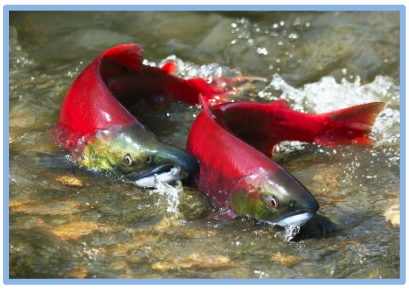

WASHINGTON -BRITISH COLUMBIA CHAPTER

# 40 YEARS OF FISH AND FISHERIES IN THE PACIFIC NORTHWEST

## 2018 ANNUAL GENERAL MEETING

**WASHINGTON-BRITISH COLUMBIA CHAPTER**
**OF THE**
**AMERICAN FISHERIES SOCIETY**

**Kelowna, BC**
**March 19 – 22, 2018**

## Oral and Poster Presentation Abstracts

# Abstracts alphabetized by presenter within each symposium
*Student Presenter

## *Symposium: Hatchery reform, progress and innovation*

**Chair: Todd Pearsons (Grant County Public Utility District)**
Date: Tuesday, March 20, 1:20 PM to 5:00 PM
Location: Vineyard 3

Hatchery reform recommendations of salmon and steelhead hatcheries in Washington and the Columbia Basin were made by the Hatchery Scientific Review Group some time ago. The intent of those recommendations was to align hatchery practices with hatchery goals. Although it is premature to evaluate the biological performances of some of the reform recommendations, the progress towards implementation of the recommendations can be evaluated. This symposium will emphasize progress towards achieving hatchery reform, and more specifically, targets of an index of domestication selection (i.e., Proportionate Natural Influence) and stray rates. Furthermore, additional concepts and refinements of hatchery reform and unconventional uses of hatcheries will also be explored. The talks in this symposium will provide examples of: 1) how reform recommendations are being implemented, 2) how well hatcheries are achieving recommendations, 3) if available, how reforms have changed biological performance, and 4) alternative concepts for hatchery reform and innovation.

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**The HSRG and hatchery reform in the Pacific Northwest**
Andy Appleby, Hatchery Scientific Review Group

Can salmonid hatcheries continue to operate in the face of the Endangered Species Act? This question is at the origin of the Hatchery Scientific Review Group (HSRG). The Hatchery Reform Project is a systematic, science-driven review of hatchery programs to achieve two goals: help conserve naturally spawning populations; support sustainable fisheries. A brief history of the HSRG is provided. In addition, a review of the basic HSRG framework (identifying population goals, population designations, population status); purposes of a hatchery program (conservation, harvest or both and types of hatchery programs, (integrated, segregated) are presented. Key elements of the HSRG recommendations for hatchery broodstock management as well as updates and refinements on selected elements are discussed.

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**Integration of hatchery and harvest to achieve population objectives using hatchery reform principles for summer/fall Chinook in the Okanogan**

Casey Baldwin, Colville Confederated Tribes

The Chief Joseph Hatchery (CJH) is the fourth hatchery obligated under the Grand Coulee Dam/Dry Falls project. Leavenworth, Entiat, and Winthrop National Fish Hatcheries were built and operated as mitigation for salmon blockage at Grand Coulee Dam since the 1940's, but the fourth hatchery was not built and the obligation was nearly forgotten. Planning of the hatchery began in 2001, and it received its first broodstock in 2013. The CJH design, operation and monitoring are structured under integrated recommendations from the Congressional Hatchery Reform Project and the Hatchery Science Review Group since planning and design began. Integration with the other H's (particularly harvest) was key in planning and implementation of the program. Selective removal of hatchery fish and the release of most natural origin fish in terminal fisheries are considered critical to the long-term viability of the population. A purse seining operation collects local-origin brood and removes hatchery fish to help achieve population objectives for PNI and pHOS. CJH harvest and brood collection efforts to affect pHOS and PNI began several years before the facility was finished and greatly improved the population status for these metrics before the first adult returns came back in 2017. This presentation will focus on the status of the natural-origin summer/fall Chinook population in the Okanogan, the results of selective harvest actions and adult management facilities on pHOS and PNI and the performance of the first adult hatchery origin returns in 2017.

