NWFSC Watershed Program Open House

NOAA Western Regional Center

7600 Sand Point Way NE

Seattle, WA

March 20, 2017

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

8:30-8:35 Welcome – Rich Zabel, Fish Ecology Division Director, Northwest Fisheries Science Center

8:35-8:40 Overview of Watershed Program research – George Pess, Program Manager, Northwest Fisheries Science Center

Session 1 – Salmon Life Cycles

8:40-9:00 **A geomorphic approach to estimating salmon rearing capacity in the Columbia River basin**. M. H. Bond (NOAA Affiliate, Ocean Associates), T. G. Nodine (NOAA Affiliate, Ocean Associates), T. J. Beechie, and R. W. Zabel (FE, NWFSC)

Historically low abundances of Columbia River basin (CRB) salmon have persisted despite restoration and policy actions spanning decades. To better evaluate the magnitude of freshwater habitat loss and likely benefits of large-scale stream tributary restoration, we used a geomorphic approach to estimate rearing capacity for spring-run Chinook salmon at the sub-basin spatial scale (HUC 8) throughout the CRB. We measured satellite imagery for main stem and off-channel habitat areas throughout the CRB at randomly selected sites stratified by land use, stream size, and estimated channel form. These measurements were used in a series of random forest models to separately predict: side channel presence, side channel area and main stem bank proportion with predictors available at the 200 m stream segment scale (land cover, floodplain width, slope, sinuosity, discharge, sediment accumulation, elevation, and bankfull width). For each sub-basin we estimated total rearing habitat as well as habitat decomposed into: side channels, main stem banks, main stem bars, and mid-channel reaches. Mid-summer parr capacity was estimated by applying parr densities to habitat estimates using three distinct data sources: literature capacity densities for individual habitats, quantile regression of electrofishing parr surveys and total habitat area, and a literature capacity of 5200 parr per hectare of wetted habitat. Overall, we found widespread agreement among the three methods of estimating rearing capacity. Historical estimates of side channel habitat indicate a loss of ca. 14%, which varies regionally. However, as valuable rearing habitat, the loss of side channels has a prominent and disproportionate effect on rearing capacity.

9:00-9:20 **Restoration in tributary, mainstem, and estuary habitats and recovery of Oregon coho salmon: results from life cycle modelling.** C. Greene, J. Rice (NOAA Affiliate, Ocean Associates) and C. Phillis (NOAA Affiliate, Ocean Associates)

Oregon Coast coho salmon are currently listed as threatened, primarily due to considerations over habitat conservation. Much effort by state and federal agencies have addressed limiting factors focused on restoring freshwater rearing habitat, although emerging analyses indicate that juvenile coho salmon life history types utilize mainstem, floodplain, and estuary habitats as well. These systems are currently not well incorporated into habitat conservation goals. To address whether current habitat conservation goals are likely to result in expected population recovery, we developed a life cycle model of Oregon coho salmon that incorporates both spatial complexity and life history diversity. The life cycle model is based on data from research on life history variation in coho salmon living in the Salmon River. Results of the model indicated that spatial complexity and life history diversity generally lowered population response to tributary habitat restoration (the focus of most habitat conservation efforts) largely because of reductions in connectivity compared to classic limiting factors models. The models also predicted that restoration of estuaries and mainstem/floodplain environments would result in larger benefits to population productivity than similar amounts of tributary restoration. These results suggest that current conservation goals in tributary habitats are over-optimistic, and that habitat conservation "portfolios" should also include floodplain and estuary components. Unfortunately, limited monitoring exists in these habitats. Better data on habitat use by different life history types will help improve model predictions of floodplain and estuary habitat conservation.

9:20-9:40 **Population modeling for developing Puget Sound Chinook Salmon Rebuilding Exploitation Rates.** M. Liermann, E. Holmes (CB, NWFSC), S. Bishop (NOAA, Northwest Region) and M. Rowse (CB, NWFSC)

Analysis of salmon adult abundance has evolved over the last several decades moving from simple spawner recruit models to analyses that incorporate measurement error and integrate abundance and age data into a single modeling framework. Here we describe the process of updating the population models used in a risk assessment framework for setting Rebuilding Exploitation Rates for Puget Sound Chinook Salmon populations. Specifically, we address issues with data quality, decisions about model form, and methods for evaluating model fit. Because both variability in environmental drivers and measurement error are typically large, resulting uncertainty in model parameters is often considerable. Therefore, a continued dialogue between those implementing these models and biologists familiar with the systems is crucial.

