney@noaa.gov), Sean Naman (University of British Columbia), Beth Sanderson (FE, NWFSC) and Aimee Fullerton (FE, NWFSC)

It has been long recognized that both physical habitat and prey availability influence stream salmonid populations; however, for a variety of reasons, research on the role of food has largely been ignored by fish scientists and managers. This knowledge gap is particularly problematic given climate warming, as the metabolism of stream fish increases exponentially with water temperature thereby increasing energetic demands to meet increased costs. To help inform on the role of food in regulating stream fish populations in the face of a warming climate, two questions are of critical importance. First, we need to understand what factors are important in determining spatial and temporal variation in stream prey availability. Second, we need to understand how variation in prey availability affects fish physiological performance in nature and how this relationship is modified by other factors, especially water temperature. Here we examine how prey availability varies across space and time, the effects of prey availability on river-rearing salmonids, and how this relationship is modified by water temperature.

11:25-11:45 **An overview of dam removal efforts on the mainstem Klamath River in the context of coho and Chinook Salmon population recovery** – Tommy Williams (Tommy.Williams@noaa.gov, Southwest Fisheries Science Center, Fisheries Ecology Division)

The proposal to remove four dams on the Klamath River represents the largest dam removal project in the US. Constructed from 1911-1962 between Rkm 311-377, removal of the dams would provide access to over 650 km of stream habitat. Fish species in the basin include ESA-Threatened bull trout, Redband trout, several ESA-listed suckers, Pacific lamprey, other lamprey species, green sturgeon, Eulachon, steelhead, coho salmon, and Chinook salmon. Chinook salmon in the basin support tribal, commercial ocean, and river/ocean recreational fisheries. NMFS is currently considering a petition to list spring-run Chinook salmon in the basin. ESA-listed coho salmon populations are part of the Southern Oregon / Northern California Coast ESU. Steelhead in the basin support a major sport fishery. Simultaneous removal of all four dams is scheduled for

2022, with volitional access available October 2022. The State of Oregon is developing reintroduction plans for the Oregon portion of the basin. Active (hatchery) re-introduction of spring-run Chinook salmon is proposed for the upper basin; volitional reintroduction is proposed for coho salmon, steelhead, fall-run Chinook salmon, and Pacific lamprey. In California, hatchery operation will be impacted by dam removal, hatchery production of Chinook salmon and coho salmon could be drastically reduced as well as marking programs that inform fishery management. Various plans are being considered in the California portion of the basin although no active reintroduction is currently proposed. Lessons learned from other western US dam removals are informing various options being considered to provide the greatest opportunity to establish viable populations and ESUs of Chinook salmon and coho salmon. Near-term management concerns are emphasizing the need to develop appropriately sequenced monitoring programs to assess restoration of habitat processes and subsequent recolonization of historical habitat with a focus on identifying critical performance measures that could trigger additional or different mitigation efforts.

11:45-12:05 **Watershed restoration in the Scott River, tributary to the Klamath River** – Michael Pollock (Michael.Pollock@noaa.gov), Besty Stapleton and Erich Yokel (Scott River Watershed Council, Etna, California), Shari Witmore (NOAA Regional Office, Klamath Branch, Arcata California), and Bob Pagliuco (NOAA Restoration Center, Arcata, California)

The Scott River is a major tributary of the Klamath River and contains one of the largest remaining populations of coho salmon in California. Situated below the four hydroelectric dams on the mainstem Klamath River, the Scott River coho salmon population may be essential to upstream population recovery efforts once the dams are removed. Scott River coho salmon are a somewhat unique population relative to the typical coastal coho populations in terms of migration length. The adults must travel over 250 km from the mouth of the Klamath through steep, mountainous terrain to reach the gently sloping Scott Valley, about 900 m above sea level, while the smolts have the reverse migration. Ongoing collaborative, multi-organizational efforts to protect and restore habitat essential to the survival of this unique population have been steadily increasing since about 2013, when the Northwest Fisheries Science Center, the NOAA Restoration Center and the NOAA Regional Office all became more involved in restoration and monitoring efforts. The US Fish and Wildlife Service also increased funding to assist with coho salmon recovery, and the California State Water Board and California Department of Fish and Wildlife have contributed to restoration efforts. The Scott River Watershed Council, a non-profit organization composed of local landowners concerned about watershed health, also began to expand its restoration efforts at the time, and since then has been the driving and coordinating organization for habitat restoration in the Scott Valley. In this presentation, we provide an overview of recent restoration projects in the Scott Valley and present data quantifying the benefits of those efforts in the context of coho salmon habitat recovery.