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**Hatchery reform in Yakama Territories**

Bill Bosch, Dave Fast, Bill Sharp, Chris Frederiksen, and Todd Newsome; Yakama Nation Fisheries

In 2005, the Hatchery Scientific Review Group (HSRG) recommended a set of principles to guide hatchery management. This talk will focus on implementation of those principles, especially those relating to scientific defensibility, in several Yakama Nation programs. In the late 1980s and early 1990s, the Yakama Nation, Washington State Dept. of Fish and Wildlife, and several consultants (some of whom later became part of the HSRG) designed an integrated spring Chinook program at the Cle Elum Supplementation and Research Facility (CESRF) on the upper Yakima River. The program used virtually all of the scientific principles later documented by the HSRG (2005). Overall results for the CESRF program will be summarized highlighting results for proportionate natural influence (as discussed by the HSRG 2011) and differences observed between the integrated program at CESRF and a segregated program established in 2002 for research purposes. We will also discuss hatchery reform planning and status for spring Chinook, fall Chinook, and Coho programs in the Klickitat River and the long-term evolution of a Coho reintroduction program in the Yakima River Basin. While implementation of hatchery reform takes a lot of time and is quite expensive, if policy makers and the public are willing to make the necessary investments, our findings to date illustrate that many of the benefits of hatchery reform as discussed by the HSRG can indeed be realized.

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**Trade-offs in multi-objective hatchery mitigation programs: You can have your fish and eat them too (but not as many as you may want)**
Peter Graf, Grant County Public Utility District

Many salmon hatcheries in the Pacific Northwest serve multiple purposes and have multiple goals. A single hatchery may contribute to conservation, to harvest, to conservation and harvest, and to meet the mitigation requirements of hydroelectric dams. A primary focus of the Hatchery Scientific Review Group (HSRG) was to address the compatibility of these multiple objectives and to recommend solutions to achieve defensible and balanced outcomes. In many instances, the HSRG recommendations resulted in a benefit to both natural production and harvest. As we continue to implement and improve hatchery programs opportunities for these 'win-win' solutions have become more scarce and choices involving trade-offs must be made. Trade-offs in hatchery management can occur at multiple levels; at the policy-level (e.g., resource allocation between the four Hs), the basin-level (e.g., program location, program size), and at the program-level (e.g., broodstock origin, smolt size). We introduce an economic model, the production possibility frontier, as a method to illustrate trade-offs and to identify complementary opportunities. By acknowledging trade-offs, and framing management decisions as choices with gains and losses, we can better evaluate outcomes and plan comprehensively for each of our collective goals.

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**Implementing hatchery reform in the state of Idaho**
Paul Kline, Idaho Department of Fish and Game

There is an established weight of evidence in the literature describing potential risks that hatcheries and hatchery-produced fish pose to natural populations of salmon and steelhead. Primary risks include competition for resources between conspecifics as well as potential reductions in the fitness of natural populations due to intraspecific genetic hybridization. Nevertheless, anadromous fish hatcheries have been part of the western landscape for over a century and continue to play an important role in addressing mitigation objectives established by a variety of legal actions and agreements. In the Columbia River drainage alone, over 200 hatchery facilities produce over 150 million juvenile salmon and steelhead annually. Approximately 15% of this production occurs within the state of Idaho. Operating anadromous fish hatcheries within a framework that emphasizes hatchery reform is becoming standard operating procedure in the west. A number of regional efforts have improved the collective understanding of the potential risks hatcheries pose to natural populations. Recent work by the congressionally mandated Columbia River Hatchery Scientific Review Group provided specific "solutions" for operating hatcheries consistent with harvest and conservation goals. In this presentation, I describe efforts underway in the state of Idaho to operate hatcheries consistent with these principles.

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**Trade-offs in genetic and ecological risk and enhancement benefits in a steelhead conservation program**

Gregory Mackey, Douglas County Public Utility District; Tom Kahler, Douglas County Public Utility District; Michael Humling, US Fish & Wildlife Service; and Charlie Snow, Washington Department of Fish and Wildlife

The Twisp River is tributary to the Methow River, a major tributary of the Columbia River in Washington, USA, supporting an Endangered Species Act (ESA)-listed (threatened) population of steelhead. The Twisp steelhead hatchery program, with a fixed release goal of 48,000 smolts, is intended to increase the natural population while maintaining genetic integrity. For the last eight years, the population has been managed for an escapement comprising 50% hatchery origin spawners (pHOS = 0.50). In 2018, ESA permit conditions reduced pHOS to 0.25. The hatchery program typically returns surplus adults that are removed at a weir to maintain the pHOS target, and the reduced pHOS target will increase removal rates. The program uses wild broodstock, raising the specter that removing wild fish from nature to use as broodstock, and then removing their progeny as returning adults, could result in mining the wild population to support the program. In addition, analysis of data from an ongoing relative reproductive success study revealed an emerging Ryman-Laikre effect where a small number of individuals contribute disproportionately to the natural population. This effect predictably results from a relatively small hatchery program (few parents) with high variance of reproductive success. Management constraints limit options for countering the Ryman-Laikre effect without increasing mining or sacrificing existing local adaptation. Twisp program stakeholders considered multiple options before selecting a management alternative that increases genetic diversity, increases the number of Twisp natural-origin spawners by reducing removal of Twisp natural-origin returns for broodstock, and diversifies the age composition of hatchery returns. Nevertheless, the selected alternative represents a compromise, with risks to existing local adaptation, and the remaining potential for mining of wild spawners. We discuss trade-offs in managing conservation programs for multiple objectives, evaluating consequences of various options considered for increasing genetic diversity while maintaining local adaptation and avoiding mining.