9:40-10:00 **Characterizing the size and timing of juvenile salmonid movement and migration from the Elwha River and two tributaries, Indian Creek and Little River**. T. Bennett, M. Liermann, G. Pess, Steve Corbett (NOAA Affiliate, Ocean Associates), M. McHenry (Lower Elwha Klallam Tribe), M. Elofson (Lower Elwha Klallam Tribe), S. Sampson (Lower Elwha Klallam Tribe), R. Paradis (Lower Elwha Klallam Tribe), and J. Stapleton (Lower Elwha Klallam Tribe)

In April of 2012, the Elwha River Dam was breached allowing 13.5 kilometers (km) of main stem river access for anadromous salmonids to the middle Elwha River between the former Elwha Dam and Glines Canyon Dam. The breach also allows anadromous salmonids to access several tributaries including two major tributaries - Indian Creek (Rkm 12.1) and Little River (Rkm 12.2). Since that time period salmonid recolonization has been a combination of relocation and natural recolonization for coho Salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*), and natural recolonization for Chinook Salmon (*O. tshawytscha*). One of the main methods to enumerate the success of the dam removal has been to quantify the number of outmigrating juvenile salmonids using screw traps. A screw trap has been placed seasonally in the main stem Elwha (~ Rkm 2.0) since 2005 and more recently, screw traps were installed in Indian Creek (2013) and Little River (2012). These traps allowed us to collect information on the number, timing, and size of emigrating fishes. All fish species captured were enumerated and a subset (n = 1,176) were sampled for length and weight. Preliminary results suggest that each species employs several life history strategies that differ between each tributary and the main stem Elwha River, especially with *O. mykiss*. We present a several hypotheses as to what these life history strategies are, and what this may mean for salmon recolonization success for the Elwha River dam removal project.

BREAK 10:00-10:20

Session 2 – Chehalis and Puget Sound

10:20-10:40 **A process-based assessment for watershed restoration planning, Chehalis River basin, USA.** T.J. Beechie, J. Hall, J. Chamberlin, P. Kiffney, M. Pollock, G.R. Pess, J. Thompson (NOAA Affiliate, Ocean Associates), G. Seixas (NOAA Affiliate, Ocean Associates), C. Fogel (NOAA Affiliate, Ocean Associates), J. Jorgensen (NOAA Affiliate, Ocean Associates)

Three key questions in identifying and prioritizing river restoration are: (1) How have habitats changed?, (2) What are the causes of those habitat changes?, and (3) How have those changes affected the species of interest? To answer these questions and assist aquatic habitat restoration planning in the Chehalis River basin, USA, we quantified habitat changes across the river network from headwaters to the estuary. We estimated historical habitat capacity to support salmonids using a combination of historical assessments, reference sites, and models.

We also estimated current capacity from recent or newly created data sets. We found that losses of floodplain habitats and beaver ponds were substantial, while the estuary was less modified. Both tributary and main channel habitats—while modified—did not show particularly large habitat changes. Assessments of key processes that form and sustain habitats indicate that riparian functions (shading and wood recruitment) have been significantly altered, although peak and low flows have also been altered in some locations. The next step is to link our habitat assessments to salmon life-cycle models to evaluate which life stages and habitat types currently constrain population sizes of spring and fall Chinook salmon, coho salmon, and steelhead. By comparing model runs that represent different components of habitat losses identified in the analysis above, life-cycle models help identify which habitat losses have most impacted each species and population. This assessment will indicate which habitat types provide the greatest restoration potential, and help define a guiding vision for restoration efforts. Future analyses may include development and evaluation of alternative restoration scenarios, including different climate change scenarios, to refine our understanding of which restoration actions provide the greatest benefit to a salmon population.

10:40-11:00 **Influence of channel width on stream shade and temperature change in a forested catchment**. G. B. Seixas (NOAA Affiliate, Ocean Associates), T. J. Beechie, C. Fogel (NOAA Affiliate, Ocean Associates), and P. M. Kiffney

Riparian forests attenuate solar radiation to stream surfaces, thereby providing a critical service to cold-water species such as anadromous fishes with narrow thermal tolerances. However, channels naturally widen downstream as they accumulate drainage area, and forest structure in many of the world's watersheds has been altered by human activities such as logging. Thus, the fraction of a channel surface expected to be shaded by riparian trees declines longitudinally, and riparian forest degradation creates a patchwork of shade along the channel network as natural widening and human-induced structural changes interact. Here, we investigate the hypothesis that the largest potential change to shade and stream temperature due to riparian degradation occurs at intermediate channel widths, provided some vegetation is present. We used an automated algorithm and LiDAR topographic data to measure current riparian shade across the Chehalis River basin, WA state; we then assumed historical tree heights based on known species distributions and calculated the change in shade from historical levels. To predict changes in stream water temperature, we found an empirical relationship between water temperature, drainage area, elevation, and our calculated shade values using an existing temperature dataset. We found the greatest change from historical conditions exists in urban, agricultural and floodplain regions, with the most change between 10 m and 40 m bankfull width. We next calculated time needed to achieve specific restoration targets, and found that this quantity also depends on channel width. We conclude by combining the measurement of shade degradation and time needed to achieve a restoration target into a 'restoration score', allowing us to efficiently map restoration priorities across the basin.