12:05-12:25 **Informing salmon conservation in California: fisheries management, flow regulation, and habitat restoration** – Stuart Munsch (Stuart.Munsch@noaa.gov, NOAA Affiliate, Ocean Associates), Correigh Greene, Rachel Johnson (SW Fisheries Science Center, UC Davis), William Satterthwaite (SW Fisheries Science Center), Hiroo Imaki (NOAA Affiliate, Ocean Associates), Patricia Brandes (US Fish & Wildlife Service), and Michael O'Farrell (SW Fisheries Science Center)

Pioneers that trekked to California in the mid-1800s found a vast, textured, and connected landscape that supported an abundant and diverse salmon stock. In the subsequent 170 years, people transformed its watershed and diminished its salmon. Two of its three stocks are now listed under the US Endangered Species Act. Today, salmon face stressors including a harsh climate, an extensive water supply system, habitat degradation, and fisheries. However, many stressors are consequences of activities (e.g., agriculture, development) that benefit people. Managers are therefore charged with maintaining viable salmon stocks and a landscape that supports human activities. Overarching management questions include, "Are salmon vulnerable to a changing climate?", "How many salmon should escape the fishery?", "How much water do salmon need?", and "Where should we restore habitat?" In this talk, I will address these questions, discussing how (1) climate and the water supply system constrains juvenile growth and rearing windows and (2) spawners, flow, and the landscape influence juvenile habitat use. It appears that coordinating decisions across management realms of fisheries, water supply, and restoration may improve the natural productivity of Central Valley salmon.

LUNCH 12:25-1:10

1:10-2:00 **Poster session**

## Session 3 – Tools

**Moderated by Jeff Jorgensen – NWFSC, FE Division, Ecosystem Analysis Program**

2:00-2:20 **Can we achieve the dream of fine-grained habitat estimation at large spatial extents? Combining satellite imagery with streamflow models throughout the Columbia River basin** – Morgan Bond (Morgan.Bond@noaa.gov, NOAA Affiliate, Ocean Associates, Inc.), Colin Nicol (NOAA Affiliate, Ocean Associates, Inc.), Oleksandr Stefankiv (NOAA Affiliate, A.I.S., Inc.), Jeff Jorgensen (FE, NWFSC), and Tim Beechie

Effective management and restoration of freshwater habitats requires an assessment of current habitat condition and the ability to forecast habitat change. Although habitat models have been employed for decades to aid in habitat assessment and projecting the benefits of restoration, our ability to make these estimations at fine resolution and large spatial scales is limited. In addition, a prominent restoration tool in the Columbia River basin (CRB) is increasing seasonal instream flow, but the habitat effects of changing flow can only be estimated at small scales with hydraulic models. Similarly, climate change models indicate likely future changes in the timing and magnitude of seasonal streamflows, which will have major implications for ESA-listed Pacific salmon. However, the population-level effects of flow changes cannot be evaluated with existing tools. We are working to solve both problems in the CRB by creating a spatially extensive high-resolution freshwater habitat assessment with automated habitat measurement of satellite imagery. By leveraging high-resolution satellite imagery and the recently available National Water Model hourly streamflow estimates, we are developing a coupled flow-habitat model for each 200 m stream reach in the CRB. Our model will allow for an assessment of the benefits or impacts of flow changes to stream ecosystems. In addition, we are testing deep learning models to automate the identification of fine-scale stream features (e.g., logjams) important to rearing salmon. Although these habitat estimates are being developed initially in support of CRB salmon life cycle models, our approach can be applied to any stream with available satellite imagery.