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**Hatchery reform in Washington State**

Brian Missildine, Washington Department of Fish and Wildlife

Washington State has probably the largest hatchery systems in the world with over 60 salmon and steelhead hatcheries producing approximately 138 million fish in 2017. Along with one of the largest hatchery systems comes the responsibility of minimizing impacts to wild fish populations. Washington Department of Fish and Wildlife (WDFW) in conjunction with the Hatchery Scientific Review Group (HSRG) has worked to minimize those impacts through policy and on the ground changes within our hatchery system. We have reduced impacts by retooling our hatcheries to meet HSRG guidelines, whether through reducing programs, constructing weirs to minimize hatchery fish on the spawning grounds, or discontinuing programs altogether. The WDFW commission has set forth policy for our hatchery systems to meet HSRG standards by 2015. This presentation will show what we have done and where we are at meeting the WDFW Commission policy.

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**Teaming to achieve hatchery reform in a Columbia River hatchery**
Todd N. Pearsons, Grant County Public Utility District; Alf H. Haukenes, Washington Department of Fish and Wildlife; Paul Hoffarth, Washington Department of Fish and Wildlife; and Steven Richards, Washington Department of Fish and Wildlife

Recent reviews of salmon and steelhead hatchery operations have led to recommendations to reform hatchery practices intended to produce a better balance of supplementation outcomes. Of particular concern was a reduction in performance of the supplemented population due to domestication selection. One of the key recommendations was to achieve an index of domestication selection termed Proportionate Natural Influence (PNI) of 0.67 or higher. The Priest Rapids Hatchery located adjacent to the Columbia River below Priest Rapids Dam was one of the hatcheries that was included in a review. We describe efforts that have been implemented to increase PNI of the Priest Rapids Hatchery program by reducing hatchery origin fish on the spawning grounds and increasing the proportion of the hatchery broodstock that is of natural origin. Prior to hatchery reform efforts PNI was estimated below the established benchmark and recently it has been above 0.67. This success was largely the result of generating creative solutions and building partnerships that could achieve goals of hatchery reform in a cost-effective manner.

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**Tradeoffs associated with implementation of hatchery reform recommendations for the Wenatchee summer steelhead program**
Catherine C. Willard, Chelan County Public Utility District

Chelan County Public Utility District (CCPUD) implements hatchery compensation programs as part of its Rock Island and Rocky Reach Hydroelectric Projects' Habitat Conservation Plans (HCPs) to achieve no net impact on plan species. Since 2009, the HCPs Hatchery Committees have been implementing Hatchery Scientific Review Group recommendations for the Wenatchee summer steelhead conservation (segregated) and safety-net (integrated) hatchery program. Significant changes to the hatchery program have included overwinter acclimation, locally collected broodstock, and PHOS management. Implementation of these recommendations has been successful as they relate to fulfilling the specific HSRG actions; however, hatchery managers are now presented with acknowledging unintended outcomes and trade-offs as a result of these modifications. The next phase of hatchery reform for the Wenatchee summer steelhead hatchery program should be for the hatchery committee members to focus on prioritization of these outcomes to support recovery of this ESA-listed species.

## *Symposium: River connectivity: technical, cultural and biological aspects of fish passage and reintroduction*

**Chair: Andy Peters (Pacific Netting Products)**
Date: Tuesday, March 20, 1:20 PM to 4:00 PM
Location: Vineyard 4

Fish passage and river connectivity barriers could be considered to be anything that hinders any life stage of fish and other aquatic organisms, energy and inert matter from moving through a waterway. Physical barriers include dams and deteriorating culverts. Environmental and biological barriers include water velocity, water temperature, quality, an increase in number of predators and deterioration of upstream habitat. Cultural barriers are comprised of the attitudes, customs and practices of people and industry. Technical barriers involve a lack of supporting or facilitating technologies, materials, engineering and know-how to address or implement solutions.

