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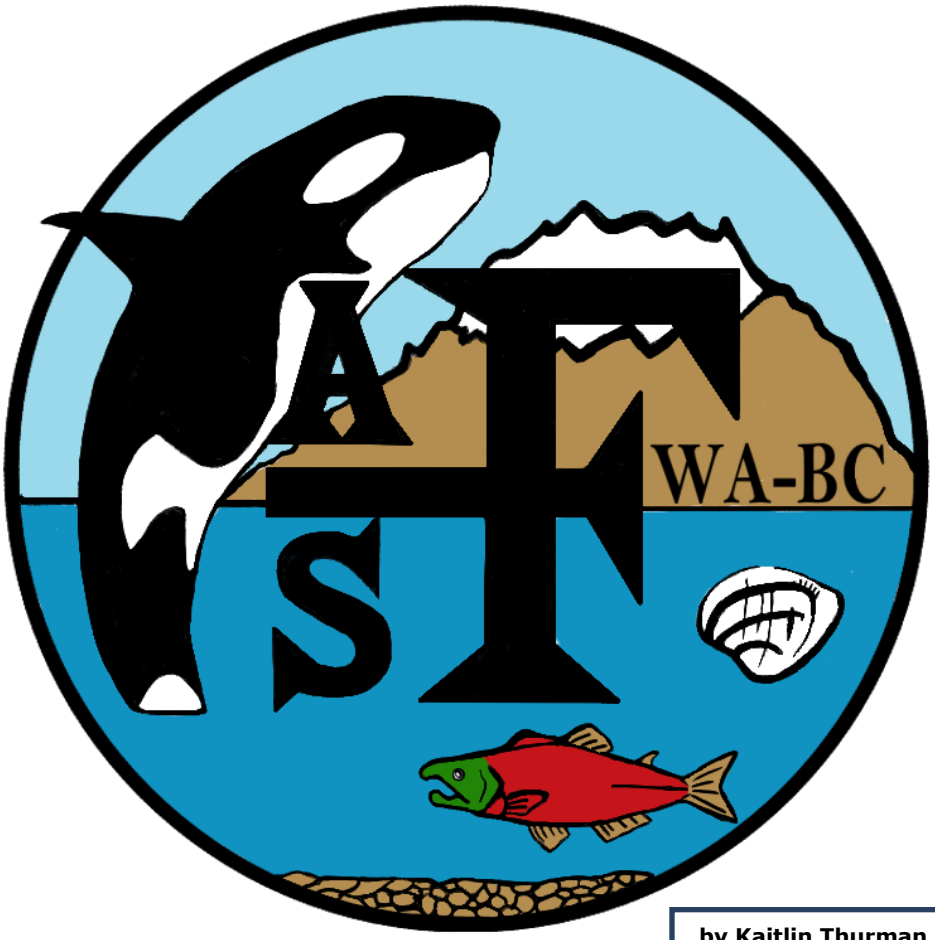

by Kaitlin Thurman

Feast and Famine from the Headwaters to the Sea

WASHINGTON-BRITISH COLUMBIA CHAPTER OF THE AMERICAN FISHERIES SOCIETY

Kitsap Conference Center, Bremerton, WA
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Symposium: Habitat restoration - the foundation for preparing a feast?

Chair: Ryan Klett (Colville Confederated Tribes)

Date: Tuesday, April 9, 1:20 PM to 3:40 PM
Location: Ballroom B

This session provides a venue for researchers focused on habitat restoration research and improvement projects to showcase their work. Topics include: influence of habitat restoration on salmon productivity, modelling methods to assess the outcome of restoration projects, and integration with recovery strategies.

Bilby - Spatial variation in salmon production and implications for habitat restoration

Robert Bilby, Weyerhaeuser Co.

Salmon production in freshwater varies spatially and often a few locations in a watershed can be responsible for supporting much of the production in an entire system. We examined 79 stream reaches in central Puget Sound to identify factors shared by sites with high densities of spawning coho salmon. Salmon density varied over 100X among these sites. Those reaches supporting high densities were consistently associated with still water habitats connected to the channel and close to spawning locations. All these sites were bordered by forest. They supported coho densities nearly 5X higher than streams in forests without still water habitat. Streams reaches with still water habitat but bordered by urban or agricultural land use supported fish densities similar to sites without wetlands. Still water habitats retain transported nutrients and the open canopy over these sites ensures adequate sunlight to drive autotrophic production. The plant growth supports high densities of aquatic insects and zooplankton, important food items for rearing salmonids. Still water habitats are typically associated with low-gradient stream reaches in unconfined valleys. We utilized LiDAR to identify sites with the channel and valley form to support still water habitat for four counties in central Puget Sound (Pierce, King, Snohomish, and Kitsap). Only about 10% of total stream length in these counties has appropriate physical characteristics to support this type of habitat. Given the sensitivity of these habitats to development, we determined which of these reaches have been impacted by past land use and those that are likely to be compromised in the future. 50% have been affected by past land conversion and another 10% are likely to be impacted over the next 3 decades. Identification of areas with high productive potential and directing protection and restoration towards these sites could substantially enhance the effectiveness of freshwater habitat restoration efforts.

Clark - Effectiveness monitoring of riparian plantings in the interior Columbia Basin streams

Christopher Clark, Shelby Burgess, and Philip Roni; Cramer Fish Sciences

Riparian enhancement is a common restoration technique in the Columbia River Basin and Pacific Northwest. Even though riparian plantings are a common component in many restoration projects, relatively few studies have evaluated their success. As part of the Bonneville Power Administrations (BPA) Action Effectiveness Monitoring Program (AEM), we used an extensive post-treatment design (EPT) to sample 21 riparian planting projects during the summer of 2018, with additional sites (nine planting and 30 invasive removal and planting) scheduled for sampling during summer of 2019. At each restoration site we sampled paired treatment and control reaches which were approximately 20 times bankfull width in length and quantified species abundance, richness, diversity, vegetation structure and cover, and stream canopy closure. Preliminary results from our first year of sampling found shrub abundance was significantly higher in treatment versus control reaches, but no differences in woody plant abundance overall, species richness, or diversity were observed. Similarly, no differences were observed in vegetation structure or cover for any of the three height cover classes (tree, shrub, or herbaceous). Percent canopy closure was significantly greater in control versus treatment reaches at both the active channel and wetted edge. Site age was positively correlated with tree abundance and species richness was negatively correlated with precipitation. This suggests that not enough time has elapsed since riparian planting at some sites to detect a significant response. Given we are in our first year of monitoring, our original sample size estimates were 30 planting and 30 invasive removal projects (60 projects total) and we have only sampled 21 projects to date, the lack of more significant differences among key metrics is not surprising. We expect stronger and more definitive results when we have completed sampling of additional sites in 2019.

Cedar - Fish, forest, and fire: Alternative riparian management to protect forests and fish

Kevin Cedar, Cramer Fish Sciences; Elaine Oneil, Washington Farm Forestry Association

Salmonid streams in the Pacific Northwest flow from forests. Eastern Washington forests have forest health issues and risks of uncharacteristically intense wildfires resulting from a history of forest management and wildfire suppression. Recently, uncharacteristically intense fires have burned and impacted riparian zones by killing or consuming much, or all, of the riparian vegetation that protects aquatic habitats and water quality for fish. In areas with forest health issues and high risks of uncharacteristically intense wildfire, forest management may be used to improve forest health, reduce the risks of uncharacteristically intense wildfire, and mitigate detrimental impacts on streams and the fish that rely on them. Forest management regulations limiting harvest in near-stream riparian areas are intended to protect aquatic habitats and water quality by maintaining forest cover and vegetation to provide shade, limit sediment inputs, supply habitat-forming large woody debris, and other functions. Simulation modeling of riparian forest data from sites across eastern Washington was used to explore riparian forest

management alternatives to address forest health issues and fire risk that may provide equal or greater protection of aquatic resources, relative the current regulations. A range of forest thinning intensities were modeled, and the resulting stand conditions were assessed to determine the effects of harvesting on stream shading, large woody debris inputs, forest health metrics, and fire risk both immediately after harvest and through 50-year forest growth simulations. Results suggest that alternative riparian forests managed could improve forest health and reduce fire risk with minimal impacts to aquatic habitats. These forest management-related impacts are much less than the impacts of uncharacteristically intense fires that are occurring with increasing frequency throughout the inland forests of the Pacific Northwest.

Klett - Supporting stream habitat restoration through modelling and data visualization

Ryan Klett and John Arterburn, Confederated Tribes of the Colville Reservation; Eric Doyle, Confluence Environmental Company

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) is a multi-decadal program which monitors salmon and summer steelhead and their respective habitats at the current extent of anadromy in the upper Columbia River. OBMEP integrates habitat monitoring data with a habitat performance model and a status and trends reporting tool utilizing a hierarchical spatial structure as its common currency. This structure is readily assembled from broadly available and regionally accepted resources which link uplands to stream corridors at coarse (subbasin, HUC4), intermediate (subwatershed, HUC6) and fine (reach, 1–4km) resolutions. The result is a spatially nested structure that organizes monitoring data, provides results at manageable scales, and informs stream restoration implementation. We present a process that has been successfully implemented to build out this structure in the Okanogan and Methow River subbasins and will demonstrate a publicly accessible cloud-based tool used to display status and trend results and evaluate habitat restoration priorities or projects.

Krall - Effects of livestock exclusion on stream banks and riparian vegetation in Washington and Oregon

Michelle Krall, Phil Roni, Christopher Clark, and Kai Ross; Cramer Fish Sciences

Exclusion of livestock to protect and improve riparian and stream habitat for the benefit of salmon and other fishes is a widespread watershed restoration technique in the Pacific Northwest. The Washington Salmon Recovery Funding Board and Oregon Watershed Enhancement Board developed a coordinated monitoring program to assess the response of instream and riparian habitat to the exclusion of livestock. Since 2004, data from 12 livestock exclusion projects were collected using a before-after control-impact (BACI) design. Monitoring included habitat surveys to measure bank erosion, riparian vegetation structure and cover, and pool tail fine sediment. Results indicate that livestock exclusion projects significantly reduced bank erosion and pool tail fine sediment and improved

riparian structure 10 years after implementation. However, there were no significant effects of livestock exclusion on canopy cover (shade). The results are consistent with previous studies, which have generally shown decreases in bank erosion and increases in riparian vegetation. The lack of stronger results is likely the result of several factors including: evidence of livestock grazing in many impact reaches, livestock exclusion in control reaches, limitations of the riparian sampling protocols, and additional noise due to poorly matched control and impact reaches. Many projects had intact fencing, but there were several instances where the fencing was not functioning as intended, allowing livestock access into the exclusion area. Future efforts monitoring livestock exclusion projects should focus on implementation monitoring to ensure livestock are actually excluded. Finally, there is fairly extensive documentation of improvement in riparian vegetation and instream habitat conditions if livestock are properly excluded, but limited information on the effects of livestock exclusion on aquatic biota. Therefore, future research and effectiveness monitoring of livestock exclusion projects should focus on evaluating the response of fish, macroinvertebrates, and other aquatic biota.

Walls* - Evaluating the effectiveness of engineered logjam projects at improving salmon habitat

*Caroline Walls, James Helfield, and Benjamin Miner; Western Washington University

The decline of Pacific salmon (*Oncorhynchus* spp.) is well-documented, and the widespread degradation of freshwater habitat has been identified as a primary contributor. In response, the last few decades have seen river restoration become a multi-million dollar a year industry in the Pacific Northwest. Despite this, salmon recovery has not occurred on a scale proportional to the effort and money put into restoration. A common form of salmon habitat restoration involves the construction of engineered log jams (ELJs). These projects are typically implemented with the assumption that they will improve freshwater habitat, and an increase in salmon numbers will naturally follow. This research seeks to test this assumption by assessing the effectiveness of ELJ projects at enhancing freshwater salmon habitat, particularly with regard to the creation of deep, complex pools. We have synthesized data from 25 ELJ projects from around Washington State, dating back to 2004. Each of these projects received intensive habitat monitoring, following a Before-After-Control-Impact (BACI) study design. Data was collected at restoration and control reaches for 1-4 years before restoration and 3-10 years after restoration, using either topographic surveys or thalweg profiles. We use mixed effects modelling to assess the outcomes of these projects in terms of three response variables: mean residual pool depth, habitat diversity, and the ratio of pool to study reach area. Preliminary results suggest it may take up to five years to see significant improvements in habitat. The next phase of this research will assess the extent to which salmon populations are responding to habitat improvements. If we find that salmon populations do not respond to habitat improvements, the restoration community may have to reevaluate its assumptions regarding the limiting factors for threatened salmon populations.

Symposium: Downstream fish passage facility performance, evaluation, and monitoring

Chair: Jacob Venard (HDR, Inc.)

Date: Tuesday, April 9, 1:20 PM to 5:00 PM
Location: Ballroom A

The successful implementation of performance evaluation and monitoring of downstream fish passage facilities is essential to determining the success of the facilities. These studies determine whether the facility is meeting performance standards and also help identify issues, troubleshoot problems, and guide next steps for potential improvements. Proper study design and implementation is necessary to accurately determine the effectiveness of the facilities, with great importance to both the owners and operators, and the agencies overseeing these facilities. The goals of this symposium are to provide results of such studies as well as lessons learned and guidance for the successful implementation of these studies, so that the necessary information is attained to accurately evaluate the performance of these facilities as well as guide the design, operation, and potential next steps for meeting requirements.