11:00-11:20 **Monitoring nearshore, delta, and freshwater habitats in Puget Sound**. B. Timpane-Padgham (Ocean Associates, NOAA affiliate) (Presenter), O. Stefankiv (Ocean Associates, NOAA affiliate) (Presenter), T. J. Beechie, G. R. Pess, J. Hall, M. C. Liermann, K. Fresh (FE, NWFSC), M. Rowse (CB, NWFSC)

The Puget Sound Habitat Status and Trend Monitoring program was initiated in 2014 to collect long-term, high quality habitat data within nearshore, delta, main stem rivers, and floodplain habitats -all of which are critical for ESA listed salmonids. We employ a hierarchical sampling design using satellite data, aerial photography, and field data to measure a number of peer selected metrics for each the four habitat types. We conducted a complete census for metrics that were found to be most reliable and repeatable. Land cover status in all habitats types is reported by land cover class and major salmonid population groups (MPG), with results showing decreased habitat quantity and quality in more developed areas. Forest dominated mainstem and floodplain sites had greater wood jam area and a greater number of side channels. Delta area and perimeter are also important habitat metrics that differ among MPGs. A complete survey of overwater structures in Puget Sound confirms that area of structures is greatest in urban environments. A key component of this project is to examine fish-habitat linkages for our selected metrics. For further details, see Hall et. al in this session. Future work will focus on collecting habitat status for additional metrics and analysis of status and trends on the completed metrics.

11:20-11:40 **Relationships between floodplain habitat complexity and productivity of Chinook salmon in Puget Sound Rivers**. J. E. Hall, T. J. Beechie, G. R. Pess, C. M. Greene, M. Liermann, K. Fresh (FE, NWFSC), M. Rowse (CB, NWFSC), M. Ford (CB, NWFSC), O. Stefankiv (NOAA Affiliate, Ocean Associates), B. Timpane-Padgham (NOAA Affiliate, Ocean Associates) J. Anderson (WDFW), J. Griffith (Stillaguamish Tribe), and M. Pouley (Tulalip Tribes).

The Puget Sound region supports populations of every Pacific salmon species, including populations listed as “Threatened” under the Endangered Species Act (ESA). To support evaluations towards recovery of listed Puget Sound salmon populations, we initiated the development the Puget Sound Habitat Status and Trends Monitoring (PSHSTM) program to develop census-based large-scale remote sensing salmon habitat-monitoring metrics. One primary goal of this program was to develop consistent measures of habitat quantity and quality that could be correlated with salmon population parameters such as abundance and productivity over space and time. With the first census of large river and floodplain habitat metrics recently completed, we conducted an initial analysis to evaluate progress towards PSHSTM program goals. The results of this preliminary analysis indicate that differences in habitat complexity among Puget Sound river systems could be detected from measures of braid and side channel to mainstem channel length ratios, braid and side channel node densities, and log jam densities. These measures of habitat complexity were also positively correlated with production rates of sub-yearling Chinook smolts. Using an information-theoretic model selection approach, smolt production rates were best explained by models that included

PSHSTM program habitat complexity metrics in combination with either peak river discharge during juvenile incubation periods or the density of contributing adult spawners. These findings provide preliminary evidence that the PSHSTM program can provide quantitative measures of habitat quantity and quality that could be correlated to important Viable Salmon Population (VSP) parameters used to evaluate salmon recovery in the ESA context.

11:40-12:00 **Developing indicators of salmon marine survival**. K. Sobocinski (NOAA Affiliate, Long Live the Kings), C. Greene and N. Kendall (WDFW)

Marine survival among Salish Sea Chinook, Coho, and steelhead has declined in recent decades. While the cause is likely multi-faceted, changes like increased pinniped abundance, changing foodweb dynamics, and anthropogenic impacts to inland marine waters have all been hypothesized as contributing factors. To address this decline in survival, we are conducting a retrospective analysis aimed at evaluating how changes in the Salish Sea system over the last four decades relates with salmon marine survival. We are developing a suite of indicators that reflect changes to the system over this time period and will use generalized linear models and multivariate time series analysis to assess trends and determine contributing factors. Using model selection, we are evaluating indicators singly and in combination, thereby addressing possible interactions and cumulative effects. For steelhead, we are evaluating a suite of indicators including: pinniped, groundfish, and herring abundances, water quality and oceanographic variables including flow and primary production, and hatchery releases. These factors were selected based on their potential as mechanistic, process-driven indicators for steelhead survival.

12:00-1:00 Poster session (see abstracts below)

<u>LUNCH 1:00-2:00</u>

Session 3 – Restoration

2:00-2:20 **Riparian forest structure and stream food webs.** P. Kiffney, S. Naman (University of British Columbia), M. Kaylor (Oregon State University) and D. Warren (Oregon State University)

Management of stream fish populations focuses on the role of physical habitat heterogeneity in regulating individual and population growth, an approach that assumes food is not limiting or unimportant. This assumption is rarely tested or evaluated despite decades of research showing the fundamental role food plays in regulating individual growth and the carrying capacity of a stream to support fish. Food limitation may be particularly important in forest streams where light and nutrients constrain primary and secondary productivity. Here we examine the linkages between riparian forest structure (e.g. dense 2nd growth stands vs. open old-growth stands), prey availability, and stream salmonid populations during summer low-flow conditions using a combination of experiments and field observations. Multiple lines of evidence support the hypothesis if water temperature is conducive to positive growth, fish populations in PNW forest streams are limited by food availability during summer low flows, which is partly determined by riparian forest structure and local habitat conditions.