2:20-2:40 **Life cycle modeling in the Grande Ronde River: data, knowledge, assumptions and goals** – Martin Liermann (Martin.Liermann@noaa.gov), Rishi Sharma (CB, NWFSC), Tom Cooney (CB, NWFSC), Ted Sedell (ODFW), Casey Justice (CRITFC), Seth White (CRITFC), Ben Staton (CRITFC) and Joseph Feldhaus (ODFW)

Salmon life cycle modeling provides a useful tool for describing hypotheses relating habitat restoration actions to population dynamics. While a large body of research linking habitat to fish metrics can guide the development of these models, there is typically still a great deal of uncertainty when quantifying effects. Here we use a life-cycle model for four Grand Ronde basin Spring Chinook salmon populations to explore the interplay between management questions, model complexity, data and assumptions. We contrast different approaches to accounting for uncertainty based on ease of communication, speed of model development, and model validation. Sources of uncertainty are broken down into three components, a) the relationship between the management action and habitat conditions, b) the relationship between habitat conditions and fish demographic parameters (like capacity), and c) the population dynamics of the current population.

2:40-3:00 **Combining NAIP-derived high resolution data (change, trees and visible water) for riparian change assessment in Puget Sound** – Kenneth Pierce Jr. (Kenneth.PierceJr@dfw.wa.gov, Washington Department of Fish and Wildlife) and Caleb Maki (Department of Natural Resources)

Advances in processing 1m aerial imagery and similar data sources are providing new tools for regional monitoring of freshwater and marine riparian condition and change. WDFW's High Resolution Change Detection project was started in 2010 to help provide highly accurate land cover change data that is relevant at all scales to help ask questions about regional as well as local land cover dynamics. Change is mapped as loss of canopy or gain in impervious surfaces. Starting in 2013, regional digital surface models developed by DNR from multi-pass aerial imagery where added to the data stack providing a Lidar-like height model at each image date derived from the same data that is used for change detection. With this additional data, we started experimenting with land cover modeling to provide a baseline for the land cover change data. Modeling canopy was very effective but major problems occurred with water and shadows and with impervious surfaces and bare ground/gravel/sand. Manually mapping visible surface water and associated gravel bars eliminates several of these problems. Additionally, mapping visible surface water provides a new map of water boundaries. Combine surface water boundaries, with high-resolution canopy cover and change in canopy cover and a riparian monitoring system emerges.

3:00-3:20 **Old-school guys using old-school tools to identify patterns and processes associated with salmon recolonization in the Middle and Upper Elwha River** – Todd Bennett (Todd.Bennett@noaa.gov), Martin Liermann, George Pess, Mike McHenry (Lower Elwha Klallam Tribe), Mel Elofson (Lower Elwha Klallam Tribe), Sonny Sampson (Lower Elwha Klallam Tribe), Rebecca Paradis (Lower Elwha Klallam Tribe), Justin Stapleton (Lower Elwha Klallam Tribe), Raymond Moses (Lower Elwha Klallam Tribe), Wilson Wells (Lower Elwha Klallam Tribe), John R. McMillan (Trout Unlimited), Roger Peters (US Fish and Wildlife Service), and Sam Brenkman (Olympic National Park)

The removal of the Elwha River dams began in 2011 and was completed in October of 2015. Numerous monitoring efforts have been occurring during that time, including juvenile salmonid sampling during the end of summer and beginning of fall. In addition, annual salmon spawner surveys were conducted for Chinook salmon, Coho salmon, and steelhead. The intent of these efforts was to document the patterns associated with salmon recolonization in the former Lake Mills reservoir and tributaries, and between the two former dam sites – Elwha and Glines Canyon dam, also known as the Middle Elwha. Between 2012 and 2019, we conducted juvenile electrofishing surveys to compliment the adult spawner surveys to quantify the change in juvenile abundance, species composition, and condition factor in 15 to 20 representative locations. We found that the pattern for adult salmon in the tributaries followed the overall pattern of juvenile salmon abundance concomitant with the benefits and impacts from dam removal. Chinook, Coho and steelhead immediately increased in the tributaries, followed by a decline during the heaviest sediment periods, then followed by an increase as sediment levels in the main stem decreased. Species composition for adults and juveniles varied on an annual basis throughout the Middle Elwha, and population estimates have increased in many of the locations since dam removal. We discuss other spatial and temporal patterns associated with length distribution and posit several hypotheses as to the reasons for these patterns. We will continue to conduct these surveys in the future in order to track patterns in juvenile salmonid distribution, abundance, and species composition as recolonization continues.