Restoring connectivity will increase habitat diversity, population resilience and restore important cultural and societal customs. While most barriers have the same general impact on fish—blocking migrations, the interactions of these barriers are complex and interdependent. Restoration of connectivity of freshwater habitats throughout the historic range of anadromous fish requires a coordinated approach.

In this symposium speakers will discuss various barriers and/or the methodologies to overcome them. Speakers will include those from industry, community, designers and developers of the passage systems, biologists and engineers responsible for designing and conducting evaluation study plans, researchers responsible for evaluating performance and project owners/operators. Presentations will include case-studies and lessons learned from other river connectivity projects.

This symposium will help attendees understand the complex and interdependent nature of fish passage and river connectivity barriers and how site specific, coordinated approaches can restore connectivity.

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**Life cycle modeling of reintroduction scenarios for summer/fall Chinook upstream of Chief Joseph and Grand Coulee dams**
Casey Baldwin, Colville Confederated Tribes

The Colville Tribes worked with the Upper Columbia United Tribes, First Nations in Canada, and several state and federal agencies and private contractors on Phase 1 planning for anadromous fish reintroductions upstream of Chief Joseph and Grand Coulee Dams. This work focused on many aspects of pre-assessment planning including habitat assessments, donor stock and risk assessments and life cycle modeling. Life cycle modeling is a critical component of evaluating potential reintroduction strategies and the potential performance of reintroduced stocks in each area and with various assumptions regarding fish survival through reservoir reaches and dams. Although final results are not yet available, the presentation will share model runs and sensitivity analyses for a reintroduction strategy of releasing 1,000 hatchery-origin adults upstream of Chief Joseph

Dam. Other scenarios for summer/fall Chinook Salmon and Sockeye Salmon reintroduction upstream of Grand Coulee Dam will be discussed. Once finalized, model scenarios for fish performance will be included in a Phase 1 report and contribute to defining the critical uncertainties and research questions for implementation in Phase 2 of the reintroduction.

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**Response of juvenile Chinook Salmon, steelhead, and other salmonids to wood placement in interior Columbia Basin streams**

Christopher Clark, Cramer Fish Sciences; Phil Roni, Cramer Fish Sciences; Andrew Muller, Cramer Fish Sciences; Shelby Burgess, Cramer Fish Sciences; and David Kaplowe, Bonneville Power Administration

Placement of large woody debris is one of the most common stream restoration techniques in the Columbia Basin and Pacific Northwest. While considerable information exists on response of Coho Salmon *Oncorhynchus kisutch* and steelhead *O. mykiss* in coastal watersheds, little information exists for streams in the interior Columbia River Basin inhabited by Chinook Salmon *O. tshawytscha* or steelhead. As part of Bonneville Power Administrations (BPA) Action Effectiveness Monitoring Program (AEM), we used an extensive post-treatment design (EPT) to sample 29 interior Columbia Basin large woody debris (LWD) placement projects to determine their physical and biological effectiveness. We sampled paired treatment and control reaches that were approximately 20 times bankfull width at each site and quantified fish abundance and habitat attributes (e.g., percent pool, LWD, gradient) during summer. The percent pool area, total number of pools, LWD, and pool forming LWD were significantly higher in treatment than paired control reaches. Juvenile Chinook Salmon, steelhead, Coho Salmon, and Cutthroat Trout *O. clarki* abundances were significantly higher in treatment than control reaches, but no significant response was detected for Mountain Whitefish *Prosopium williamsoni* or dace *Rhinichthys* spp. The response of Chinook Salmon and Coho Salmon was positively correlated with increase in LWD and pool area. Our results indicate that wood placement projects in the Upper Columbia are resulting in reach-scale increases in juvenile salmonid abundance and that the most successful projects are those with the most intensive wood placement.

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**Flexible, adaptable upstream passage for reintroduction**

Steve Dearden, Whooshh Innovations

In efforts to re-establish populations of migratory fish in areas previously blocked by man-made barriers, upstream migration of adults needs to be facilitated past those barriers. Passage solutions need to meet the standards of being safe, timely, efficient and effective. While traditional upstream adult passage solutions may meet these agency standards, the upfront planning and implementation costs associated with these solutions severely impacts the timing and financial viability of these reintroduction programs. In an environment of increasing pressures on fish populations caused by climate change and habitat degradation, solutions that are cheaper and quicker to deploy are needed. In this talk we describe a pilot adult volitional passage system that took less than 3 months to install in 2017 at a high head dam in Washington, and the results from that system. This

pilot was made possible by collaboration of private industry, tribal interests and the federal government. We will look at the technology used and additional testing that has been performed to make sure that the solution meets the acceptable passage standards. The impact of this study on other passage and reintroduction programs being contemplated in the Columbia basin will also be discussed. Biologists, engineers, and tribal members may be able to use this project as an example to accelerate other passage implementations with industry and government participation.