2:20-2:40 **Klamath River restoration: Do we need fewer dams or more dams?** M. Pollock and B. Cluer (NOAA Fisheries West Coast Region California Coastal Office)

The 40,800 km^2 Klamath River Basin in northern California and southeastern Oregon supports Chinook salmon, coho salmon, and steelhead populations, among other anadromous species. It is just one of three rivers that pass through the Cascades or Sierra Nevada to the Pacific. Historically, anadromous fish populations supported important commercial, recreational, and tribal fisheries. However, many anadromous fish populations have declined substantially in abundance. In particular, coho salmon are now listed as threatened under both the federal Endangered Species Act and the California Endangered Species Act. A series of hydropower dams near the California-Oregon border have limited anadromous runs to the middle and lower basin, but a recently signed accord calls for the removal of these dams by 2020.

The Scott River is an undammed major tributary to the Klamath basin located on the drier eastern side of the coast range in about the middle of the Klamath basin as a whole. It drains one of the few substantial low gradient valleys below the hydropower dams and is one of the best remaining coho salmon producing streams in the basin. As such, it is critical both to the recovery of downstream coho populations and to the recolonization of upstream habitat once the hydropower dams are removed.

The Scott River itself has undergone substantial habitat alteration and degradation in the past 165 years from placer mining, logging and agriculture. Currently restoration efforts are underway to improve habitat conditions for coho salmon in the Scott River valley, by creating

slow water habitat using Beaver Dam Analogues (BDAs), and also through off channel pond creation, screening intake diversions, bank stabilization, riparian planting, water conservation, acquisition of water rights and land conservation easements. We discuss the initial results from restoration efforts using BDAs in the context of coho salmon recovery in the basin in general and discuss other opportunities for salmon habitat restoration in the Klamath River basin.

2:40-3:00 **Restoration monitoring in the Snohomish River estuary**. J. Chamberlin, J. Hall, C. Rice, T. Zackey (Tulalip Tribes), F. Leonetti (Snohomish County), and M. Rustay (Snohomish County)

The Snohomish river delta has been the focus of major estuary restoration efforts in recent years. Implementation of three large (300-400 acres each) levee breach projects in the estuary between 2015 and 2020 presents a unique opportunity to evaluate individual, interactive, and cumulative effects of large delta restoration projects. Evaluations of biological or physical responses to restoration are often predicated on site level expectations for a given project. However, landscape context is critical in estuary restoration planning and assessment due to the complexity and size of estuaries, the diversity and mobility of juvenile salmon rearing in them, and the unique attributes and cumulative effects of individual restoration projects. In addition, landscape position can be extremely important given certain positions in the delta are less accessible to salmon and/or habitat development is less likely to be sustained through sediment supply. Beginning in 2011, we developed a comprehensive system-wide monitoring effort to understand the relationship between physical processes (flow, sediment transport), environmental variation (temperature, salinity) and biological components (fish distribution and timing, species assemblages), and how they change or alter one another throughout the landscape. Specifically, the program incorporates intensive, year-round fishing of multiple habitat types, continuous sampling of temperature, salinity and water level, and fine scale measurements of elevation due to sediment accretion or subsidence across the entire estuarine landscape. Such information will aid project evaluation, both individually and cumulatively, and further inform prioritization of future restoration and recovery planning throughout the delta.

3:00-3:20 **Effects of shoreline armoring and overwater structures on fish ecology in Puget Sound**. S. Munsch (UW SAFS, now NOAA Affiliate, Ocean Associates), J. Cordell (UW SAFS), J. Toft (UW SAFS)

Nearshore ecosystems are increasingly recognized as critical habitats for fish of cultural, ecological, and economic significance. These ecosystems are often densely inhabited by juvenile fish, highly productive, and refuges from predation, leading ecologists to characterize them as nurseries. However, people are transforming nearshore ecosystems globally to support demands of growing coastal populations. Many shorelines are modified by armoring (e.g., seawalls, riprap) that minimizes erosion, and overwater structures (e.g., piers, docks) that facilitate waterfront use. These modifications affect the ecology of nearshore systems by restructuring, eliminating, and shading shallow waters. In this talk, I will discuss how shoreline

modifications affect fish ecology in Puget Sound where many waterfronts are armored and overwater structures are common. Along armored shorelines, fish assemblages differed from unarmored sites, fish consumed less epibenthic and terrestrial prey, beach spawning was less successful, and fish were larger. Under large overwater structures, visually-oriented fish were less abundant and they fed less. Shade from overwater structures also interrupted localized movements of migratory fish. Thus, shoreline modifications impaired habitats by limiting feeding, reproduction, ontogenetic habitat shifts from shallow to deeper waters, and connectivity. Restoring shallow waters and substrate complexity, and minimizing shading underneath overwater structures, may rehabilitate habitats compromised by shoreline modifications. The reconstructed Elliott Bay waterfront along downtown Seattle will incorporate such features designed to improve habitat along its highly modified shoreline. This unprecedented effort to improve fish habitat along an urban shoreline can inform shoreline habitat management in Puget Sound and elsewhere.

3:20-3:40 **Hyporheic zone function in urban floodplain restoration.** S. A. Morley, L. D. Rhodes (EFS, NWFSC), A. E. Baxter (NOAA Affiliate, Lynker Technologies), G.W. Goetz (NOAA Affiliate, UW Joint Institute for the Study of Atmosphere and Ocean), K. Lynch (Seattle Public Utilities),and S. Damm (Seattle Public Utilities).