Ackerman - Fitting a square fish into a round bypass - when passage standards and fish biology don't match

Nick Ackerman, Portland General Electric

Portland General Electric's License for the Clackamas River Hydro Project includes a downstream passage survival standard of "97% smolt survival" through a three-dam project. Issuance of the License in 2010 initiated a series of improvements to downstream passage facilities throughout the Project. These improvements resulted in high fish collection efficiency estimates, increased collection of downstream migrants, and improved returns of wild fish to the Project. Early indications though are that PGE is falling short of meeting the passage standard for Chinook. This is partly driven by the broad array of outmigration strategies of juvenile Chinook passing through the Project. Chinook pass at all times of the year, and at any time some Chinook appear highly motivated to move downstream while others appear to be passively drifting despite similar external appearances. How do we measure whether we are meeting the "smolt survival standard" when we can't tell which Chinook are smolts and which are not? This presentation will describe the difficult situation PGE finds itself in trying to read the tea leaves in the passage data, refine evaluation strategies, and ultimately decide if the passage standard has been met.

Brower - Wells Dam juvenile bypass baffle PIT detection system

Matt Brower, Biomark, Inc.; Tom Kahler, Douglas County PUD; and Steve Anglea, Biomark, Inc.

Douglas County Public Utility District (DCPUD) owns and operates Wells Dam on the Columbia River, Washington, USA. The Wells project has ten generating units rated at a combined 840 megawatts. Eleven gated spillway openings can pass a flood of over 33,311 m3/s. The hydrocombine structure is 355 m in length and the dam is 1,360 m long overall. The unique hydrocombine design incorporates the powerhouse, spillway, switchyard and fish facilities into one unit instead of separate structures. The Wells Dam juvenile bypass system comprises modifications to 5 of the 11 spillways to enhance bypass efficiency. Each bypass bay utilizes a baffle structure consisting of 64 approximately 1.2 m x 1.2 m openings arranged in 4 columns of 16 openings.

DCPUD installed a juvenile PIT-tag detection system at Wells Dam in 2016 and 2017 to determine compliance with FERC-license obligations. Detections at Wells Dam are used to determine travel time between Wells Dam and Rocky Reach Dam, the next dam downstream, and those data are used to calculate passage date at Wells Dam for the thousands of fish detected at Rocky Reach Dam but not at Wells Dam.

DCPUD worked with Biomark to design and install a PIT-tag array in a subset of the Spill Bay 2 bypass baffle openings. Biomark used thin-wall shielded antennas to minimize the amount of flow constriction and allow placement within the steel structure. Each antenna is connected to a Biomark IS1001 reader housed in a submersible enclosure and mounted to the downstream side of the bypass baffle. The 16-IS1001s are connected to a pair of Biomark IS1001-Master Controllers. Power to the IS1001-MCs is provided using an isolation transformer. All diagnostic and tag-detection data is transmitted to a data-collection computer through a fiber optic cable and then to Biomark's BioLogic web portal.

Murauskas - The evolution and practicality of fish passage standards at high-head dams in the Pacific Northwest

Joshua Murauskas, Mark Weiland, and Joe Miller; Four Peaks Environmental

The Pacific Northwest epitomizes the challenges and successes of fish passage in modified rivers. Technologies have progressed from headwater facilities constructed in the 1880s, to large hydroelectric projects in the 1930s, and to high-head dam collectors in the 1950s. In response to federal protection of 28 salmon and steelhead populations under the Endangered Species Act in the 1990s, "passage standards" became commonplace in regulatory lexicon. We review the history of the mid-Columbia River "No Net Impact" passage standard, the Federal Columbia River System passage standards, and the introduction of passage standards to high-head dams during relicensing efforts in the 2000s. We discuss the practicality of a single standard across the highly variable physical and ecological nature of reservoirs above high-head dams. We contend that the lack of baseline information, inability to conduct test-control evaluations, varying levels of extirpation, atypical life history strategies, and non-native species introduce significant

challenges in accurately characterizing collector performance and compliance with standards at high-head dams.

Peterson - PIT detection barge: new approach for challenging monitoring locations

Phil Peterson and Erek Arnold, West Fork Environmental; Gordon Axel and Gabriel Brooks, NOAA Fisheries

Regardless of the field methods, unbiased detection or enumeration of juvenile fish from large open channel habitat continues to be one of the most difficult tasks for fisheries management. For complex river systems, in order to distinguish between sub-basin and mainstem effects it is essential to obtain estimates at key locations. A top priority for management agencies within the Columbia River Basin is to enable better detection rates for the hundreds of thousands of PIT-tagged juvenile salmon and steelhead at Bonneville Dam. Several innovative approaches have been employed for detection below Bonneville in the past including NOAA Fisheries-operated towed arrays, fixed pile dike antennas, and most recently towed flexible antennas. A fourth approach, utilizing fixed arrays of vertical antennas deployed from an anchored barge platform is showing potential and may be an effective method to provide detections in unprecedented locations. Here we report results obtained from three recent deployments of the West Fork PIT detection barge and describe enhancements that are being made to a mainstem class barge which will be deployed during the spring of 2019. These improvements include larger antennas that will automatically retract and reset for debris offloading. These modifications will facilitate deployment of barges into boat restricted zones near mainstem dams and potentially boost acquisition of previously undetected fish.

Stachura - Data automation and visualization to support fisheries management at high-head dams

Megan Stachura, Samuel Haffey, and Josh Murauskas; Four Peaks Environmental

Robust data collection, management, and analytical frameworks are essential to monitoring the success or improving the performance of fish passage facilities at hydroelectric projects in the Pacific Northwest. When managed effectively, these data can be used to enable rapid diagnostics and adaptive management to improve successful fish passage. Collected data often include release, detection, recapture, and mortality records of tagged fish, enumeration of adults or juveniles, water quality, climatology, facility operations, and hydraulic measurements. These data routinely come from diverse and often disparate sources, creating a cumbersome task for analysts. Based on experience at over 20 hydroelectric facilities in Washington and Oregon, we demonstrate how a multi-disciplinary approach to data management combining expertise in natural resource management and software engineering can be used to integrate datasets into actionable information in near-real-time. We will discuss several potential aspects of an effective data management system, including: (1) the use of databases and related resource to

compile, manage, and back-up data, (2) automatic loading processes that can provide data in near-real-time and improve staff efficiency, (3) existing data systems that can provide software and frameworks for data loading and management, such as the Columbia Basin PIT Tag Information System (PTAGIS), and (4) platforms that facilitate development of data dashboards showing near-real-time, database-drive analyses and visualization (e.g. Shiny, Django). The methods we will describe for managing multiple datasets in a single system enhances quality control, improves efficiency, and routes information to project managers enabling rapid adaptive management.

Thompson - Methods for evaluation of performance standards at downstream fish passage facilities at Pacific Northwest hydropower projects

Audrey Thompson, The Adipose Group

Many hydropower operations in the Pacific Northwest have regulatory obligations to move juvenile salmon downstream during periods of out-migration. To satisfy regulations, a variety of trap-and-haul programs and infrastructure have been implemented through the region in an effort to move juvenile fish downstream with the minimal possible impact. Many of these programs including the construction of bypasses, surface collectors, traps, etc. designed to capture juvenile fish in the forebay of hydropower dams, all with established standards for efficiency, survival, passage rates, etc. Advanced methods for determining the performance of trap-and-haul programs relative to established standards are important to ensure accurate measurement of performance metrics. Active telemetry studies have been implemented through the region to provide these metrics—the application, lessons-learned, and key points for consideration in this type of evaluation are presented following successful implementation of telemetry studies at trap-and-haul programs throughout the Pacific Northwest.

Venard - Application of Pacific Northwest fish passage lessons learned to expanding global opportunities

Jacob Venard, HDR, Inc.

In the Pacific Northwest, fish passage is part of the journey for migrating fish between the headwaters to the sea in the highly modified environment with dams, reservoirs, and altered river conditions. For decades, this region has been on the forefront of the evolution of fish passage and provides a reference for effective application to those who are newly encountering providing for fish passage. Global reliance on dams for flood control, irrigation, potable water and hydropower means that more barriers are being constructed than removed. The growing global reliance, along with expanding environmental effects of population growth, water demands, and global warming will require effective fish passage at these facilities in order for the continued survival and sustainability of fish populations. Access to key habitats that remain suitable in these changing conditions will become even more important, as will the duration spent migrating to these areas and exposed to deleterious conditions that they experience in

their migration route. Within the path from headwaters to the sea, fish passage is one part of the fish survival equation that we can continue to directly influence. One of the keys to future success is answering the question for existing facilities: Does this work? Accurately answering this question for existing fish passage facilities in relation to passage regulatory requirements, management and recovery goals, and other factors is important for the effective application of fish passage technology at other sites and locations. The application lessons learned from other fish passage designs to future designs must be a critical part of the process to establish the expectations and achieve the goals for populations in these locations.

Verretto - Baker hydroelectric project floating surface collectors

Nick Verretto, Puget Sound Energy

Welch - Los Padres downstream bypass evaluation: field study out of a suitcase

Ian Welch, Mike Garello, and Shaun Bevan; HDR, Inc.

A downstream passage bypass structure was constructed at the Los Padres dam on the Carmel River in California that included a floating weir collector and a downstream bypass pipe and outfall. The objective of the study was to evaluate if fish experience injury or mortality as a result of the hydrology, pipe geometry, and physical structure of the bypass pipe itself. The study comprised of video from a fish-eye-view of passage through the pipe and an injury evaluation using live hatchery rainbow trout at three flow levels. The remote site location and river conditions presented challenges. With the limited resources of what we could pack in our rental car, ingenuity and creativity was required to design and implement a temporary collection system. An initial capture method proved unsuccessful, and a new method was devised on the fly in the field that used netting rigged to the outfall pipe itself to dewater and divert fish for collection and holding. Test fish were released into three locations along the bypass to isolate sections that may contribute to injuries, and a control group was released directly into the capture netting. All test fish were PIT tagged for unique identification prior to the testing, and held for 48 hours after pipe passage to observe any delayed effects. Extremely low rates of minor external injuries were observed in all groups. All test fish survived at least 48 hours after passage, indicating there were no occurrences of internal trauma or injury that was not observable during the external examinations that would potentially cause delayed mortality in bypassed fish.

Symposium: Environmental DNA (eDNA) as a tool for detection of aquatic species

Chair: Sarah Brown (Washington Department of Fish and Wildlife)

Date: Tuesday, April 9, 3:40 PM to 5:00 PM
Location: Ballroom B

Environmental DNA (eDNA) is a promising new tool to non-invasively monitor species of conservation concern. eDNA is DNA that is left in an environment (water, air, soil), as an organism passes through and leaves behind shed cells. This DNA can be detected through traditional molecular genetic techniques (qPCR, sequencing, etc.), and can potentially link a species to a geographic region. This technique is of particular interest to rare or threatened species, which are difficult or costly to detect through traditional means. This session will focus on the use of eDNA as a tool to aid in detection of aquatic species.

Brown - Environmental DNA monitoring for Pacific, Western River and Western Brook Lamprey from the Nisqually River

Sarah Brown, Jessica Olmstead, and Joy Polston-Barnes; Washington Department of Fish and Wildlife

Three sympatric species of lamprey occupy freshwater systems of Washington State, the Pacific Lamprey *Entosphenus tridentatus*, Western Brook Lamprey *Lampetra richardsonii*, and Western River Lamprey *Lampetra ayresii*. The Pacific Lamprey is a primitive species that was once common throughout the Pacific Coast, and within Washington State. However, over the past few decades, this species has experienced widespread declines. Much less is known about the Western Brook and Western River Lamprey, though, it is thought that they are experiencing local declines. The ability to accurately detect rare organisms is imperative to aid in conservation efforts. Rare species are typically present at very low densities, which are often difficult to detect with traditional methods. eDNA methods have been widely applied to monitor occurrence of a species in aquatic systems. Our goal was to 1) Determine if eDNA analysis of sediment can detect the presence of larval lamprey species (Pacific Lamprey, Western Brook Lamprey, and Western River Lamprey) in the Nisqually River, Washington, and 2) Compare the detection rates of larval lamprey, using both electrofishing and eDNA analysis of sediment, and water. We detected both Pacific Lamprey and *Lampetra* spp. through sampling eDNA in the sediment. *Lampetra* spp. were detected at every site (in 90% of the sediment and 100% of the water eDNA samples), and appear to be more abundant throughout the sites sampled than Pacific Lamprey. Pacific Lamprey were minimally detected at one site in a sediment sample. These results indicate that Pacific Lamprey are present in the Nisqually River, however, potentially at low numbers. We show here that analysis of sediment eDNA successfully detects the presence of larval lamprey, in the sites where they were physically detected through electrofishing.