3:20-3:40 **Invertebrate eDNA metabarcoding: benefits and limitations for stream monitoring applications** – Sarah Morley (Sarah.Morley@noaa.gov), Linda Rhodes (EFS, NWFSC), Giles Goetz (CB, NWFSC), and Linda Park (CB, NWFSC)

Benthic invertebrates have long been used to assess the biological condition of water bodies throughout the world. In recent decades, these data are often used in regulatory contexts to enforce clean water regulations and direct conservation and restoration efforts. The emergence of rapidly developing molecular techniques provides an opportunity to improve upon some of the limitations of traditional invertebrate monitoring protocols. In this study, we compare traditional invertebrate sampling and identification with metabarcoding of environmental DNA (eDNA) collected from the same set of samples. Using eDNA (shed DNA fragments typically collected from soil or water samples) for species identification is a form of non-lethal sampling that can potentially integrate taxa presence over a larger sample area and increase detection of rare species. Metabarcoding (high-throughput sequencing of selected gene "barcode markers") of extracted eDNA can identify multiple taxa simultaneously, and can detect minute differences that may not be possible via morphological identification. While these emerging tools hold much promise, their real-world application has many methodological challenges. One such limiting factor is the lack of published barcodes for many invertebrate taxa. Our study therefore consists of two main parts. First, we are directly obtaining DNA sequences from our voucher specimens with unknown barcodes to add to existing databases as needed. Next, we will compare species identification generated from professional taxonomists to that produced by high-throughput sequencing of our eDNA samples. Currently, we are working on the first objective of our study. This presentation will provide an overview of the advantages and disadvantages of molecular techniques, identify steps needed to successfully employ these methods, and discuss relevant stream monitoring applications.

3:40-3:45 Closing remarks – George Pess, Watershed Program Manager

3:45-4:30 **Poster session**

# Posters

(Displayed in the room across the foyer from the auditorium)

Theme: **Puget Sound**

- **The impacts of jellyfish on Puget Sound's pelagic environment** – Correigh Greene (Correigh.Greene@noaa.gov), Julie Keister, Haila Schultz, and Amanda Winans (University of Washington), Briana Gabel (Highline College), Gabriela Hannach (King County Environmental Lab), Hem Nalini Morzaria-Luna (CB, NWFSC), Isaac Kaplan (CB, NWFSC), and Kathryn Sobocinski (Western Washington University)

In Puget Sound, a region with declining salmon and forage fish populations, gelatinous zooplankton (jellyfish) are a dominant component of the marine ecosystem and their populations appear to be increasing. One of the most conspicuous taxa is the moon jelly, *Aurelia labiata,* which has been observed to form huge aggregations visible in aerial surveys. This medusa competes with fish for zooplankton prey, can feed directly on fish eggs and larvae, and may significantly influence the pelagic environment by removing phytoplankton or phytoplankton grazers or by increasing dissolved nitrogen in the water column. These impacts have important consequences for ecosystem health and management of declining fish populations in Puget Sound, but quantitative data on the trophic and biochemical impacts of jellyfish aggregations in this ecosystem are lacking. Studies of jellyfish sampled across Puget Sound in 2011 confirm correlations with chlorophyll concentrations, ichthyoplankton, and metabolically active bacteria. These suggest the strong potential for multiple ecosystem effects, particularly where moon jellyfish form aggregations. Based on funding from NWFSC's internal grant program in 2019, we initiated experiments on moon jellyfish diets and additional field surveys centered on moon jellyfish aggregations. The pilot experiments document a high potential for consumption of a wide variety of taxa, and the field surveys corroborate the strong potential for ecosystem impacts including higher volumes of diatoms and dinoflagellates within aggregations. This project will receive additional support from Washington Seagrant (PI Julie Keister), which will fund additional experiments and fieldwork as well as ecosystem modeling of jellyfish increase/decrease scenarios using the Atlantis Ecosystem model.

- **Examining cumulative anthropogenic impacts upon pinniped-mediated marine mortality of steelhead using an encounter rate model** – Correigh Greene (Correigh.Greene@noaa.gov), Brianna Ganzon and Zachary Duckworth (Seattle University)

Marine survival of some of Puget Sound's salmon stocks (Chinook, Coho, and Steelhead) have been declining in the last decade, leading to multiple hypotheses on the causes of declines. One possible commonly cited cause is the increase in predation from burgeoning populations of harbor seals, which have benefited from protections afforded as a charismatic marine mammal. While predation from increasing numbers of seals has almost certainly increased as the population has grown, attributing declines solely to increasing seals ignores the multiple other pathways that can influence predator-prey encounters. We use an encounter rate model of seals and steelhead to evaluate the impact of predation in the context of other trends including changes in body size, outmigration abundance, water clarity, light pollution, and declines in buffer prey. This model affords examination of potential cumulative effects, of which few other models are currently capable.