The inclusion of hyporheic design elements is an innovative, but largely untested, approach in urban stream restoration. In fall of 2014, the City of Seattle completed multiple floodplain reconnections projects intended to enhance hyporheic function in Thornton Creek. To evaluate overall biological response, NOAA Fisheries monitored microbial and invertebrate community structure at restored and unrestored reaches, and at forested reference reaches. Additionally, we tested whether assisted recolonization could speed biological recovery by seeding one restored reach with invertebrates and microbes from forested reference reaches. Independent of seeding actions, we found that taxonomic structure of both microbial and invertebrate hyporheic communities was significantly different between restored and unrestored reaches. Microbial heterotrophic production in hyporheic water was greater in restored than in unrestored reaches. Hyporheic invertebrate density and taxa richness were also higher at restored than at unrestored reaches, and comparable to reference reaches. We did not detect differences in nutrient concentrations or benthic invertebrates relative to restoration. In the seeding experiment, we observed limited changes in microbial or invertebrate taxonomic structure. However, we identified four aquatic invertebrate taxa that may have established populations in Thornton Creek due to assisted recolonization. Our results examine only the beginning portion of the restoration response trajectory. As Thornton Creek finds a new equilibrium within its expanded floodplain, continued monitoring will evaluate the role of hyporheic design in improving the health of urban streams.

3:40-4:00 **Ecosystem response to the removal of the Elwha River dams**. G. R. Pess, M. C. Liermann, S. A. Morley, T. R. Bennett, T. J. Beechie, M. Moser (FE, NWFSC), A. Kagley (FE, NWFSC), K. Frick (FE, NWFSC), S. Corbett (NOAA Affiliate, Ocean Associates), O. Stefankiv (NOAA Affiliate, Ocean Associates); M. McHenry (Lower Elwha Klallam Tribe), R. Moses (Lower Elwha Klallam Tribe), W. Wells (Lower Elwha Klallam Tribe), M. Elofson (Lower Elwha Klallam Tribe), R. Paradis (Lower Elwha Klallam Tribe), and S. Sampson (Lower Elwha Klallam Tribe); J. Duda (USGS), A. Ritchie (USGS), A. East(USGS), M. Foley (USGS), J. Warrick (USGS), C. Magirl (USGS), G. Gelfanbaum (USGS), and C. Curran (USGS); J. Bountry (USBOR) and T. Randle (USBOR); J. McMillan (Trout Unlimited), K. Denton (Independent contractor), S. Brenkman (ONP), R. Peters (USFWS), J. Anderson (WDFW), T. Quinn (UW), and C. Tonra (The OSU)

Worldwide stream and watershed restoration efforts cost $2 billion annually. Many of these projects are typically local-scale activities that do not have a measureable and quantitative effect on ecosystem function or services. One type of ecosystem restoration technique that can have a large-scale effect is dam removal. Dam removal allows for the re-connection of upstream and downstream ecosystem processes such as organism movement, the rapid transformation from a lentic to lotic conditions in former reservoirs, immediate shifts in community species structure, and accelerated habitat creation through sediment deposition. Here we show that the Elwha River dam removal, the largest dam removal that has ever been undertaken, results in rapid ecosystem changes due to the longitudinal reconnection. The downstream delivery of tens of millions of metric tonnes of sediment transported from former reservoirs in 5 years has resulted in the re-establishment of an estuarine river delta. The allowance of organism movement has meant the re-establishment of anadromous fishes in areas that have been void of such species for 100 years. Life history diversity of these species has immediately increased, even during dam removal. Our results demonstrate the critical importance of maintaining longitudinal connectivity for maintaining ecosystem services that depend upon organisms and inputs crossing ecosystem boundaries.

4:00-5:00 Poster session

Posters

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

Correlation of abundance and distribution of freshwater sunfish in the Snohomish River estuary to seasonal surface temperature anomaly. B. Boyer (NOAA Affiliate, Veteran's Conservation Corps.), J. Hall, J. Chamberlin, A. Kagley (FE, NWFSC)

One of the largest Pacific Northwest restoration and mitigation efforts has recently begun at the mouth of the Snohomish Estuary. The efforts improve critical estuarine and riparian habitat for several species indigenous salmonids. This important transitional zone, between the marine environment and the freshwater riverine environment, provides an intermediate habitat necessary for the biological change of migrant salmonids as well as a rearing ground for juveniles. There are myriad of anthropogenic alterations of the Snohomish Estuary that impacts salmonid survival; competition with invasive species for resources further complicates indigenous fish vitality. Our survey period, spanning from 2001 to 2014, has documented the presence of non-indigenous freshwater sunfish (*Perciform Centrarchidae*). Through an analysis of seasonal surface temperature anomalies, we have identified correlations of warm and cold seasonal parameters to the abundance and distribution these invasive species.