Caldwell - Use of eDNA methods to predict extent of fish occupancy and identify potential habitat breaks

Lucius Caldwell, Dan Bingham, Lindsey Belcher, Nate Putnam, and Dave Wasgatt; Cramer Fish Sciences

We conducted a parallel methodology study evaluating the ability of targeted eDNA sampling to identify fish-bearing streams and habitat breaks within small, fish-bearing, headwater streams. Our study focused efforts on 47 segments within 14 stream networks across southern Washington State. We conducted standard "protocol surveys" that included backpack electrofishing streams to locate fish, plus simplified longitudinal profiles and habitat surveys to characterize streams and quantify potential habitat breaks. Concurrent with our protocol survey, we collected 105 water samples for eDNA analysis from 57 sites across our 47 segments. Site selection was based on survey extent, fish observations, and field identification of potential habitat breaks. These 57 sites included 11 positive control sites (fish observed above sample), 27 presumed negative test sites (no fish observed above sample), and 19 unknown status test sites (no observations at the time of collection, subsequent validation using protocol survey). We found that qPCR analysis of these waterborne eDNA samples returned correct results for 10/11 of positive control sites (sensitivity = 91%) and 27/27 of presumed negative sites (specificity = 100%) for an overall correct assignment of 97% of the sites. Next, we explored the use of water samples collected at the downstream extent of a protocol survey to predict fish occupancy in 19 unknown status test sites. We found that qPCR analysis of eDNA samples collected at the downstream survey boundary accurately predicted 100% of subsequent protocol survey fish observations (19/19 negatives and 1/1 positive). When considering all known-status cases (controls and tests), the conditional probability of subsequently observing fish, given a positive qPCR eDNA result, was 100%, and the conditional probability of subsequently not observing fish, given a negative qPCR eDNA result, was 98%. Thus, we found that eDNA analysis offers the ability to identify extent of fish occupancy within small, headwater streams.

Peters - Perspectives from the World Fish Passage workshop

Kathleen Peters, Kitsap County

This presentation is my summary of a one day workshop in Albury, NSW, Australia: International Fish Passage Conference eDNA workshop December 2018. Topics included applications of eDNA for fish passage including case studies from Australia and Oregon. The workshop organizers shared their presentation materials with the 28 participants, from 16 countries.

Young - A molecular reinterpretation of the biodiversity of *Cottus* in western North America

Michael Young, Rebecca Smith, Kristy Pilgrim, Kevin McKelvey, Michael Schwartz, Dan Isaak, and Sharon Parkes; U.S. Forest Service

The taxonomy of sculpins (*Cottus*, Cottidae) remains one of the last major puzzles in the systematics of North American freshwater fishes. Among ichthyologists, sculpins are regarded as the most difficult fishes to identify to species because purportedly diagnostic morphological characters are often ambiguous or plastic. This has led to the questionable assignment of the same species name to geographically disparate specimens. To address this uncertainty, we began a West-wide effort to clarify the evolutionary history and taxonomy of sculpins using molecular tools. First, we crowd-sourced collection of specimens (n = 7,489 and counting) via outreach to biologists across the West, and compiled the results of those efforts on a webpage (https://www.fs.fed.us/rm/boise/AWAE/projects/fish_tissue_collection.html). Second, we sequenced mitochondrial (COI and cyt b) and nuclear (S7 and rhodopsin) genes of specimens from most 4th-code hydrological units in the West, and applied standard phylogenetic techniques to assess patterns of diversity. Those analyses revealed that, with respect to their distributions in Washington: 1) the cedar sculpin *C. schitsuumsh*, recently described from northern Idaho and western Montana, is also present in the eastern Cascades; 2) the Paiute sculpin *C. beldingii* is absent because its representatives are likely valid as *C. tubulatus*, a species first described in 1932; 3) the torrent sculpin *C. rhotheus* represents a complex of 3-4 species; 4) the shorthead sculpin *C. confusus* is also part of a species complex but with an extremely restricted range in the state; 5) *C. hubbsi* is widely distributed and little diverged, whereas *C. bendirei* is not present; 6) *C. gulosus* is absent; and 7) presumed specimens of *C. confusus* in northwestern Washington are instead members of a lineage related to slimy sculpin *C. cognatus*, and are distinct from a Rocky Mountain lineage of this taxon in northeastern Washington.

Symposium: Salmon predators – orca and many other mouths feed

Chair: Mike Ford (National Oceanic and Atmospheric Administration)

Date: Wednesday, April 10, 9:00 AM to 11:40 AM
Location: Ballroom B

The recent decline of the Southern Resident orca population has sparked public and government officials' interests to a degree that is turning the heat up on potential management actions aimed to recover the population. However, salmon are a critical piece of the food web for many other species, and commercial and recreational management must be considered too. This symposium will describe orca prey limitations and some of the other "mouths" targeting orca prey, assess fisheries influence on salmon consumption of other predators, and look at some key salmon predator and fisheries studies that may play a role in developing a predator balance to allow for orca recovery.

Couture (CANCELED) - Increase in Chinook abundance for SRKW: reduce fishing or reduce seals

Fanny S. Couture, C.J. Walters, V. Christensen, and G. Oldford; University of British Columbia

The recent decline of the Southern Resident Killer Whale (SRKW) population has been widely attributed to the depletion of Chinook and Coho salmon populations in British Columbia. The decline of these salmon species is likely to be linked to pinniped predation as these consume much larger tonnages of fish along the B.C. coast than fisheries. Harbour seals are indeed important salmonid predators, especially for salmon smolts in the critical early marine phase. As the Harbour seal population in British Columbia has stabilized at about 110.000 individuals (40.000 for the Strait of Georgia), it is important to estimate the associated predation pressure on salmon populations and evaluate the potential impacts of alternative management scenarios.

This research aims at reconstructing Harbour seals, Coho, and Chinook populations in the Strait of Georgia over the last century, and to estimate seal predation pressure on salmon smolts in their first year. Further, to predict future Chinook and Coho salmon potential population status under different Harbour seal population levels.

Evidence suggests that the Harbour seal population at the end of the 1800s was roughly half of the current level. Results also show a strong positive correlation between seal abundance and Coho and Chinook mortality during their first year. An additional analysis shows that a potential seal reduction to around 20.000 seals would not result in full recovery of Chinook and Coho populations, but that salmon abundances could at least double over the next decade. These analyses have implications for the ongoing debate on the relative impacts of Harbour seal culling and fisheries limitations for Chinook in British Columbia. This research suggests that a controlled harvest of Harbour seal populations in British Columbia may enhance Chinook and Coho populations, hence potentially promoting SRKW population recovery.

Feddern* - Reconstructing a century of coastal productivity and predator trophic position indicators in coastal WA and the Salish Sea with archival bone

*Megan Feddern and Gordon Holtgrieve, University of Washington; Eric Ward, NOAA NWFSC

After passage of the Marine Mammal Protection Act of 1972, pinniped populations along the west coast of North America experienced exponential population increases following historic lows in the 1970’s. In Puget Sound and coastal Washington, this increase in pinniped abundance corresponded with changes in large scale climate conditions (Pacific Decadal Oscillation; PDO) and depletion of prey species (forage fish, salmon). Increasing pinniped populations have created new challenges for fisheries management, particularly because some of their prey species are commercially important or protected (e.g., salmon, herring) and little is known about the impact pinnipeds have on fish populations

or marine food webs. The objective of this research is to quantify long-term changes in harbor seal trophic position to understand how populations of this generalist predator have impacted and responded to changes in prey abundance and primary productivity with changing climate regime.

140 bone specimens collected from ~1940-present were analyzed for 15N/14N of 11 individual amino acids (AAs), including both trophically fractionated (trophic) and trophically conserved (source) amino acids. Animals conserve certain "source" AAs during trophic transfers from prey to predator, and 15N/14N ratios of these "source" AAs reflect the environmental N sources for the organism. Trophic AAs, in contrast, are fractionated with each trophic transfer at a consistent rate per trophic level per amino acid. Trophic and source AA data were used to calculate trophic position and as indicators of primary productivity respectively. Changes in trophic position and productivity over time were compared to changes in indicators of ecosystem condition (prey availability, marine mammal abundance) and environmental condition (sea surface temperature, Pacific decadal oscillation regime shifts) to determine the relationship between harbor seal trophic position and ecosystem dynamics.

Ford - Lack of prey as a limiting factor for orca recovery

Mike Ford, National Oceanic and Atmospheric Administration

The southern resident killer whales are a small population of fish-eating killer whales that inhabit the Salish Sea and Pacific Northwest coastal waters and occasionally range from California to northern British Columbia. They are the southernmost of a number of fish-eating killer whale populations that extend north around the Pacific Rim, and were listed in 2005 as an endangered Distinct Population Segment (DPS) under the Endangered Species Act. Unlike most Pacific killer whale populations, the southern residents have failed to achieve sustained population growth following protection from direct take and harassment with the passage of the Marine Mammal Protection Act in 1972. A status review in 2016 confirmed the population's endangered status, and indicated that the population will decline further unless birth and survival rates increase from recent levels. A lack of any viable births in the last three years combined with highly publicized images of extremely thin, dying whales has only reinforced the population's precarious status.

The 2008 recovery plan for the population identified multiple interacting factors as causes for the population's poor status, including inbreeding depression, disturbance, contamination, and lack of prey. Recently, lack of adequate prey, particularly Chinook salmon, has received increasing attention as the primary limiting factor. In this talk, I summarize the evidence that does, and does not, support the hypothesis that lack of prey is the primary factor limiting the population's recovery and discuss potential management options for increasing prey to benefit the whales.

Lincoln* - Managing salmon for wildlife: Do fisheries limit salmon consumption by bears in small streams?

*Alexandra Lincoln, Ray Hilborn, Aaron J. Wirsing, and Thomas P. Quinn; University of Washington

Ecosystem-based management requires consideration of how human use of a resource affects organisms such as predators that also depend on that resource. Pacific salmon are an important resource for both fisheries and coastal brown bears (*Ursus arctos*), as salmon consumption has been positively linked to bear density, size, and reproductive rate. Using 16 to 22 years of empirical data in four different small salmon-bearing systems in southwestern Alaska, we explored the relationship between salmon availability and consumption by bears. We found a negative relationship between the annual biomass of salmon available to bears and the biomass consumed per fish, and a saturating relationship between salmon availability and the total annual biomass of salmon consumed by bears. Under modeled scenarios, bear consumption of salmon was predicted to increase only with dramatic (on the order of 25–50%) reductions in harvest in commercial fisheries. Even such large reductions in fishing were estimated to result in relatively small in increases in per capita salmon consumption by bears (73–146 kg/bear/season, 4–8% of estimated per capita total). We conclude that while bears foraging on salmon in small streams may be limited by salmon harvest in some years, current management of the system we studied is sufficient for bear populations to reach maximum salmon consumption every 2–4 years. Consequently, allocating more salmon for brown bear conservation would be unlikely to result in an ecologically significant response in these systems.

Oldford - Preying on the weak? Possible non-additive effects of seal predation and stress-related mortality in juvenile Coho and Chinook in the Salish Sea

Greig Oldford, Carl Walters, and Villy Christensen; University of British Columbia

Declines in the past several decades in first year marine survival of Salish Sea coho and Chinook have prompted alarm. Over the same period, another significant change has been a dramatic increase in harbour seal populations. Independent estimates of seal food consumption rates and diet composition, along with regressions of mortality rates from Coded Wire Tag (CWT) data on seal abundance, lend credibility to a hypothesis that most of the increase in mortality on coho and Chinook is due primarily to seal predation. This has prompted calls to reduce this pressure via a culling program or seal harvest. But what is the likelihood such programs would have the intended results? To test the effects of reducing predation, ecosystem models typically assume additive effects of predation and other mortality rates in prediction of net production. This results in predictions of substantial increases in production when predator abundances are reduced. However, other changes in the Salish Sea have been observed over the same period, particularly a climate change induced increase in water temperature. This and other environmental changes may increase stress factors like hunger, disease, or parasite loads and lead to greater predation vulnerability. Here, we challenge the assumption that mortalities are

additive and propose a vulnerability exchange model to account for non-additive mortality effects. Results underline highly uncertain outcomes of any seal predation reduction proposals intended to increase coho and Chinook production. We recommend implementing any proposed seal reduction program carefully and as an adaptive management experiment.

Touhy - Developing a place-based, selective salmon fishery in the Lower Columbia River, Washington

Adrian Touhy, Wild Fish Conservancy

Conventional harvest techniques utilized in mixed-stock commercial salmon fisheries frequently result in bycatch mortality, impeding salmonid recovery and constraining fishing opportunities in the U.S Pacific Northwest. Building upon two years of research demonstrating the ability of commercial fish traps to effectively target hatchery-origin salmon while reducing bycatch mortality rates relative to conventional commercial fishing gears, Washington State's first commercial trap fishery in over 83 years was established in the lower Columbia River to evaluate the feasibility of the gear in a commercial setting for mark-selective commercial harvest. A modified fish trap was constructed, operated, and monitored in a test fishery from August through October 2018. Revenue and stock-specific catch were determined for the period of operation; total fishery mortalities were estimated based upon stock-specific encounters and established release survival rates. Results demonstrate that the trap effectively harvested commercially viable quantities of hatchery-origin Chinook *Oncorhynchus tshawytscha* and coho salmon *O. kisutch* while significantly reducing estimated wild salmonid mortalities relative to the conventional gillnet. During the fishery, 1,157 hatchery-origin Chinook and coho salmon were harvested. A total of 2,538 wild salmonids were successfully released with zero adult salmonid immediate mortalities; approximately 23 wild adult salmonids likely perished post-release from trap fishery operations over a 32-day operational period. Comparing these results to the conventional gillnet fishery, it appears that use of fish traps for mark-selective commercial harvest may generate significant increases in wild salmonid escapement while meeting the economic needs of fishermen and industry in the lower Columbia River and elsewhere in the Pacific Northwest.