- **Methods to quantify aggregations of moon jellies (*Aurelia labiata)* using aerial capture image processing** – Tayler Nichols (Nicholta@oregonstate.edu, Oregon State University), Correigh Greene, Julie Keister (University of Washington), Christopher Krembs and Skip Albertson (WA Department of Ecology)

The Eyes Over Puget Sound (EOPS) monthly flight-monitoring program captures aerial images that qualitatively describe the abundance of moon jellyfish (*Aurelia labiata*) in Puget Sound. These images have been successful in capturing the public's interest in the health of Puget Sound and highlighting the potential negative ramifications of jellies. However, to further understand the role that jellyfish have in an ecosystem, it is critical to quantify the data that has been collected. Quantifying the surface area of aggregations in aerial photos can aid in assessing ecosystem health and become an ecosystem indicator for eutrophication. Creating a quantitative index first requires establishing a rigorous data acquisition protocol. This process begins by marking ground reference points on selected images known to contain jelly aggregations. By marking landforms and anthropogenic structures (e.g., spits, coves, marinas, and bridges), we can use these ground points to eliminate perspective and tilt bias inherent in aerial images. Images are flattened into a two dimensional overhead plane using an orthorectification process. Aggregations of jellies are then accurately outlined, mapped, and measured using ImageJ. This data then can be used to provide a quantitative indicator of ecosystem health and deepen understanding of the ecological role that *Aurelia labiata* may have in Puget Sound.

- **Urban floodplain reconnection - more than drainage benefits: an overview of project performance results** – Katherine Lynch (Katherine.Lynch@seattle.gov, Seattle Public Utilities), Paul Bakke (U.S. Fish and Wildlife Service), Steve Damm (Seattle Public Utilities), Skuyler Herzog (Colorado School of Mines), Ed Kolodziej (UW Tacoma), Jennifer McIntyre (WSU Puyallup), Sarah Morley, Katherine Peter (UW Tacoma), Chapin Pier (Seattle Public Utilities), and Linda Rhodes (EFS, NWFSC).

Over the years, the City of Seattle's urban creeks have been rerouted, channelized, and disconnected from their floodplains to accommodate roads, buildings and infrastructure. Seattle Public Utilities (SPU), increasingly in partnership with Seattle Parks and Recreation (Parks) and Seattle Department of Transportation (SDOT), is using public open-space planning, watershed science, and principles of asset management to maximize the value of its capital investments in drainage infrastructure. In particular, SPU has begun restoring water-land connections (floodplains) in urban areas, in order to provide benefits beyond stormwater management, such as, public open natural space, water treatment, habitat, and ecological and climate resilience. SPU collaborated with regional researchers from NOAA Northwest Fisheries Science Center, University of Washington-Tacoma, Colorado School of Mines and Washington State University to assess the performance of two floodplain reconnection projects, constructed in the Thornton Creek watershed during 2014. The poster provides highlights from the team's research results, covering physical, biological and water treatment performance of the projects.

- **Summary of baseline data for Salmon Habitat Status and Trends Monitoring Program** – Britta Timpane-Padgham (Britta.Timpane-Padgham@noaa.gov, NOAA Affiliate, A.I.S., Inc.), Alex Stefankiv (NOAA Affiliate, A.I.S., Inc.), Jason Hall (Cramer Fish Sciences), Caleb Fogel (NOAA Affiliate, Ocean Associates Inc.), Colin Nicol (NOAA Affiliate, Ocean Associates Inc.), Timothy J. Beechie, and George R. Pess