Among the freshwater sunfish identified within the Snohomish Estuary were Largemouth Bass, Smallmouth Bass, Crappie, Bluegill and Pumpkinseed. Our analysis has shown correlation between abundance and distribution of the non-native fishes in the oligohaline and freshwater areas of the estuary with warm and cold seasonal surface temperature anomalies. This relationship was not found to be significant during spring, summer, or fall seasonal temperature anomalies. However, we did identify a significant correlation of low abundance and distribution of centrachids throughout each year that exhibited a cold winter temperature anomaly. There were similar patterns found with the other non-native freshwater species. Results from this study will also note the recent portions of the estuary occupied by these and there catch per effort of these fish within the estuary. This information may give insight into how a disturbance to a system, even in the form of remediation, may alter fish communities in heavily altered ecosystems and provide guidance for future mitigation efforts

Pacific Lamprey (*Entosphenus tridentatus*) Restoration in the Elwha River Drainage Following Dam Removals. M. L. Moser(FE, NWFSC), R. L. Paradis (Lower Elwha Klallam Tribe), S. C. Corbett (Presenter, NOAA Affiliate, Ocean Associates), M. L. McHenry (Lower Elwha Klallam Tribe), and J. Stapleton (Lower Elwha Klallam Tribe)

Much attention has been directed towards restoration of iconic salmonids to the Elwha Basin. However, lamprey species (river lamprey, *Lampetra ayresii* and Pacific lamprey *Entosphenus tridentatus*) were also potentially blocked by the dams. The historic population was never documented; however, anecdotal observations suggest the Elwha lamprey population was

large. Lamprey contribute vital marine-derived nutrients to areas where they spawn, filter water, and provide food for native fish and wildlife and potentially buffer predation during critical salmonid migration periods. However, the ability of native lampreys to recolonize lost habitats, like those in the upper Elwha drainage, is unknown. Since dam removal, larval, juvenile and adult lamprey have been encountered at outmigrant traps, captured during electrofishing, and observed spawning at mainstem locations and/or tributaries to the Elwha River. This indicates rapid re-colonization of areas that were inaccessible to lamprey prior to dam removal. To further document migration behavior and re-colonization of Pacific lamprey we intend to tag 40 adult Pacific lamprey with both a passive integrated transponder (PIT) and a radio transmitter to track movements using an existing array of PIT antennas and radio receivers. In addition, we plan to surgically implant larval Pacific lamprey with 8.4-mm PIT tags to monitor outmigration activity of juveniles. This work will be coupled with genetic sampling for both species identification and parentage analysis. Lamprey nest surveys will be conducted to identify spawning locations and timing. These research activities will provide data needed to help with management and restoration of Pacific lamprey in the Elwha River and at other dam removal projects in the historic range of this species.

Reconstructing historical patterns of primary production in Puget Sound using growth increment data from shells of long-lived geoducks (*Panopea generosa*). J. Eccles (NOAA Affiliate, Long Live the Kings), C. Greene, K. Sobocinski (NOAA Affiliate, Long Live the Kings), L. Campbell (WDFW), R. Sizemore (WDFW), C. Krembs (DOE), and J. Newton (UW)

Bottom-up hypotheses predict that changes in primary production affect marine survival of species like Pacific salmon. Long-term records of primary production would provide important data to test these predictions. However, direct observations of primary production (in situ fluorometers, water chemistry, and satellite observations of color back-scatter) have relatively short time series (< 30 years). We are investigating whether growth increments of geoduck clams (*Panopea generosa*) are correlated with primary production in different sub-basins of greater Puget Sound. Geoduck are long-lived (older specimens live >100 years), widely distributed throughout the Salish Sea, and deposit annual growth rings in their shells. Shell samples from aged geoducks have been collected by the Washington Department of Fish and Wildlife in three sub-basins within greater Puget Sound (Strait of Jan de Fuca, South Puget Sound, and Central Basin). Geoducks from a fourth site (North of San Juan Island) will be collected in the spring. Using growth indices, the known correlation of growth indices with sea surface temperature and other long-term measurements, and existing basin-level records of temperature and primary production, we will model historical patterns of primary production in different regions of greater Puget Sound. Preliminary analyses at one existing site suggest that residual growth (after accounting for temperature variation) can explain variation in marine survival of local coho salmon stocks. This indicates the method has promise for retrospective hypothesis testing.

Stream shading, temperature change, and wood recruitment in the Chehalis River basin. C. B. Fogel (NOAA Affiliate, Ocean Associates), G. Seixas (NOAA Affiliate, Ocean Associates), T. J. Beechie, P. Kiffney, G. R. Pess, and M. Pollock

Riparian forests provide important services to salmonids including temperature regulation through shading, and creation of habitat structure and complexity through the input of woody debris. Much of the Chehalis River basin has been modified by human activities such as logging, agriculture, and urban development. We hypothesize that modification of riparian forests within the Chehalis River basin has led to summer temperature increases above upper thresholds for salmonids, leaving a portion of the basin inhospitable. We also hypothesize that the removal of mature trees and narrowing of riparian buffers have limited the input of wood into stream systems. We estimated current tree height and riparian buffer widths at equally spaced locations throughout the basin using a combination of LiDAR topographic data and aerial photographs. We used these estimates, and assumed heights for mature trees under historical conditions to identify regions of impaired wood recruitment, and calculate changes in stream shading from historical conditions. We found that wood recruitment is impaired for the majority of the basin. Streams with functioning wood recruitment were more concentrated within commercial and federal forests, whereas streams with impaired wood recruitment were more concentrated in urban and agricultural regions. Stream shading from riparian forests decreased across the basin, with the greatest changes occurring in urban and agricultural regions. We intend to use our results to inform future restoration efforts in the Chehalis River basin as to the regions of highest restoration potential with respect to riparian forest conditions.