Welch - A survey of the coast-wide collapse in northeast Pacific Chinook and Steelhead survival: Looming problems for set piece solutions

David Welch, Kintama Research Services Ltd

Accelerating decreases in survival are evident for northern Hemisphere salmon populations. We collated smolt survival during downstream migration and smolt-to-adult (marine) survival data for all regions of the Pacific coast of North America excluding California to examine the forces determining salmon returns. A total of 3,055 years of annual survival estimates were available for Chinook Salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss*. We found that over the past half century marine survival

collapsed by a factor of at least 4–5 fold to similar low levels (~1%) for most regions of the west coast. The size of the decline is too large to be compensated by freshwater habitat remediation or cessation of harvest, and too large-scale to be attributable to specific anthropogenic impacts such as dams in the Columbia River or salmon farming in British Columbia. Within the Columbia River, both smolt survivals during downstream migration in freshwater and adult return rates (SARs) of Snake River populations, often singled out as exemplars of poor survival, appear unexceptional and are in fact higher than estimates reported from other regions of the west coast lacking dams. We also present new results applying concepts from information theory to formally define the importance of different segments of the life history to determining overall survival. We conclude that no one life history phase is likely to primarily determine recruitment in Pacific salmon, but that the freshwater phase is of surprisingly little importance. Using this new formalism, we also quantify the low statistical power of analyses looking to identify environmental drivers occurring in some part of the migratory life history. The failure of management to, so far, correctly identify the drivers of salmon collapse and respond appropriately suggest that the future of most west coast salmon populations is bleak.

Symposium: Salmonids in the Skokomish River Basin: past, present, and future

Chair: Phil Sandstorm (Tacoma Power)

Date: Wednesday, April 10, 1:20 PM to 4:40 PM
Location: Ballroom B

Tacoma Power completed construction of Cushman No. 1 Dam and No. 2 Dam by 1930 impounding the North Fork Skokomish River and creating Lake Kokanee and Lake Cushman. For a number of years there was no passage above the dams, and the only fish in those lakes were fish that were trapped during construction or planted to maintain a fishery. In recent years Tacoma Power has invested to create adult passage (2013) and juvenile passage (2014) through trap and haul systems. Two conservation hatcheries (North Fork Skokomish River Hatchery and Saltwater Park) were created in 2014 to aid in reintroduction efforts, and monitoring and evaluations efforts have been initiated to further the understanding of existing populations and performance of hatchery programs. This symposium will focus on how the initial construction of the dams impacted salmonid populations in the North Fork Skokomish River, what we are learning while reintroduction and recovery actions are occurring, and future issues that will likely be encountered in this basin. At the end of the session we would like to hold a panel discussion focused on future directions for research efforts and populations as reintroduction and progression towards recovery continue. After a brief discussion the panel of representatives (from multiple agencies) would field questions from the audience.

Belleyea - Skokomish estuary restoration monitoring

Lisa Bellevea, Skokomish Indian Tribe

In 2007 the Skokomish Tribe broke ground with a phased estuary restoration project. Since then almost 1,000 acres have been reintroduced to tidal inundation. The main objective of this project was to restore salmon habitat to help revive the existing salmon populations and also support the introduction of new populations, like sockeye. A monitoring plan was created in order to measure the success of the project. With funds provided by the Environmental Protection Agency the Tribe has been conducting estuary monitoring since 2011. Monitoring includes vegetation surveys paired with pore-water salinity and sediment changes; tidal channel depth, temperature, and salinity; as well as fish presence, timing and abundance.

Two of the main problems this restoration project addresses are the decline and loss of salmon habitat and flooding. Our monitoring results show that native saltmarsh plants are dominate in the restoration area; salmon are utilizing the habitat; sediment is accreting, which could help offset the impacts of sea level rise; and even though we have seen seven of the top ten Skokomish River crests since 2015 the impacts of the flooding to the surrounding community have been greatly reduced. One important lesson here is that monitoring is essential in order to understand the efficacy of such projects.

In addition to the large estuary restoration project there are many ongoing and planned projects throughout the watershed. These projects will complement the estuary restoration and are intended to promote natural sediment distribution and increase floodplain connectivity. The increase in off-channel habitat connectivity will provide both refugia for threatened species and more floodwater dispersion.

Bleich - The future of hatcheries, management, and monitoring in the Skokomish Basin

Matt Bleich, Tacoma Power

The preceding speakers discussed the tremendous efforts that have been placed on salmon recovery in the Skokomish basin and the history that lead to those efforts. The partnerships formed with the Skokomish Tribe, state and federal agencies and Tacoma Power will continue to be critical in making strides in understanding limiting factors and implementing meaningful steps toward recovery in the future. These groups will be required to work through a multitude of challenges in order to surpass the startup phase of these programs and work together toward recovery. Among these challenges are efforts such as monitoring the interaction of fish assemblages, water quality, and food webs associated with associated habitats; development of salmon habitat programs designed to improve and expand spawning and rearing habitat; improvement of fish collection and passage programs to reconnect watersheds and collect brood stock; development of basin wide fish and hatchery management plans designed to coordinate and sustain recovery efforts of salmon population; and incorporation of harvest management strategies into fish and hatchery management plans.

Hoffnagle - Spawning ground surveys in the North Fork Skokomish River

Tim Hoffnagle, Tacoma Power; Anthony Battista, Skokomish Tribe

Spawning ground surveys have been conducted to assess spawner abundance and spatial/temporal distributions of Pacific salmon in the North Fork Skokomish River (NFSR). Surveys are conducted year around, since mature salmon may be found in the river in all months. Fall Chinook Salmon *Oncorhynchus tshawytscha* return to the NFSR and spawn from August through early November, peaking in mid-September. Total abundance has been increasing from 298 in 2008 to 1,325 in 2017. Spring Chinook Salmon have only recently been reintroduced into the NFSR, with the first release of BY 2014 smolts occurring in 2016 and the first females returned in 2018. Coho Salmon *O. kisutch* return in early September and spawn from October through March, peaking in December. Escapement has ranged widely from 63 in 2010 to 20,516 in 2004. A few summer Chum Salmon *O. keta* return to the NFSR and spawn in September. Fall Chum Salmon return to the river and spawn in large numbers from October through early January, with a peak in late November/early December. Total Chum Salmon escapement from 2008-2018 has ranged from 1,107 in 2010 to 12,362 in 2013. Pink Salmon *O. gorbuscha* return to the river and spawn in odd-numbered years from August through October, with a peak in September. No escapement is calculated for Pink Salmon but the number of live salmon counted has ranged from a low of 16 in 2011 to 5,059 in 2015. Winter steelhead *O. mykiss* arrive and spawn from February through June, peaking in May. Estimated escapement of steelhead in the NFSR has ranged from 3 in 1998 to 139 in 2016 and escapement from 2015-2018 exceeded that of all other years since 1998. We will continue to monitor escapement and evaluate the effects of the new salmon supplementation programs as the data become available.

Leischner - North Fork Skokomish River habitat – past, present and future

Florian Leischner and David Cogswell, Tacoma Power

The North Fork Skokomish River salmon habitat has been drastically affected by the Cushman Hydro Project. The dams have altered habitat-forming processes of the river downstream and inundated several miles of the river upstream. Unlike most dams in the Pacific Northwest, discharge from the dams is mostly diverted out-of-basin directly to Hood Canal and hence impacts on the habitat and stream channel downstream has been somewhat unique. Changes to the stream habitat have also been compounded by the effects of local land uses such as forestry and agricultural development. Tacoma Power's Cushman FERC license issued in 2012 includes habitat restoration requirements and changes to the flow regime that will off-set some of the dams and land use impacts. The license also includes long-term habitat monitoring that provides opportunities for collaborations with other entities to study the impacts of unique hydro operations and responses to changes in the downstream flow regime and habitat restoration.

McCormick - Screw trap monitoring on the North Fork Skokomish River

Megan McCormick and Tim Hoffnagle, Tacoma Power

Tacoma Power has operated a 5 ft diameter rotary screw trap in the lower North Fork Skokomish River (NFSR), annually since 2012 to document the number, fork length, weight, and migration timing of juvenile salmonids emigrating from the lower NFSR, by species and origin (natural or hatchery). Two separate locations have been used; however, the current trap location has been consistent since 2015. The early years of the monitoring program documented juvenile salmonid movements before hatchery supplementation began in the lower NFSR in 2016. All species of Pacific salmon *Oncorhynchus* spp. found in the Skokomish Basin have been caught in the trap, with an annual mean of approximately 377,000 natural-origin salmonids captured from 2015-2018. Seasonal trapping efficiencies for natural-origin salmonids have varied by species and year, but have either improved or stayed above the 10% recapture goal since 2016, with the exception of steelhead/Rainbow Trout *O. mykiss*, which has stayed above 5%. Overall, the trap performs well with a four year mean of 12.5% trapping efficiency. Abundance estimates of natural-origin Chinook Salmon *O. tshawytscha* migrants decreased from 18,306 in 2015 to only 3,243 in 2016 but increased in 2018 to 156,430. Estimates of Coho Salmon *O. kisutch* migrants passing the trap have steadily decreased from 20,470 in 2015 to 3,879 and 4,734 in 2017 and 2018, respectively. Chum Salmon *O. keta* fry abundance was consistent in 2015–2017 with a range of 502,767–856,703 fry but abundance was very high in 2018 with 5,277,435 fry. Estimated *O. mykiss* migrant abundance has increased steadily from 1,660 in 2015 to 7,634 in 2018. Future monitoring will be essential to assess the effectiveness of Tacoma Power's salmonid restoration and supplementation program and to evaluate hatchery-origin versus natural-origin interactions.

Noyes - Performance of Cushman juvenile fish collector 2015–2018

Chris Noyes, Tacoma Power

Performance evaluations have been conducted annually at the Cushman Juvenile Fish Collector (JFC) since 2015. The primary passage metrics evaluated include System Survival (SS), or the percentage of PIT-tagged fish released at the head of the reservoir that survive through collection, transport, and release downstream of the Cushman hydroelectric Project, and Fish Collection Efficiency (FCE), or the percentage of PIT- and acoustic tagged fish that approach and are subsequently captured in the JFC. Results during study years 2015–2018 using Coho Salmon ranged between 18.6% and 48.4% for SS, and 32.9% and 61.4% for FCE. The 2018 evaluation represented the initial year using Sockeye Salmon, with SS and FCE estimates of 35.3% and 40.5%, respectively. Fine-scale monitoring near and within the JFC suggest that many fish reject collection at consistent points. In addition, significant numbers of study fish in all evaluation years move extensively throughout Lake Cushman, often after entering and exiting the collector.

Ollenburg - North Fork Skokomish River hatchery programs

Andrew Ollenburg, Tacoma Power

Tacoma Power operates two hatchery facilities, North Fork Salmon Hatchery and Saltwater Park Sockeye Salmon Hatchery, where winter-run steelhead, Coho Salmon, spring-run Chinook Salmon, and Sockeye Salmon are reared. The North Fork Salmon Hatchery was commissioned in 2015 and Saltwater Park Sockeye Salmon Hatchery was commissioned in 2016. This Supplementation program operates with the guidance of the co-managers (WDFW and Skokomish Indian Tribal Community) and is consistent with the 2009 Cushman Settlement Agreement. The facilities are run as conservation hatcheries and each one of these programs are unique and have different purposes. The steelhead and Coho Salmon populations are derived from natural origin native North Fork Skokomish River stocks while the spring-run Chinook Salmon and Sockeye Salmon programs are reintroduction programs, using eggs from the Skagit Basin. Steelhead eggs are taken from redds in the North Fork Skokomish River, while Coho Salmon fry are captured over a two week period the season at a rotary screw trap and transferred to the North Fork Salmon Hatchery. The Chinook Salmon program was initiated in 2015 and 59,616 smolts were successfully released into the North Fork Skokomish River. The first releases from the other programs occurred in 2017 were 8,528 winter steelhead, 9,716 Coho Salmon, and 239,728 Sockeye Salmon. Full production targets for these facilities are 300,000 subyearling and 75,000 yearling spring-run Chinook Salmon, 15,000 smolt and 225 adult winter-run steelhead, 10,000-30,000 Coho Salmon, and 2,000,000 Sockeye Salmon. We describe early program performance in the hatchery and the first adult returns of spring-run Chinook Salmon to the watershed.

Pavel - The Skokomish River: A tribal perspective

Joseph Pavel, Skokomish Indian Tribe

The Skokomish River watershed has been the homeland of the Skokomish Indian Tribe from time immemorial. The Skokomish, largest of nine permanent village sites, are successors to the Twana (tuwaduq) people who made the Hood Canal watershed there home. Skokomish (synonymous with "the big river people") history, culture, and tradition are intertwined with the landscape of the Hood Canal Watershed and the Skokomish River.