In 2014 and 2015, we began a habitat status and trend monitoring program for the Puget Sound Chinook, Hood Canal Summer Chum, and Puget Sound Steelhead Evolutionarily Significant Units (ESUs). The purpose of this monitoring program is to provide consistent habitat data for evaluating trends in the habitat listing factor at each 5-year status review for the listed ESUs. This monitoring program is satellite- and aerial-imagery-based, covering large river, floodplain, delta, and nearshore habitats. One of the key listing factors for Puget Sound Chinook salmon, Hood Canal summer chum salmon, and Steelhead is the quantity, quality, and distribution of habitat supporting these species. Hence, having consistent habitat data across the ESU and each Major Population Group (MPG) within each ESU is an essential component of any five-year status review. In Phase I of this project, we developed a monitoring program to fill this data need, covering the four distinct salmon spawning and rearing environments: large rivers, floodplains, deltas, and the nearshore. Each of these environments provides habitat for key life stages of Chinook salmon, chum salmon, and steelhead. In Phase II of the project, we evaluated our sampling strategy, revised protocols accordingly, and completed necessary base maps for floodplains and baseline data for several of our delta and nearshore metrics. Phase III has consisted of expanding our methods to the Oregon Coast Coho Salmon ESU in 2018 and completing sampling of our metrics using updated protocols. We have developed 22 protocols for monitoring land use and habitat changes. Here we summarize the status of the metrics we have completed to date and report results for a few of our more commonly used metrics.

Theme: **Salmon Response to Habitat Change**

- **Quantifying loss of historical floodplains and implications for salmonids in the Chehalis River basin** – Colin Nicol (Colin.Nicol@noaa.gov, NOAA Affiliate, Ocean Associates, Inc.), Caleb Fogel (NOAA Affiliate, Ocean Associates, Inc.), Jeff Jorgensen (FE, NWFSC), and Tim Beechie

Floodplains are essential habitat for many species, but are often the site of human development. Off channel habitat is critical for salmonid species, particularly in the winter months where the floodplains can act as a refuge from floodwaters in the main river. Using the Chehalis River basin as the study area, our goal was to quantify the current and historical floodplain habitat area, and relate habitat change to population change for coho, spring Chinook and fall Chinook. To map current and historical floodplains, we used the General Land Office surveys from the late 1800s in combination with contemporary aerial imagery and high-resolution terrain maps. To relate floodplain areas to habitat use, we assigned average densities and survivals to each unit based on habitat type, species and lifestage. This resulted in a set of spatially explicit capacities and productivities we used to parameterize species-specific lifecycle models. Our floodplain mapping results showed past practices of dyking and draining have caused significant losses of marsh, pond and slough habitat, particularly in the Black and Skookumchuck basins. Historically in the floodplain of the lower mainstem there was over 600 hectares of pond habitat, 60% of which has been lost. Basinwide, approximately half of all historical floodplain habitat has been lost, and of the remaining marsh and pond habitat, more than 80% has been modified and is in a degraded state. The results of the lifecycle models showed that under historical floodplain conditions -- holding all other conditions at current levels -- coho salmon and spring Chinook spawner abundance increased by more than 50%, with approximately a 20% increase for fall Chinook. Our analysis showed restoring floodplain habitat in the Chehalis basin has substantial benefit to all three salmonid species.

- **Salmonid response to rising stream temperature in the Chehalis River basin** – Caleb Fogel (Caleb.Fogel@noaa.gov, NOAA Affiliate, Ocean Associates, Inc.), Colin Nicol (NOAA Affiliate, Ocean Associates, Inc.), Tim Beechie, and Jeff Jorgensen (FE, NWFSC)

Stream temperatures in the Pacific Northwest are projected to increase with climate change, placing additional stress on native salmonid species. In the Chehalis River basin, Washington, USA, peak summer stream temperatures are predicted to increase by as much as 2°C by late-century. In this study we assessed the impact of increased stream temperatures on three salmonid species (spring-run Chinook salmon *Oncorhynchus tshawytscha*, fall-run Chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*) in the Chehalis River basin. Using life cycle models, we estimated the potential consequences of increased stream temperature on these species using species- and life-stage-specific relationships between temperature and survival. Additionally, we assessed the potential for habitat restoration, including floodplain reconnection and increased stream shading from riparian planting and growth, to offset the effects of future temperature increases. We applied a temperature effect on rearing survival for all species, however the magnitude of the effect varied among species. Coho rear in streams throughout the entire summer, and therefore experience the warmest summer temperatures. Juveniles of both runs of Chinook salmon migrate out of fresh water before summer temperatures reach their peak, therefore temperature had a diminished effect on rearing survival for these two species. Spring-run Chinook salmon are the only species with adults holding in the river during the warmer summer months, and therefore they are the only species for which peak temperatures affect prespawn survival, one of the most sensitive parameters in our life cycle model. Because of this, spring-run Chinook are particularly vulnerable to stream temperature increases. Results from the life cycle models indicated that increased summer temperatures produce significant declines in spawner abundance for coho and spring-run Chinook salmon, and small decreases for fall-run Chinook salmon. When the life cycle model included proposed habitat restoration actions there were opportunities to mitigate the negative impacts of future increases in temperature.