The Skagit estuary Intensively Monitored Watershed project: results after 20 years of restoration. C. Greene, E. Beamer (Skagit River System Cooperative), and J. Anderson (WDFW)

The Skagit Intensively Monitored Watershed project examines the responses of Chinook salmon to restoration in the Skagit River estuary. The effort comprises monitoring juvenile Chinook salmon population characteristics in three distinct areas: the Lower Skagit River by Washington Department of Fish and Wildlife, the Skagit estuary and shoreline areas of Skagit Bay by the Skagit River System Cooperative, and neritic habitat of Skagit Bay by the Northwest Fisheries Science Center. Over 900 acres of restoration have occurred in the Skagit estuary over the 20-year duration of monitoring. We are testing hypotheses of the following system-level responses of salmon cohorts to estuary restoration: 1) reduced local density (less crowding due to increased habitat area), 2) longer residency within the estuary, 3) greater body size of estuary rearing fish at emigration to Skagit Bay, and 4) reduced proportion of small fry migrating directly into Skagit Bay shoreline habitats. In turn, we are testing whether these hypothesized changes influence marine survival and returns of adult salmon. Thus far, we have found strong evidence for estuary habitat limitations in the data collected prior to restoration, and detected a negative relationship between marine survival and the frequency of fry migrants into Skagit Bay. Analyses using Before-After-Control-Impact (BACI) and Before-After study designs to detect the effects of multiple restoration events supported some of these hypotheses, although

analysis of trends is complicated by the challenges of inferring benefits to individual fish from data on cohort-level responses.

Connectivity and estuary habitat use in juvenile fish: an analysis of tide gates and culverts. J. Hall, C. Greene, and E. Beamer (Skagit River System Cooperative)

Pacific Northwest estuaries are important rearing areas for a number of ecologically, commercially, and culturally important species. Most estuary habitat within Puget Sound (80% loss) and the Columbia River estuary (>65%) have been converted to agricultural, industrial, or residential uses through structures that limit tidal connectivity (e.g., dikes/levees, culverts, and tide gates). Culverts and passages may limit fish passage even though they may allow tidal flow through structures by creating flow constrictions, increased velocities, or perched passages. Traditional tide gates passively limit connectivity by opening during ebbing tides to allow drainage and closing on the rising tide, and can therefore restrict fish passage. Self-regulating tide gates (SRTs), which allow partial tidal inflow, have been proposed as a way to restore some degree of tidal wetland structure and function required compared to traditional tide gates. The form and design of such structures vary greatly, and the physical and biological effects have not been rigorously examined. To address this knowledge gap, we conducted a literature review of fish behavior and movement related to fish passage in natural tidally influenced systems and structures that limit tidal connectivity. We also conducted spatially extensive and temporally extensive field studies to evaluate the physical and ecological characteristics of structures in tidally influenced channels. Our spatially extensive study included an evaluation of ten existing SRTs in five different estuarine systems with comparisons to traditional tide gated and natural tide channels. The temporally extensive study examined trends in fish densities at three SRTs over multiple years compared to reference channels. From these combined efforts, we provide a framework for evaluating reductions in tidal connectivity and fish passage, and design and operation guidelines for improving tidal connectivity and fish passage at structures.

The use of portable and stationary PIT tag antennas to track movements and determine the fate of cutthroat trout, *Oncorhynchus clarkii*, in a small urban creek system. K. Hanson, P. Roni (Cramer Fish Sciences), J. Hall, S. Morley, and M. Liermann

The popularity of employing various PIT tag technology to study fish behavior is expanding whether scanning a stream with a mobile tag reader or installing permanent stationary antennas in the streambed. However, few researchers utilize both methods concurrently, and even less do so in an urban stream setting. In this study, fate of PIT tagged cutthroat trout (*Oncorhynchus clarkii*) was examined over four years in a small urban creek system in Seattle, Washington (USA) using both stationary and mobile antennas. We assigned fate categories of outmigrant, resident or mortality to each fish based on their detections by mobile and stationary antennas. In addition, we examined survival, growth and movement of fish emigrating to and from the study sites. Results show that 83.4% of tagged fish were detected by stationary antennas, mobile antennas, or both. Outmigrants made up 60.7% of fish detected

by stationary antennas, followed by residents (25.5%) and mortalities (13.8%). Recaptured fish from annual electrofishing surveys had a relative growth rate of 0.1-3.0% body mass/day. Mobile scans showed the greatest percentage of movements consisted of relatively short distances ranging from 1-50 m and the majority of movements, regardless of distance, were upstream. Stationary antennas showed 73.3% of fish moving downstream. Results show that mobile and stationary antennas, when used in tandem in small stream systems, provide useful information on fish fate and movement at both fine and larger scales. Juvenile cutthroat trout seems to make upstream movements of short distances at a fine-scale, but move downstream on a larger scale. The small size of most urban streams lends itself well to impressive antenna efficiencies for both mobile and stationary antennas leading to increased confidence in collected data.