Since first recorded contact with European culture in 1792 the lives of the People and the landscape of the Skokomish River and Hood Canal have been significantly altered. Smallpox, settlement, timber extraction, agriculture, hydroelectric facilities, resource competition, and other associated development practices have all contributed to the altered watershed function, productivity and the well-being of the Skokomish community.

The Skokomish Indian Tribe is a federally recognized tribe, party to the Treaty of Point No Point, 1855. The tribe continues to promote, for present and future generations, an independent, sovereign nation that preserves the traditional values, and treaty rights of

the Twana people. The health and functionality of the Hood Canal and Skokomish River watershed is vital to the well-being of the People. The Tribe is engaged in several initiatives to restore, recover, protect, and maintain a healthy, productive, and self-sustaining natural resource base core to the cultural, spiritual, subsistence, and economic health of the community.

Peter - Reservoir productivity: from water quality and zooplankton to Sockeye Salmon *Oncorhynchus nerka*

Matt Peter, Tacoma Power

Lake Cushman is a 9.6 mile long hydropower storage reservoir located on Washington's Olympic Peninsula that feeds the lower North Fork Skokomish River. Tacoma Power is working with various stakeholders to reintroduce several salmonid species to the watershed. An understanding of productivity in this monomictic reservoir is needed to assess and adaptively manage Lake Cushman as a Sockeye Salmon *Oncorhynchus nerka* rearing area. The composition and relative abundance of zooplankton populations are important indicators of lake productivity that link directly to the dynamics of Sockeye Salmon populations.

The primary focus of lake productivity monitoring was to analyze zooplankton community characteristics (density and biomass by taxa) in the context of water quality parameters. Biweekly water quality profiles were assessed at three meter depth increments at sampling stations longitudinally throughout the lake. Parameters included depth, dissolved oxygen, pH, temperature, turbidity, conductivity, and Secchi depth. Bimonthly zooplankton samples collected from the pelagic zone were paired with the water quality profiles. Zooplankton density and biomass analyses were compared with limnological data to assess relationships that influenced the productivity of Lake Cushman and its ability to serve as a nursery for Sockeye Salmon.

Lake Cushman was classified as oligotrophic (low productivity). Temperature, Secchi depth, and conductivity demonstrated the strongest relationships to the density and biomass of the common crustacean zooplankton taxa within Lake Cushman. Dominant species included *Daphnia* spp., *Eubosmina longispina*, *Holopedium glacialis*, *Diacyclops thomasi*, *Epischura lacustris*, and *Skistodiaptomus oregonensis*. We estimate smolt production capacity estimates based on zooplankton data collected to date. Our first release of Sockeye Salmon to the reservoir occurred in June 2017 and the longer-term impact of the stocking on the zooplankton populations is a significant unknown. Assessments will continue for a minimum of 12 years following the initial release of Sockeye Salmon to address these concerns.

Symposium: Contributed papers 1

Chair: Alf Haukenes (Washington Department of Fish and Wildlife)

Date: Wednesday, April 10, 1:20 PM to 5:00 PM
Location: Ballroom A

Alexiades - Indigenous integration of aquatic sciences and Traditional Ecological Knowledge for undergraduate culturally responsive education (i-NATURE): Piloting a culturally inclusive approach to STEM education for underrepresented minority undergraduates

Alexander Alexiades, Heritage University

American Indian/Alaska Native (AI/AN) students have the lowest college enrollment and graduation rates of any underrepresented minority population at mainstream U.S. colleges and universities, and are the least represented minority in the STEM fields. i-NATURE seeks to understand and address this enrollment deficit and prepare students for the future. The primary goal of i-NATURE is to develop and pilot a new, culturally-responsive, place-based model for Fisheries and Aquatic Science curriculum that can provide a seamless transition from high school to the STEM workforce for AI/AN. i-NATURE seeks to create this model for STEM education by establishing a strong collaboration between Heritage University, the Yakama Nation Fisheries, and partnerships with several tribes, agencies, and universities around the Pacific Northwest. The program is tailored to meet the needs of AI/AN and other URM students in a culturally responsive manner while simultaneously helping students acquire the skills and knowledge most critical for success in the STEM workforce and graduate school. The model aims to increase retention and learning outcomes in STEM fields and provide a strong foundation in data analysis and computing that will prepare students for graduate school and the 21st century workforce.

Gao - The Pacific Razor Clam populations in Washington revealed by stable isotopes

Yongwen Gao, Makah Fisheries Management; Joseph Gilbertson, Hoh Natural Resources Department; Hongyan Zhang, University of Michigan

The Pacific razor clam fishery in Washington State has been co-managed by the coastal Indian Tribes and the state, but little is known about the growth and population structure of the clams due to difficulties of tagging and monitoring. Here we report the results of a pilot study using stable isotope ratios (d13C and d18O) of razor clam shells collected in two groups (juvenile vs. adult) and from two sites (Kalaloch Beach and Roosevelt Beach) where distinct biological differences in clam growth and survival rates were observed. The d13C values of razor clam shells ranged from -2.88 to -0.30‰, whereas d18O values of the same samples ranged from -2.16 to +1.39‰. Between the two sites there were

significant differences in d13C values especially for juvenile clams. The d18O profiles from two representative shells demonstrated similar patterns of rapid growth as juveniles and seasonal patterns throughout the life span. Profiles of d13C were sinusoidal but did not show seasonality and signatures of ocean acidification. We concluded that stable isotope analysis of razor clam shells is a potential new tool in shellfish research and management.

Hall - Large river habitat complexity and productivity of Chinook Salmon in Puget Sound rivers

Jason E. Hall, Cramer Fish Sciences; Correigh M. Greene, NOAA NWFSC; Oleksandr Stefankiv, NOAA NWFSC; Joseph Anderson, WDFW; Britta Timpane-Padgham, NOAA NWFSC; Timothy J. Beechie, NOAA NWFSC; and George R. Pess, NOAA NWFSC

While numerous studies have shown that large river habitat complexity can be important to fish ecology, few have quantified how complexity at watershed scales influences productivity at population scales. This scale mismatch complicates recovery strategies that require a regional approach to develop recovery objectives. We used outputs from an effort to track habitat status and trends across ten of Puget Sound's large river systems to examine whether subyearling Chinook salmon productivity relates to watershed-scale habitat complexity. We derived five habitat complexity metrics that quantified densities of wood jams, off-channel habitat, and node densities at watershed scales from a remote sensing census of aerial imagery. These metrics revealed gradients in habitat complexity across Puget Sound's large river systems, and that subyearling Chinook productivity was positively related to basin-scale habitat complexity. We also observed that population-scale coefficient of variation for subyearling Chinook productivity declined with increasing habitat complexity, supporting the idea that habitat complexity buffers populations from annual variation. Using multi-year aerial imagery for a subset of systems, we demonstrated that our remote sensing approach and habitat metrics for large river systems can detect changes in habitat over time from natural processes, restoration, and development. Given the relationships between subyearling Chinook productivity and habitat complexity, and the ability of our approach to detect changes in habitat over time, this approach may provide a useful means to track and evaluate aggregate effects of habitat changes on the productivity of Endangered Species Act listed Chinook salmon populations over time. This is particularly relevant to regional salmon recovery efforts given the emphasis on habitat restoration in Puget Sound's regional recovery strategies and the need to evaluate progress towards recovery within these populations.

Johnson - Bull Trout movement at multiple life stages in the White River, Washington

Jeffery Johnson and Roger Peters, U.S. Fish and Wildlife Service; Rebecca Lofgren, Mount Rainier National Park; Benjamin Wright, Mount Rainier National Park; and Erik Marks, Puyallup Tribe of Indians

Bull Trout *Salvelinus confluentus*, listed as threatened under the Endangered Species Act, commonly exhibit a diversity of life history strategies within the same watershed and the presence and extent may vary among basins. The contribution of variable strategies to the stability and abundance of a population is largely unknown. We have implemented a long-term project to assess the variability in life history, and population contribution of these different strategies for Bull Trout in the White River, Washington. A trap and haul facility in the lower river has provided extensive and detailed information about large migratory fish that migrate downstream of this facility. However, this facility fails to sample downstream migrants, fish <300mm, or less migratory fish that remain upstream. To garner information about earlier life stages, we tagged and monitored fish movement in the upper basin with a network of Passive Integrated Transponder tag antennas. In 2017 and 2018, we installed multiple antennas, which included a mainstem site and tributaries with historically high spawning activity. Additionally, we sampled and tagged fish captured throughout the upper basin. This effort resulted in the capture and tagging of 59 and 196 fish in the upper basin during 2017 and 2018, respectively. From both years, 27 tagged fish from the upper basin, and 146 tagged fish from the lower river have been detected. These detections suggest as many as six different migration or life history strategies are present. Continued tagging and monitoring with an expanding network of antennas will further illuminate the diversity of life history strategies, and potentially allow estimation of population contribution for each strategy. This research hopes to provide a comprehensive assessment of population contribution by life history strategy for Bull Trout in the White River, which may prove useful for Western Washington as a whole.

Naman - Comparing bioenergetic vs. correlative habitat suitability models for stream salmonids

Sean Naman, University of British Columbia; Jordan Rosenfeld, BC Ministry of Environment; Jason Neuswanger, South Fork Research; Eva Enders, Fisheries and Oceans Canada; and Brett Eaton, University of British Columbia

Evaluating fish habitat suitability is crucial for navigating trade-offs between human water use and fish production. Current approaches generally use correlative statistical models based on measured habitat preferences (use relative to availability) for a target species. While these models range in statistical rigour, they continue to be criticized on the grounds that habitat preference is often a poor indicator of the fitness consequences of habitat use. For drift-feeding salmonids, bioenergetic foraging models that link hydraulic conditions and prey abundance to a fish's energy balance offer an alternative suitability metric, which mechanistically links habitat to a more direct correlate of fitness. However, while bioenergetics models show promise, they lack rigorous empirical validation and it remains uncertain whether bioenergetics vs. frequency based approaches differ in their predictive ability. Here, we evaluate the ability of correlative vs. bioenergetic habitat suitability models to predict density and growth of juvenile salmonids (rainbow and cutthroat trout) in B.C. streams. We also describe the development of user-friendly software to generate bioenergetic habitat suitability indices for broader application. Generally, bioenergetic models outperformed correlative ones, suggesting they provide a

more rigorous method to predict salmonid responses to altered habitat and flow. However, caveats associated with model parameterization remain.

Pearsons - Long-term successes in fisheries management: Species recovery, dam evolution, and hatchery reform

Todd N. Pearsons, Grant County Public Utility District

Natural resource management is filled with challenging problems and there are societal limitations to the kinds of solutions that are possible. Conservation strategies that balance multiple societal values are most likely to be broadly accepted and successful. Three examples of success are provided to illustrate approaches that could be used more broadly. First, the Oregon chub *Oregonichthys crameri* was the first species to be delisted as a result of recovery. Two key reasons that led to recovery were: 1) key investments in science, and 2) development of inexpensive approaches such as transplanting fish into suitable locations. Second, dam evolution has included some favorable environmental outcomes such as environmental flows, improved passage, removal of antiquated dams, and quick responses to emergencies. Third, hatchery reform of Salmon and steelhead hatcheries has been widely implemented across the western United States which has allowed continued harvest in the midst of Salmon and steelhead recovery. Some of the reasons for success of hatchery reform included: impetus for change caused by the Endangered Species Act, inclusion of experts from a variety of management organizations, development of commonly applied tools and indices, and application of a goal-oriented, scientific process. Some characteristics that were common to all three successes included favorable contexts for change, creative problem solving, inclusion of key individuals, and strategic application of science.

Peters - Do fin rays offer a non-lethal approach for assessing life history patterns using geochemical analysis?

Roger Peters, U.S. Fish and Wildlife Service; Jeffery Johnson, U.S. Fish and Wildlife Service; Michaela Lowe, University of Washington; Kimberly Larsen, U.S. Geological Survey; Lisa Wetzel, U.S. Geological Survey; Lance Campbell, Washington Department of Fish and Wildlife; Laurel Low, AmeriCorps

Chemical analysis of otoliths is a common method for assessing stock, population structure, and life history patterns of fish populations, including extent of anadromy. Unfortunately, otolith removal is lethal, which prompted us to assess non-lethal methods that provide similar information for limited or at risk populations. Through multiple studies, we investigated the efficacy of alternative methods to provide information previously gained from otolith analysis. We examined scale and fin ray microchemistry of Bull Trout *Salvelinus confluentus* collected from the Hoh River, Washington. We found that both scales and fin rays appeared to be suitable indicators of anadromy, with the latter being superior in detail. Based on this finding, we investigated if fin rays can be removed without increasing mortality or sublethal effects using both laboratory and field studies.