- **Restoration potential for salmonids in the Chehalis River basin** – Jeff Jorgensen (Jeff.Jorgensen@noaa.gov, Northwest Fisheries Science Center, Fish Ecology Division, Ecosystem Analysis Program), Tim Beechie, Caleb Fogel (NOAA Affiliate, Ocean Associates, Inc.), and Colin Nicol (NOAA Affiliate, Ocean Associates, Inc.)

Preserving and improving freshwater habitats are needed for salmonid populations' persistence. In many circumstances, habitats are degraded and there is a need to understand the scope and scale of possibilities for fish habitat improvements. What can be done? Where? By how much? Which fishes will benefit? In the Chehalis River Basin in southwestern Washington State, we have constructed tools and techniques with input and participation from stakeholders to identify potential opportunities for habitat improvements. The goal is to provide information for stakeholders -- in the form of evaluations of outcomes of alternative habitat restoration strategies -- who will decide what actions to implement, which locations will receive habitat actions, and how much each area is to be treated. Our process included constructing physical models of the basin, and then estimations of fish habitat quality and quantity for freshwater life stages and which were unique to each species (coho, spring- and fall--run Chinook salmon, and winter steelhead). In the third part of the process, we used information from the previous two components to parameterize spatially explicit life cycle models, which simulated population responses to changes in habitat and climate. Through this process, we found that restoring floodplain and wood abundance would provide some benefits to all of the species. Modeling of shade-induced water temperature reductions suggested that there are some opportunities for riparian restoration to lower stream temperatures, which had large effects on prespawning survival of spring-run Chinook salmon. We also found that proposed barrier removals could bolster some local subpopulations of coho and steelhead, but the overall benefit potential of barrier removal was relatively small. By combining these tools together, we have developed a comprehensive process to evaluate habitat restoration strategies.

- **Factors controlling the variability in invertebrate prey: consequences for stream-rearing salmonids in the Cedar River, W**A – Jacob Bowman (Jacob.Bowman@yotes.collegeofidaho.edu, College of Idaho, NOAA Hollings Scholar Program), and Peter Kiffney

Invertebrate drift, the downstream transport of invertebrates within the water column in lotic systems, is integral to energy flow as it is a key part of the diet for many stream-rearing fish. Although drift is clearly important to the flow of energy in streams, our understanding of drift is poor. For example, we have a poor understanding of the natural range in drift concentrations or of the factors that contribute to this variability. In this study, we examine factors contributing to temporal variability in stream drift from the Cedar River and tributaries, an area where anadromous salmonids were locally extirpated since 1901 by Landsburg Dam until a fish ladder was installed in 2003. We expected stream drift to increase with salmon recolonization because previous experiments in the Cedar River demonstrated salmon carcasses limited benthic production. Invertebrate drift was collected from riffles in the Cedar River main stem and tributaries during multiple years between 2005 and 2015. An increase in drift biomass was observed coincident with adult anadromous salmon population growth, potentially due to inputs of marine-derived nutrients from salmon carcasses after spawning and death. Our study provides insight into connections between adult salmon populations and the freshwater ecosystems that support them, which will aid in the management of salmon species across the Pacific Northwest.

Theme: **Tools**

- **Mapping historical riparian vegetation in the Columbia River basin** – Oleksandr Stefankiv (Oleksandr.Stefankiv@noaa.gov, NOAA Affiliate, A.I.S., Inc.), Tim Beechie, and Morgan Bond (NOAA Affiliate, Ocean Associates, Inc.)