Influence of a recent drought on freshwater environments in California. S. Munsch (NOAA Affiliate, Ocean Associates and C. Greene

Temperature and flow are determinates of habitat quality in freshwater fish. These conditions are mediated by weather patterns such as drought. California has experienced a drought beginning in 2011, and among its likely ecological consequences is stress to freshwater fish habitats. In particular, the amount and temperature of water available to fish may lie outside adequate ranges. In this ongoing project, we are quantifying the effects of drought on freshwater flow, freshwater temperature, and snowpack in California. Preliminary analysis suggests that during the drought, (1) freshwater systems experienced more severe periods of low flow and were increasingly warm, although temperatures did not appear to be anomalously high compared to the past decade, and (2) mountain snowpack decreased. We did not find evidence that drought affected the magnitude of short periods of high-intensity flow. Thus, the drought appears to have decreased the availability of suitable habitat for fish, including salmonids.

A geomorphic approach to estimating large-scale salmon habitat in the Columbia River basin. T. G. Nodine (NOAA Affiliate, Ocean Associates), M. H. Bond (NOAA Affiliate, Ocean Associates), T. J. Beechie, and R. W. Zabel

Large-scale estimates of stream habitat available to juvenile salmon are important for evaluating rearing capacities, informing life cycle models, and prioritizing restoration efforts. Using remotely sensed geomorphic and land cover reach characteristics we estimated contemporary and historical habitat areas throughout all Columbia River tributaries greater than 8 m wide. We quantified the total surface area of mainstem habitat using a 1:100 k stream network and modeled bankfull width. Side channel habitat area, which is valuable for juvenile rearing and common in island-braided streams of the Pacific Northwest, was predicted for each 200 m reach in our stream network using random forest models. The models predict side channel presence and magnitude with variables: land cover, floodplain width, slope, sinuosity, discharge, sediment accumulation, elevation, and bankfull width. Historical side channel area,

or restoration potential, was estimated by providing the model with historical land cover and unrestricted floodplain width attributes. To construct the models we used aerial imagery to measure mainstems and side channels at 2,130 random, spatially balanced sites across the basin stratified by land cover, stream size and channel type. We found that 35% of measured stream segments displayed multi-threaded channel morphology and side channels comprised 24% of the measured wetted area.

Influence of channel width on stream shade and temperature change in a forested catchment. G. B. Seixas (NOAA Affiliate, Ocean Associates), T. J. Beechie, C. Fogel (NOAA Affiliate, Ocean Associates), and P. M. Kiffney

Riparian forests attenuate solar radiation to stream surfaces, thereby providing a critical service to cold-water species such as anadromous fishes with narrow thermal tolerances. However, channels naturally widen downstream as they accumulate drainage area, and forest structure in many of the world's watersheds has been altered by human activities such as logging. Thus, the fraction of a channel surface expected to be shaded by riparian trees declines longitudinally, and riparian forest degradation creates a patchwork of shade along the channel network as natural widening and human-induced structural changes interact. Here, we investigate the hypothesis that the largest potential change to shade and stream temperature due to riparian degradation occurs at intermediate channel widths, provided some vegetation is present. We used an automated algorithm and LiDAR topographic data to measure current riparian shade across the Chehalis River basin, WA state; we then assumed historical tree heights based on known species distributions and calculated the change in shade from historical levels. To predict changes in stream water temperature, we found an empirical relationship between water temperature, drainage area, elevation, and our calculated shade values using an existing temperature dataset. We found the greatest change from historical conditions exists in urban, agricultural and floodplain regions, with the most change between 10 m and 40 m bankfull width. We next calculated time needed to achieve specific restoration targets, and found that this quantity also depends on channel width. We conclude by combining the measurement of shade degradation and time needed to achieve a restoration target into a 'restoration score', allowing us to efficiently map restoration priorities across the basin.

Exploring drivers for declining marine survival in Pacific salmon using qualitative network modeling. K. Sobocinski (NOAA Affiliate, Long Live the Kings), C. Greene and M. Schmidt (Long Live the Kings)

Coho (*Oncorhnychus kisutch*), Chinook (*O. tshawytscha*), and steelhead (*O. mykiss*) in Puget Sound and the Strait of Georgia have shown declines in marine survival over the last 40 years. While the cause of these declines is unknown, multiple factors, acting cumulatively or synergistically, have likely contributed. To evaluate the potential contribution of a broad suite of drivers on salmon survival, we used qualitative network modeling (QNM). QNM is a conceptually-based tool which uses networks with specified relationships among the variables.

In a simulation framework, potential models of the network are developed and then subjected to user-specified perturbations. Our network was comprised of 33 variables, including: environmental and oceanographic drivers (e.g., temperature, precipitation), primary production variables, foodweb components from zooplankton to top predators, and anthropogenic impacts (e.g., habitat loss, hatcheries). We included salmon traits (survival, abundance, residence time, fitness, and size) as response variables; we invoked perturbations to each node and suites of drivers and evaluated the responses of these variables. The model showed that anthropogenic impacts resulted in the strongest negative responses in survival and abundance. Also, feedbacks through the foodweb were strong, beginning with primary production, suggesting that several foodweb variables may be important in mediating effects on salmon survival within the system. With this model, we were able to compare the relative influence of multiple drivers on salmon survival.