Laboratory studies with Rainbow Trout *Oncorhynchus mykiss* indicated that there was no significant difference in survival and growth between treatment and control fish. Preliminary field results with Bull Trout suggest migration rate, survival over a yearlong period, and growth are not impacted. In addition, we are currently conducting a basic lab-based experiment with rainbow trout to define the relationship between otoliths and fin rays, as well as determine the resolution of inference from geochemical analysis. These analyses will help us better understand the inferences and level of detail that can be obtained from fin rays. Based on these findings, we have implemented a number of studies to assess life history patterns, large-scale freshwater migrations, and interbasin movements of Bull Trout in western Washington and further document the viability of a nonlethal method to garner population level attributes of an at-risk species.

Richards - Spatial distribution of adult hatchery and natural origin fall Chinook Salmon in the Hanford Reach of the Columbia River

Steven Richards and Alf Haukenes, Washington Department of Fish and Wildlife; Todd Pearsons, Grant County Public Utility District

The recovery locations of post-spawn female Chinook Salmon carcasses are frequently summarized during monitoring programs and the data used to illustrate spawning distribution of the population under study. Carcass survey data are subject to potential biases that have been attributed to fish sex, fish size, and drift from redd locations. We are characterizing the impact of these potential biases on the interpretation of Hanford Reach carcass surveys. Our evaluations of drift include tagging and releasing post-spawn Chinook Salmon carcasses and measuring distances between release and recovery locations. The average length of drift during years evaluated ranged from 3.1 to 27.5 km and illustrate that the method and location of release contributes to the distances measured for drift. We derived an adjustment factor from our carcass drift tests and following adjustment, the relationship between the spatial distributions of females and the number of redds was improved. Finally, we have applied a drift adjustment on carcass survey data describing the location of hatchery and natural origin females; preliminary inspection of these data suggest differences in the spatial distribution of hatchery and natural origin fish within the Hanford Reach. Mainstem systems like the Hanford Reach present unique challenges in the design of carcass drift studies and interpretation carcass surveys. While presenting these results, our approaches to these challenges will be discussed.

Sutton - Bull Trout exhibit life history responses after dam removal in the Elwha River, Washington

Samuel J. Brenkman, National Park Service; Roger J. Peters, U.S. Fish & Wildlife Service; Roger A. Tabor, U.S. Fish & Wildlife Service; Joshua J. Geffre, National Park Service; Kathryn T. Sutton, U.S. Fish & Wildlife Service

Bull Trout *Salvelinus confluentus* is a federally threatened species with diverse migratory patterns and specific habitat requirements. Connected stream systems and access to cold

water and clean substrate, often found in headwaters streams, are necessary for the greatest diversity of life history expression. Prior to dam removal in the Elwha River, Bull Trout were isolated downstream, between, and upstream of two impassable dams. Dam removal from 2011 to 2014 restored access to 130 km of spawning and rearing habitat and reconnected the estuary to headwaters, offering the potential for Bull Trout to expand life history strategies. To assess responses of Bull Trout to dam removal, we used size and age data collected prior to and after dam removal as well as radio telemetry and diet data collected after dam removal. Bull Trout were among the first species to migrate upstream of both former dam sites and progressively expanded their upriver migration annually, reaching the headwaters by 2017. Radio-tagged fish were observed to move downstream and make multiple trips from the river to the estuary, indicating a resumption of anadromy. Comparisons of body size before and after dam removal revealed a significant increase in length, length at age, and weight at length. Bull Trout appear to rely heavily on anadromous Pacific salmon (*Oncorhynchus* spp.) for much of their annual energy demand. Because Bull Trout are highly mobile and capable of binge feeding, they are able to exploit this prey base that varies widely in time and space and is expanding from dam removal. Results suggest Bull Trout were early colonizers of the Elwha River after dam removal, and access to the sea conferred size benefits. This study offers insight into responses of a vulnerable fish to dam removal, and establishes a baseline for future monitoring efforts in the restored Elwha River.

Tabor - Effect of artificial nighttime lighting on subyearling salmonids in the Lake Washington system

Roger Tabor, USFWS; Alex Bell, USFWS; Mark Celedonia, USFWS; Zachary Moore, USFWS; Lyle Britt, NOAA Fisheries; Rebecca Haehn, NOAA Fisheries; David Beauchamp, USGS; Scott Stolnack, King County; Daniel Lantz, King County; John Green, RGB Optics; Tim Robinson, RGB Optics; and Liz Perkin, McDaniel College

Artificial nighttime lighting is a common condition especially in urban areas; however, the consequences of this lighting on aquatic ecosystems are often poorly understood. Artificial nighttime lighting has been shown to affect the behavior of many aquatic organisms, including juvenile salmonids. Earlier research (1997–2001) on sockeye salmon fry in the Cedar River found fry were attracted to artificial lighting which delayed their migration and made them more vulnerable to predation. Results of acoustically-tagged Chinook salmon smolts in Lake Washington and the Ship Canal also indicated they were strongly attracted to lights. In 2014 and 2015, we conducted field experiments in the nearshore area of Lake Washington and Lake Sammamish to test the attractive quality of three light intensities on nearshore fish abundance, which we also compared to abundances from control nights without light treatments. For each month (March to May), the total number of subyearling salmonids was greater on the lighted night than they were on the control night. In both lakes, most subyearling salmonids were collected in the bright-light treatments, an intermediate amount in the dim-light treatments, and few in the no-light treatments. In 2017 and 2018, we tested the effect of different types of lights (primarily LED lights with different spectra) in the nearshore area of Lake Washington using the same light intensity (20 lux). Similar to earlier experiments, substantially more

subyearling salmonids were collected in the lit treatments than in the no light control treatment; however, we were unable to detect any differences among the different lights. We believe the prudent management goal would be to minimize artificial nighttime lighting as much as possible to reduce potential predation risk especially where ESA-listed salmonids are present.

Symposium: Uninvited guests at the feast; consequences of non-native species introduction and spread

Chair: Paul Spruell (Eastern Washington University)

Date: Thursday, April 10, 9:00 AM to 11:40 AM
Location: Ballroom A

Anthropogenic changes to the environment often have unintended consequence with respect to community composition and structure. In many cases these environmental changes may allow populations of non-native species to increase in number substantially and may facilitate the colonization of new habitats, thus expanding the range and effect of these exotic species. In this symposium, we will examine the effects of non-native species including consideration of their current and future ranges, their direct and indirect on native species, and management actions aimed at mitigating their effects. summary report may be written with contributions from all participants.

Glaser* - The compensatory responses of intentionally overharvested Brook Trout *Salvelinus fontinalis* populations in the Canadian Rockies

*Dylan Glaser and John R. Post, University of Calgary; Dylan J Fraser, Concordia University (Montreal, QC)

Compensation is the ability of populations to alter per capita rates in response to changes in population density. Populations compensate for density reduction via increases in per capita population growth rates, survival rates, or somatic growth rates. Examining compensatory responses is necessary for determining the amount of harvest that populations can withstand, or to determine the efficacy of a harvest control program in the case of invasive or introduced species. To examine compensatory responses, we experimentally removed 50% of the population of invasive lake-dwelling Brook Trout in several lakes in the Canadian Rockies. We measured demographic characteristics in the populations at pristine states before harvest, and then returned the following year to measure demographic responses to this harvest. Although growth is one of the most studied density dependent responses, it remains difficult to detect and interpret. Here, we use a variety of analytical methods to detect growth in body size. Preliminary results show small growth responses to reduced density that mainly affected smaller bodied cohorts. In general, there was a negative relationship between individual body growth and initial, pristine population densities. It also appears difficult to detect a change in body growth relative to experimental manipulation of the population density. After examining survival

data, it appears that survival is also playing a role in compensation. Our findings demonstrate a need to examine multiple demographic responses when assessing rapid compensatory responses to harvest.

Jasper* - Diet composition of Lake Trout *Salvelinus namaycush* in Upper Priest Lake, Idaho

*Coty Jasper, Derek Entz, Andrew Huddleston, Tyler Janasz, and Paul Spruell; Eastern Washington University

Lake Trout *Salvelinus namaycush* were intentionally introduced to the Priest Lake system in 1925 with the intentions of creating a recreational fishery. As the Lake Trout population increased within this system, the native Bull Trout *Salvelinus confluentus* population began to decline. Possible negative impacts of Lake Trout on Bull Trout include direct effects such as predation, or indirect effects, such as resource competition. In this study our objective was to estimate the frequency of piscivory in Lake trout from Upper Priest Lake and document any possible Lake Trout predation upon Bull Trout in the Upper Priest Lake system. We obtained Lake Trout samples from this system during annual gill netting, which is performed to suppress Lake Trout. We then performed stomach dissections to identify incidents of piscivory. Although Mysis shrimp were predominant pretty items, 61 of 153 examined stomachs contained partially digested fish tissue. We then extracted DNA from these tissues and used a species DNA barcode located in the cytochrome oxidase one gene of the mitochondrion to identify said fragments. Out of a total of 61 samples 63.4% were identified as Lake Trout; 19.0% were identified as Pygmy Whitefish *Prosopium coulteri*; 14.2% were identified as kokanee *Onchohynchus nerka*; and 1.5% were identified as Yellow Perch *Perca flavescens*. Therefore, we suggest that the effects of Lake Trout on Bull Trout are not direct effects, but rather indirect effects such as resource competiton.

Jorgensen* - Quantitative food web analysis to detangle density dependence in restored habitats

*John Jorgensen and Alex Fremier, Washington State University; Paul Anders, Cramer Fish Sciences

Accurately detangling density dependence in lotic ecosystems containing native anadromous salmonids is central to identifying limiting factors and prioritizing actions that increase or restore natural production. Geomorphic and habitat-based monitoring metrics, models, and assessments (primarily abiotic) have been developed and employed to assess ongoing physical limitations in such riverine environments. Though needed and useful, their application has failed to adequately resolve ongoing uncertainties of biological limitation. While biological assessment tools that use static metrics (abundance, biomass and diversity) have inherent value, they cannot directly quantify energetic limitations (food availability and trophic routing) and ultimately fail to assess density dependence. To identify and quantify density dependent factors, which ultimately lead to habitat carrying

capacity, monitoring protocols and subsequent analytical procedures must capture dynamic food web processes that directly affect energetic routing.

Used as a pre and post-restoration monitoring tool, an empirical based, quantitative food web approach allows researchers and managers to evaluate the effectiveness of specific restoration actions and the additive value of multiple restoration prescriptions in co-limited stream reaches. While empirically derived food web models have been used in limited academic studies, there is a critical lack of available and applicable analytical tools to directly evaluate density dependence in a broader more holistic restorative context.

Here we present: 1) a brief overview of a quantitative bio-energetic approach and discuss associated advantages and disadvantages in the context of stream restoration, 2) initial project results comparing community and taxa-specific aquatic insect production between a restored and an unrestored stream reach, and 3) a new quantitative analysis tool (R package) and its application in a larger management context.

McCroskey - Abundance of Smallmouth Bass *Micropterus dolomieu* in the Upper Spokane River, Washington

Taylor McCroskey, Oregon Department of Fish and Game; Charles D. Lee, Washington Department of Fish and Wildlife; Allan T. Scholz, Eastern Washington University; Paul Spruell, Eastern Washington University

Non-native Smallmouth Bass *Micropterus dolomieu* in the Spokane River are of concern because of the potential that they may prey upon or compete with a declining population of native Redband Trout *Oncorhynchus mykiss gairdneri*. To assess the potential impact of this invasive species, we estimated the abundance of Smallmouth Bass in the upper Spokane River, Washington. Fish were captured in the summer of 2015 by raft electrofishing and angling in a 5.3km reach just downstream of the Washington / Idaho boarder. A total of 410 fish ≥ 30 mm total length (TL) were captured and marked during the survey. Populations were estimated by mark-recapture methods using the POPAN model executed in Program MARK. The number of Smallmouth Bass ≥ 200 mm TL in this reach was estimated at 1,307 ± 862. This represents a 125% increase in Smallmouth Bass density when compared to a 2008 population estimate made in a similar area. Although these data do not directly indicate that Smallmouth Bass pose a threat to native Redband Trout, Smallmouth Bass density is increasing in an area used by Redband Trout for spawning, increasing the possibility of negative interactions.

Saluskin - The Outro

Brian Saluskin, The Yakima Nation

Mackinaw (Lake Trout *Salvelinus namaycush*) Reduction: The Yakama Nation (YN) started deploying gill nets during the spawning season (October–December) when the mackinaws come into shallow rocky areas around the perimeter of the lake to spawn. The YN and Washington Department of Fish and Wildlife (WDFW) collaborated on a Mackinaw Removal

Proposal before the beginning. A scientific collection permit is requested from the YN Fish & Wildlife Committee, dates and location of gillnet deployment is shared with WDFW and they notify their Fish & Game Officers of our intentions. All harvested fish are sampled for length, weight, sex, age, and stomach contents. When available WDFW Biologists accompany and assist the YN in the collection of Mackinaw and data. After all data has been collected mackinaw are placed in plastic bags and frozen until the gill netting process has been completed for the season. Frozen mackinaw are placed back where they were caught, the rotting carcass creating a fungus that would affect the embryos of mackinaw that have successfully spawned.