Successful restoration of riparian areas depends in part on accurate identification of species compositions that are suited to local geomorphic and climatic conditions, which often relies on the identification of reference conditions for riparian vegetation communities. However, in heavily modified landscapes a lack of undisturbed reference sites often hinders the description of reference conditions to help guide planning efforts. In such cases, use of historical information is frequently employed to help guide the identification of reference conditions. We developed a GIS dataset that depicts pre–settlement riparian vegetation in the Columbia River basin to guide stream restoration for endangered salmon. To do this, we first created a data layer of historic riparian vegetation information from survey notes that were taken mid–19th to early 20th century during the Public Land Survey System conducted by the General Land Office. We utilized environmental variables, such as mean annual precipitation, average minimum and maximum temperature, and elevation in Random Forest classification algorithm to predict riparian vegetation functional groups (Conifer–dominated forest, Deciduous forest, Sage, and Willow–Shrub) as well as the probability of occurrence of most common individual species (Fir, Cottonwood, Sagebrush, and Willow) at stream reach level in the basin. We believe that, using the predicted vegetation functional group and species occurrence maps we can reasonably estimate reference riparian condition in the Columbia River basin and our approach can be applicable to other areas in the United States.

- **Using aquatic environmental DNA (eDNA) to track fish recolonization following dam removal on the Elwha River, Olympic National Park, Washington** – Jeff Duda (Jeff.Duda@usgs.gov, USGS), Marshal Hoy (USGS), Dorothy Chase (USGS), Carl Ostberg (USGS), Sam Brenkman (Olympic National Park), Mike McHenry (Lower Elwha Klallam Tribe), and George Pess

The removal of two Elwha River dams is the largest dam removal project in history and a significant salmon restoration project in the Northwest region. A key goal is the recolonization of anadromous fish into spawning and rearing habitats upstream, most of them contained within protected wilderness areas within Olympic National Park. Use of some “front country” sampling techniques, especially those requiring regular equipment maintenance (e.g., sonar) or unwieldy, logistically intensive equipment (e.g., screw traps), were prohibitively challenging in the roadless backcountry regions of the National Park. We developed and optimized a collection of species-specific molecular markers for use in PCR amplification of aquatic environmental DNA (eDNA). We targeted 11 fish species (all Pacific salmon, Rainbow Trout/Steelhead, Bull Trout, Cutthroat

Trout, Eastern Brook Trout, Pacific Lamprey and River Lamprey), sampled before and after dam removal. The sampling locations range across  56 river kilometers at 10 front country and 14 back country sites from both the Elwha River (n=14) and its tributaries (n=10). Sampling occurred from 2014 to 2017, approximately monthly at front country locations and quarterly or annually in the backcountry. Pacific salmon, trout, and lamprey all showed different spatial and temporal patterns of eDNA detection and levels of recolonization past former dam locations. Surveys of eDNA appears to hold promise for examining patterns of species presence/non-detection for the purpose of tracking the rate and extent of recolonization of migratory fish species in the Elwha River.

- **Utilizing resilience metrics for restoration prioritization and monitoring: a Salish Sea case study** – Britta Timpane-Padgham (Britta.Timpane-Padgham@noaa.gov, NOAA Affiliate, A.I.S., Inc.), Terrie Klinger (SMEA, UW College of the Environment), and Tim Beechie

Ecological restoration is widely practiced as a means of rehabilitating ecosystems and habitats that have been degraded or impaired through human use or other causes. Restoration efforts now are confronted by climate change, which has the potential to influence long-term restoration outcomes. Concepts and attributes from the resilience literature can help improve restoration and monitoring efforts under changing climate conditions. We systematically examined the published literature on ecological resilience to identify biological, chemical, and physical attributes that confer resilience to climate change. We identified 45 attributes explicitly related to climate change and classified them as individual- (9), population- (6), community- (7), ecosystem- (7), or process-level attributes (16). We summarize the attributes and their relationship to restoration principals in a decision support table and provide an example application with the Puget Sound Habitat Monitoring Program to illustrate how these results can be used in monitoring and restoration planning. We suggest that (1) including resilience as an explicit planning objective could increase the success of restoration projects, (2) considering the ecological context and focal scale of a restoration action is essential in choosing appropriate resilience attributes, and (3) certain ecological attributes, such as diversity and connectivity, are more commonly considered to confer resilience because they apply to a wide variety of species and ecosystems. We propose that identifying sources of ecological resilience is a critical step in restoring ecosystems in a changing climate.