Silver - Invasive Northern Pike suppression in Lake Roosevelt, Washington

Alix Silver, Spokane Tribe of Indians; Holly McLellan, Colville Confederated Tribes; and Charles Lee, Washington Department of Fish and Wildlife

Northern Pike *Esox Lucius* are an invasive species in Washington State. The Washington Department of Fish and Wildlife (WDFW) reclassified Northern Pike as a Prohibited Species in 2011. The reclassification was partially in response to the establishment of an invasive Northern Pike population within Box Canyon Reservoir, an impoundment of the Pend Oreille River. In Box Canyon Reservoir the Kalispel Tribe of Indians and WDFW collaboratively implemented an aggressive gill net suppression project which removed nearly 17,000 Northern Pike between 2012 and 2015. The Pend Oreille River meets the Columbia River in Canada upstream of Franklin D. Roosevelt Lake (Lake Roosevelt, WA). In 2015 a burgeoning Northern Pike population was detected within Lake Roosevelt. The Lake Roosevelt co-managers (Confederated Tribes of the Colville Reservation, Spokane Tribe of Indians, and WDFW) view Northern Pike as a serious and immediate threat, and responded promptly with baseline monitoring and suppression efforts. Monitoring and suppression on Lake Roosevelt is challenging due to the scale of the reservoir and annual flood control operations at Grand Coulee Dam. Prior to 2013 observations of Northern Pike within Lake Roosevelt were rare. Incidental catch of Northern Pike in fishery monitoring surveys has been steadily increasing. In 2016 the Lake Roosevelt co-managers implemented limited Northern Pike suppression, removing 1,225 Northern Pike and documenting age-0 recruitment for the first time. Throughout 2017, approximately 4,771 Northern Pike were removed, increasing geographic distribution was documented, and age-0 recruitment was again observed. In 2018 weather, fires and funding limited suppression effort, although 1,836 Northern Pike were removed, documenting increasing distribution. A formal Northern Pike suppression project is currently under development. Northern Pike pose an immediate threat to the Lake Roosevelt subsistence and recreational fishery which is supported by annual releases of hatchery salmonids. Furthermore, a growing Northern Pike population threatens hundreds of millions of dollars of downstream investment in anadromous salmon, sturgeon, and lamprey recovery throughout the Columbia River drainage.

Vadas - Long-term population response of Coastal Cutthroat Trout to environmental fluctuations in a temperate-rainforest stream: hydrology, temperature, and invasive weeds and other biotic factors

Robert Vadas, Washington Department of Fish and Wildlife

Each spring during 2001–2012, we counted trout redds in mainstem and tributary habitats in well-forested Irely Creek, finding a statistically significant relationship between redd counts and the previous year's minimum level for downstream Irely Lake (Vadas et al. 2016), where all or most adults rear to adulthood. Run-size estimates (twice the redd count) were at viable levels during the first two years, but escapement has since declined by an order of magnitude, reflecting more-frequent (including consecutive-year) lake dry-outs along with expansion of exotic reed canarygrass in the lake. Indeed, wet years elicited incomplete CCT-run recovery, as resultant population increases were weaker than population drops from lake dry-outs. Although surface water in adult habitat was limiting with a short time delay for this trout, cumulative-year hydrologic indices for lake level were even better predictors of escapement than were single-year indices. Complications for biotic parameters were curvilinear responses, likely reflecting density dependence for the highest trout-escapement year (2002), but quadratic-regression terms did not improve predictive ability. The mechanistically valuable variables for our best multiple-regression models included (a) cross-year conditions for lake level (that assumed moderately good Cutthroat recovery after past dry-outs) and peak-spawning temperatures (reflecting the trout's coldwater preferences); and (b) last-year Cutthroat escapement and Coho-carcass counts. Hence, both physical and biotic (stock/trophic) factors appeared to be important for cutthroat productivity, in negative ways except for late-winter salmon counts. So our best monotonic-regression model can realistically predict future trout escapements, based on environmental changes from natural and human impacts, to be tested with more-recent (2015–2018) redd-count data collected with the help of volunteers. If reed canarygrass is contributing to lake dewatering, or at least stagnation (water-quality) impacts during partial dry-outs, then this emergent weed's removal (starting in 2018) should improve lake conditions and thus contribute to improved trout escapements in future years.

Symposium: Contributed papers 2

Chair: Gabriel Temple (Washington Department of Fish and Wildlife)

Date: Thursday, April 11, 9:00 AM to 11:20 AM
Location: Ballroom B

Dittman - Developing methods to improve homing by hatchery salmon

Andrew Dittman, NWFSC, NOAA Fisheries; Maryam Kamran, Oregon State University; Marc Johnson, Oregon Department of Fish and Wildlife; Beatriz E Noriega-Ortega, Leibniz-Institute of Freshwater Ecology and Inland Fisheries; Gabriel Singer, Leibniz-Institute of Freshwater Ecology and Inland Fisheries; David Noakes, Oregon State University

Adult Pacific salmon are renowned for their ability to home to their natal streams to reproduce. Salmon imprint as juveniles on the olfactory signatures of their rearing water and later use this information to home back to their natal site as adults. Straying from the natal site is a natural component of salmon life histories that facilitates beneficial gene flow and colonization of vacant habitat. However, some straying can result from a failure to properly imprint upon or later recognize the olfactory signature of a natal stream or hatchery. While artificial propagation doesn't inherently lead to elevated straying, some hatchery rearing practices can increase stray rates which can result in negative genetic and ecological interactions with natural-origin salmon. In this paper, we describe ongoing studies examining methods to improve homing by fall Chinook salmon released from the Elk River Hatchery (ERH) in southern Oregon. These efforts are important because a large percentage of the hatchery fish do not return to the hatchery but rather spawn in the river with the wild population of Chinook salmon. Like many hatcheries, the ERH utilizes mainstem river water for rearing and one concern is that the water emanating from the hatchery does not provide a unique enough olfactory signature for returning adults to distinguish it as their natal site. To establish a unique olfactory fingerprint for the hatchery we explored the feasibility of adding chemicals to hatchery water to impart a unique chemical signature that would facilitate imprinting and homing. First, we tested whether the chemistry of the water exiting the hatchery differed from river water entering the hatchery. We also identified candidate odors and chemicals that could be detected and learned by salmon, elicited no innate responses, and was safe and economical for improving homing.

Jones - Advances in oxygen supplementation

Tod Jones, Redd Zone, LLC

The critical function of oxygen in animal respiration and life function is well known and documented. The ameliorating benefit of supplementing water bodies for salmonids has also been demonstrated and utilized for decades. Several devices for that purpose have been developed and deployed resulting in improved fish health and enhanced growth rates. Barnaby Watts, a US Forest Service employee, designed the LHO (Low Head Oxygen) unit for streams depleted in oxygen either through thermal pollution or biological oxygen demand. The principals of Redd Zone, LLC began using the LHOs at the Gnat Creek Hatchery in 2002 resulting in healthier Spring Chinook smolts and improved SARs. Redd Zone has now optimized pressurized systems taking advantage of that pressure to increase the absorption of O2 achieving in excess of 200% oxygen saturation while removing unwanted nitrogen gas.

Kennedy - Ecological differences of juvenile Steelhead produced by natural origin and local hatchery origin adult Steelhead spawning in the wild

Benjamen Kennedy, Matt Smith, Douglas Peterson, and Roger Root; U.S. Fish and Wildlife Service

Recent data suggest that steelhead produced from local hatchery origin (HOR) steelhead spawning in the wild have lower fitness than their natural origin (NOR) counterparts. Despite this pattern, the mechanisms behind this phenomenon remain poorly understood. To increase our understanding of this pattern we investigated possible differences in important life history traits related to fitness between juvenile steelhead produced by local HOR and NOR steelhead spawning in the wild. By integrating genetic parentage assignment and ecological data, we looked for differences in fish length, weight, condition, spatial distribution, and migration timing among each parent type. Adult steelhead were collected and sampled via an electric weir and released upstream to spawn naturally. Juveniles were collected and sampled via electrofishing and a rotary screw trap. Additionally, juvenile steelhead were PIT tagged and migration behavior was measured via instream PIT tag antenna arrays. Results from this study are currently being analyzed and they will be presented during the presentation.

Lauver - Investigating an ecological method for determining hatchery release timing of salmon

Eric Lauver and Todd N. Pearsons, Grant County Public Utility District

A primary goal of releasing Chinook Salmon smolts from a hatchery facility is for them to survive their outmigration in as high a number and in as good a condition as possible, and to do so without having negative impacts on non-target taxa of concern. Fish migration readiness (e.g., degree of smoltification), environmental factors (e.g., flow and passage conditions at hydro projects), and ecological interactions (e.g., competition and predation) should all be considered when scheduling releases. Because these factors may differ among years, optimal release times may also differ among years. However, parameters such as historic release dates, availability of staff, shifting workloads, and availability of equipment or other resources often determine when fish are released. A conceptual model for determining optimal release timing that considers the natural environment, fish readiness, and ecological interactions is presented. The conceptual model is evaluated via current-year and retrospective analysis of release timing relative to these metrics. An advantage we hope to realize by using a model-informed approach to set release time is continual improvement in the way we achieve optimal outmigration survival and ecological interactions, even as environmental changes occur.

Olson - The pros and cons of vaccination of hatchery stocks against disease

Wendy Olson, Tom Goodrich, Kyle Garver, and Hugh Mitchell; AquaTactics

Warmer water temperatures and changing ocean conditions due to climate change can pose significant health risks to fish. This increase in stress lowers their ability of the immune to fend off disease. Diseases of particular concern in salmonids of the Pacific Northwest include Vibriosis, Bacterial Kidney Disease, and Infectious hematopoietic necrosis virus (IHNV). While these diseases have shown to have a significant health impact on cultured and laboratory populations, the disease impact on wild fish remains largely unknown since sick and dying fish are rarely recovered. Vaccines and other health additives have been shown to have a positive impact on the fish's ability to fight these diseases in captive situations. It is therefore possible that vaccinating fish in the hatchery may give them a significant advantage in the wild, resulting in an increase in returns. This talk will focus on the pros and cons of fish vaccination and the potential impact it may have on fish hatchery returns.

Taylor* - Using bioenergetic modeling to evaluation prey limitations in lacustrine Brook Trout

*Timothy Taylor and Barry C. Moore, Washington State University; Benjamin K. Cross, U.S. Fish and Wildlife Service

The management of fish populations often requires an understanding of how density-dependent effects influence population dynamics. In systems where natural populations are supplemented with stocking, the question of 'how much food is available' becomes increasingly important. One typical approach for assessing density-dependent interactions is to identifying disparities between fish consumption rates and food availability. The objective of our study was to determine if lake prey production could support current Brook Trout population abundance in Owhi Lake, Washington. Brook Trout were collected seasonally from 2015 to 2017, recording information on length, weight, age, diet, growth, and mortality. Population abundance was estimated in summers using hydroacoustic surveys. Littoral invertebrates and pelagic zooplankton were collected concurrently with fish to enumerate biomass and production. Bioenergetics modeling was used to estimate prey consumption for Brook Trout. In conjunction with supply-demand comparisons, we used growth efficiencies and maximum consumption rates to further identify potential season and annual food limitations. Our results suggest that prey production could support Brook Trout consumption demands for all years, but littoral invertebrate consumption was near to, or exceeded, prey production in summer and fall 2017. Growth efficiency was lowest and maximum consumption rates were highest in summer 2017 compared to all seasons and years. In addition to observed diet switching in summer 2016 and 2017 from littoral invertebrates to zooplankton, we concluded that lower growth efficiencies, lower annual survival rates, and increased consumption rates were influenced by littoral invertebrate production. Lastly, model results were most sensitive to population abundance and prey energy density. For this system, summer littoral prey abundance was the primary density-dependent limiting factor for Brook Trout.

Poster Session

Date: Tuesday, April 9, 6:00 PM to 9:00 PM
Location: Ballrooms C & D

Andy - Pacific Lamprey

Latonia Andy and Alex Alexiades, Heritage University; Ralph Lampman, Yakama Nation Fisheries

Pacific Lamprey *Entosphenus tridentatus* are potentially exposed to stress during transport between dams on the Columbia River, but the effects of vibration from transportation at various life stages is largely unknown. To better understand how transportation affects early life stage Pacific Lamprey, Yakama Nation Fisheries Pacific Lamprey Project and Heritage University jointly conducted vibrational studies at the Prosser Fish Hatchery in Prosser, Washington. We examined Pacific Lamprey embryos (13 days post fertilization; prior to hatching), prolarvae (21 and 29 days post fertilization; prior to feeding stage), and larvae (37 days post fertilization; initial feeding stage) by placing them on a vibration platform (99-Level Pivotal Vibration Platform; Best Choice Products, Irvine, CA) for one to three hours to simulate the effects of truck transport (low and medium intensity vibration). We used 100 individual lamprey from each of the four life stages for each treatment. We also evaluated the effect of 2 types of media within the transport container to assess whether they can mitigate any negative impacts: 1) fine sediment which is the natural habitat for larval lamprey; and 2) coconut fiber spawning mat which is used as cover for pro-larvae during artificial propagation. We also included a control treatment which experienced all the same treatment except for the vibration. Overall, in this study we found that Pacific Lamprey benefitted from being transported without additional media such as fine sediment or coconut fiber spawning mat. And we learned that reduced vibration will decrease Pacific Lamprey mortality, mortality was increased by high vibration in comparison to the control treatment which included no vibration. These vibrational studies will help us determine the degree of sensitivity of early life stage lamprey to vibration stress and provide preliminary guidelines for transporting artificially propagated lamprey.

Brower - Diverse options for monitoring fishway effectiveness using PIT tag technology

Matt Brower, Steve Anglea, Biomark, Inc.

Fishway designs are as varied as the species that use them. After almost two decades of designing PIT tag detections systems to monitor fish passage, Biomark has developed an offering of antennas that range in size, shape and construction technique, to provide an optimal solution for each location and budget. Biomark uses it's IS1001 Multiplexing Transceiver System (IS1001 MTS) as the backbone for monitoring systems and selects

power and remote monitoring solutions depending on the specific location and unique customer requirements.

Capetillo - Fish diversity and abundance of the Upper Toppenish Creek, Yakima, Washington

Brooke Capetillo, Tim Ressigue, and Alexander V. Alexiades; Heritage University

To the Yakama Nation, the passage fish of the Columbia river and its tributaries are of paramount importance to our culture and health. In order to document fish passage, we used mark-recapture methods conducted with a screw trap and PIT- tags to mark fish such as pike minnow and salmonid over (>90mm) and we also documented non-target species abundance. The site located at Toppenish Creek has dam abutments which create a hydraulic pressure gradient that limits successful fish passage. During my research there was a 66% difference in species abundance compared to the previous year. Also, there were lower water levels due to farming irrigation systems connected to the creek and a lack of rainfall creating a drought. To conclude, there was a decrease in abundance and diversity in the fish community due to unsuccessful fish passage and drought.

Cline* - Habitat complexity and environmental influences on intertidal Coast Salish food availability in the Southern Gulf Islands

*Amy Cline and Marco B.A. Hatch, Western Washington University

First Nations peoples of the Salish Sea have gathered food on rocky intertidal beaches since time immemorial. First Foods such as chitons, limpets, and rock crabs are gathered on a variety of rocky intertidal beaches ranging from flat bedrock to more complex structures. Within this complexity gradient exists beaches that are modified by First Nations Peoples. One example of this modification is clam gardens. Clam gardens are rock walls constructed by First Nations Peoples at the lowest tide line, these walls retain sediment and lessen the slope of the beach to provide ideal clam habitat. Clam gardens are located from Southeast Alaska to the Southern Salish Sea. Most of the research on clam gardens are focused on bivalve production, however the rock wall provides a complex habitat. Within this complex habitat a number of First Foods are found. As First Nations are asserting their inherent rights to maintain and practice management such as clam garden tending, it is important to understand the ecological function of these features. The purpose of this study is to quantify the relationship between habitat complexity, abiotic factors, and food availability. The study was conducted in the territories of the Hul'qumi'num and W̱SÁNEĆ First Nations Treaty groups, in the Southern Gulf Islands of British Columbia. Transect surveys determined invertebrate species, habitat complexity, temperature, and water flow. First Foods species were community derived. Species biomass will be calculated using length weight regressions for each species. Habitat complexity was measured using a chain and a profile gauge. Temperature was continuously monitored using loggers. Water flow was measured using clod cards. Data will be analyzed using a General Linear Mixed Model to understand the influence of

environmental factors on biomass. This study will highlight the role of First Nations management practices in supporting diverse marine food systems.

Coles* - Bull Trout *Salvelinus confluentus* can detect conspecific pheromones in a two choice Y-maze

*Hannah Coles, Allan T. Scholz, Paul Spruell, and Mark Paluch, Eastern Washington University; Raymond Ostlie and Jason Connor, Kalispel Tribe of Indians

Two stocks of Bull Trout *Salvelinus confluentus* were tested in a two choice Y-maze to determine if they could detect pheromones from the same natal population (population specific pheromones PSP) or from a different (conspecific) population of Bull Trout (CSP). Fish from the Pack River (PR), Idaho and the Metolius River (MR), Oregon were transferred to a fish hatchery where Y-maze studies were conducted. The Y-maze was constructed to supply well water at 12°C (blank) to both arms with the temperature and discharge of each arm matched to within 0.1°C and 0.01 l/s. One arm was randomly selected to be supplied with pheromones from fish held in stock tanks. Four types of tests were conducted with each stock: 1) blank supplied to both arms; 2) PSP + blank in one arm; 3) CSP + blank in one arm; 4) PSP + blank in one arm and CSP + blank in the other. Chi Square (χ^2) Goodness of Fit tests with two degrees of freedom were used to compare the frequency at which fish entered each arm to the theoretical distribution that assumed they randomly selected an arm. Both stocks exhibited no preference when blank water only was present [PR: (χ^2=4.79; p=0.091; n=28); MR: (χ^2=4.67; p=.097; n=27)]. Both stocks preferred the PSP arm over the blank arm during PSP tests [PR: (χ^2=14.00; p<0.001; n=27); MR: (χ^2=21.94; p<0.001; n=28)]. Both stocks preferred the CSP arm over the blank arm during CSP tests [PR: (χ^2=15.07; p<0.001; n=26); MR: (χ^2=16.72; p<0.001; n=31)]. During the PSP vs. CSP tests, both PR and MR spent equivalent frequency in PSP and CSP arms therefore exhibited no preference [PR: (χ^2=2.96; p=0.227; n=29); MR: (χ^2=4.90; p=0.086; n=31)]. These results showed Bull Trout could detect pheromones from other Bull Trout but could not differentiate between PSPs and CSPs.

Goheen* - Competition driven semelparity of Brook Stickleback *Culaea inconstans* in Turnbull National Wildlife Refuge

*Sasha Goheen, Eastern Washington University

The evolution of a semelparious reproductive strategy is usually contributed to extreme predation which allows a species only one reproductive opportunity. Competition driven semelparity (CDS) is a single reproductive cycle before death that is driven by competition between parents and offspring. In metabolic theory, the somatic maintenance rate increases faster with animal body size than the rate of food intake and the critical resource density where ingested energy to cover maintenance requirements increase with body size, suggesting that smaller-bodied juveniles may competitively exclude their larger-bodied parents. Brook Stickleback *Culaea inconstans* are small fish (about 5 cm long at maturity) considered to be an annual species that have invaded the historically

fishless waters of Turnbull National Wildlife Refuge (TNWR) in Spokane County, Washington. There is a strong diet overlap between Brook Stickleback juveniles and adults which may result in non-overlapping generations due to CDS since there are no local piscivorous predators in TNWR. The objective of this study was to gather evidence to determine if CDS is occurring in the Brook Stickleback populations at TNWR by examining relative densities of adults to juveniles and cohort growth over a season. Fish were captured using baited minnow traps in two ponds at TNWR, three times a month for three months, and measured for length immediately after capture. No clear evidence of mortality of the largest fish was observed, as predicted by a CDS model. Though a pulse of juveniles was observed in early spring as expected, data was inconclusive, likely due to early spring juveniles reaching similar lengths as adults very quickly and possible low levels of continual reproduction throughout the summer.

Mavros - Multi-objective urban stream habitat monitoring

Bill Mavros, 48 North Solutions; T. Dalziel, City of Sammamish; L. Werre, City of Sammamish; C. Fisher, 48 North Solutions

Recent low numbers of kokanee spawners have raised fears of extinction in the Lake Sammamish basin. With the potential for environmental degradation due to urbanization in tributaries to Lake Sammamish, there is an increased awareness to monitor and assess the long-term conditions of Ebright Creek, one of the most productive kokanee streams in the basin. Successful monitoring and assessment of biological and stream habitat quality conditions require effective tools that can be easily understood by both the constituents living in the surrounding communities and by local managers for multi-objective planning. To meet these objectives, a baseline stream habitat and a macroinvertebrate assessment was conducted by the City of Sammamish in summer of 2015, and monitoring was initiated in summer of 2016 as part of long-term monitoring and assessment of environmental conditions of the stream. Ecological indicators, including both biotic and abiotic components, were integrated into the study design to better understand the relationship between the physical habitat and biotic metrics to characterize the stream's health and to evaluate whether the stream habitat and/or the biotic community in Ebright Creek are being degraded by increased urban development or by natural disturbance processes. Physical habitat metrics such as channel dimensions, pool frequency, large wood counts, sediment characteristics and hydrologic conditions were collected in nine survey reaches to characterize the stream habitat integrity. A macroinvertebrate assessment was conducted to monitor aquatic invertebrate biological community trends and richness at four index sites. Overall, the preliminary habitat monitoring results of this study have indicated that the combination of abiotic and biotic indicators shows promise as an effective tool that can reliably detect change in status or stream conditions. These indicators can then also be easily presented to the constituents living in the surrounding communities and to local managers. Preliminary results observed in the biotic metrics corroborate with the physical habitat metrics trends and may be indicative of chronic and acute stream habitat alterations caused by landslides and/or by urbanization.

McArthur - UAVs – An efficient way to monitor restoration

Kerrie McArthur and Phil Bloch, Confluence Environmental Company

Rapid improvements in small unmanned aerial vehicles (UAVs) and image processing software have made aerial mapping of restoration sites feasible. UAVs are viable tool for comprehensively collecting information in restoration sites to characterize both ground elevations as digital surface models and vegetation height throughout a survey area. UAVs collect overlapping low elevation photos that can be combined into a single map using software. The maps can then be analyzed to characterize habitats. This process has facilitated mapping of eelgrass and other intertidal resources, riparian structure, and vegetation type and height. Aerial orthomosaics generated can be analyzed using supervised and unsupervised classification techniques to map habitat types, such as forested, emergent, shrubland, open water. Canopy heights can also be generated and provide be a useful metric for characterizing ecological structure or habitat functions. Repeat UAV flights rapidly documents changes over time.

By capturing information about the entire survey area, UAV based mapping overcomes limitations associated with line intersect and quadrat-based sampling methods. Further, the aerial perspective may allow for the identification and interpretation of patterns of vegetation change or response to disease, anthropogenic or natural features that are not easily identified from the ground. UAVs provide a lower elevation platform for capturing imagery than traditional plane-based platforms, and allows surveys to target elevations appropriate for surveys. However, these benefits come with tradeoffs such as the limited endurance of UAVs, and regulatory maximum flight elevation.

Weather, light, tidal elevation, UAV flight elevation and time of year all influence the observations made with UAVs. Inter-annual monitoring will also demonstrate the potential utility of UAV based mapping to track changes in shoreform or vegetation over time.

Taylor* - Evaluating the efficacy of non-lethal ageing in a lacustrine Brook Trout population

*Timothy Taylor and Barry C. Moore, Washington State University; Benjamin K. Cross, U.S. Fish and Wildlife Service

Fisheries management requires a firm understanding of population structure and dynamics, for which age composition data are central. For Brook Trout, age estimates using otoliths are generally considered most accurate but collecting them requires fish to be sacrificed. Routine lethal sampling on small, conservation, or threatened populations may be unsustainable. Therefore, it is important to determine if alternative, non-lethal structures can provide accurate age data. We evaluated non-lethal structures (scales and pectoral fin rays) in conjunction with otoliths collected from a lentic Brook Trout population. Three independent readers with different levels of ageing experience estimated fish ages. We used age bias plots, percent agreement, and coefficient of variation to determine how scale or fin ray age estimates compared to otolith estimates. Prior experience with ageing specific structure types was the primary variable affecting correlation with otolith-determined age. In general, fin rays and scales did not

consistently reflect otolith age. Average between-structure percent agreement (within one year) was 80–82% for both scales and fin rays. Individual percent agreement within one year was highest for the most experienced reader (92% and 86% for fin rays and scales, respectively). Between-reader age estimates agreed more if readers had similar experience ageing specific structures. Average between-reader percent agreement was 90% for scales and 78% for fin rays. Coefficient of variation for all comparisons was > 15%. Our study suggests that otolith data remains the preferred option, but use of non-lethal methods may be employed in cases where impacts from population assessment collections would be unacceptable. In such cases, we suggest using experienced age structure readers to obtain more accurate estimates.

Temple - Yakima Steelhead VSP Project: resident/anadromous *O. mykiss* studies

Gabriel Temple, Washington Department of Fish and Wildlife; Chris Frederiksen, Yakama Nation and Zack Mays, Yakama Nation; Ryan Fifield and Todd Seamons, Washington Department of Fish and Wildlife

Rainbow Trout/steelhead *Oncorhynchus mykiss* exhibit the most complex life history diversity of any of the Pacific salmonids. The complexity of their life history expression complicates effective management and in fact, our general understanding of the species. The anadromous form known as steelhead, are of low abundance in the Yakima Basin where they are listed as a threatened species under the Endangered Species Act, thus mandating implementation of formal recovery actions. However, the resident form known as Rainbow Trout exhibit a robust population in the Yakima Basin and provide a popular "Blue Ribbon" trout fishery. Interestingly, both resident and anadromous life history forms are known to interbreed in the Yakima and either ecotype may produce offspring of the opposite type, even when the life histories are isolated from one another. A complex suite of genetic and environmental factors are thought to influence life history expression in our basin and this is important because recovery actions intended to benefit the anadromous form as mandated under the ESA may have unanticipated results on the expression of life history pathways. We designed a sophisticated monitoring program intended to monitor the status and trend of both life history types in order to facilitate recovery actions intended to benefit the anadromous life history form.

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