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**Using a major highway construction project to improve both transportation and stream connectivity – The I-90 case study**

Paul W. James, Department of Biological Sciences, Central Washington University

The Interstate-90 Snoqualmie Pass East Project in Washington State is a major highway renovation project that is designed to improve road safety over a mountain pass as well as enhance ecological connectivity. The highway design includes the construction of multiple wildlife crossing structures, the majority of which are new bridges that replace culverts at stream crossings in the upper Yakima River basin. Westslope Cutthroat Trout *Oncorhynchus clarki lewisi* occur in most of the streams that cross the highway in the project area, but little is known about their populations or movements within and between streams. Our objectives were to determine the distribution and abundance of Cutthroat Trout in the affected streams before and after the removal of fish passage barriers and installation of stream habitat structures. Fish were monitored using PIT tags before and after construction to monitor growth and movements during recapture events over several years.

The results thus far have shown that new stream crossing structures are being used by Cutthroat Trout soon after completion and some individuals in one stream had moved upstream above a previously impassable barrier following its removal and channel reconstruction. Bull Trout *Salvelinus confluentus* were known to occur in only one stream, but we found juvenile/sub-adult individuals in four other streams over multiple years suggesting that some individuals are attempting to disperse into other streams. The pre-construction efforts to gather baseline information proved to be essential in evaluating post-construction success in terms of immediate effects on specific populations and long-term effects on aquatic connectivity within the upper watershed.

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**Recent developments in temperature and algae control**

Andrew Peters, Pacific Netting Products

Iron Gate Reservoir, formed by Iron Gate Dam, is the downstream-most hydroelectric reservoir on the mainstem of the Klamath River. The reservoir is subject to blooms of the cyanobacteria *Microcystis aeruginosa* which produce the toxin microcystin.

To address this issue an impermeable intake barrier curtain was installed in the reservoir. The curtain resulted in the withdrawal of deeper waters from Iron Gate Reservoir. By segregating reservoir surface waters with higher blue-green algae concentrations, monitoring indicated reductions in microcystin, *Microcystis aeruginosa*, *Aphanizomenon*

*flos-aquae*, and chlorophyll-a and reduction in water temperatures, causing downstream of the dam conditions to be similar to those in the deeper waters upstream of the curtain.

This presentation will review the curtain design, materials, engineering, operations and maintenance considerations, lessons learned and study findings.

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**PIT tag technology: a flexible tool for fish passage and reintroduction projects**
Phil Peterson, West Fork Environmental

Passive integrated transponder (PIT) tag technology has been around the fisheries research and monitoring world now for several decades. Its use has expanded into virtually every area of fisheries science especially fish passage and species reintroduction projects. In part this is because of the fine scale data that individual tag data can provide but just as importantly is the fact that the antenna technology is highly adaptable to so many engineered and natural settings. Specific project examples are provided that explore this structural adaptability of PIT tag antenna arrays to both natural and engineered situations for monitoring fish passage and species reintroduction.

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**Anadromous fish reintroduction in the Upper Columbia River Basin - An overview**
Stephen Smith, Upper Columbia United Tribes

Habitat supporting annual production of millions of adult salmon and steelhead in the Columbia Basin was lost when, first Grand Coulee and then multiple dams were constructed on the upper Columbia River and its tributaries. At the time of dam construction, fish passage was deemed infeasible at high head dams. However, with recent improvements in fish survival at lower, run-of-river dams and new adult and juvenile fish passage technologies applicable to high head dams, anadromous fish reintroductions may now be viable.

Native American tribes and Canadian First Nations are spearheading an effort to assess the viability of reintroductions; their joint paper on a comprehensive reintroduction outlines a concept for restoring anadromous fish populations above six projects in the U.S. and Canada. In its Columbia River Basin Fish and Wildlife Program, the Northwest Power and Conservation Council has included a phased approach to investigating and implementing fish passage at the two U.S. projects, Chief Joseph and Grand Coulee dams. The six-dam, comprehensive reintroduction is an issue being considered in modernization of the Columbia River Treaty between the U.S. and Canada.

An overview is provided of the tribes' anadromous fish reintroduction concept, Phase 1 reconnaissance work currently underway in the U.S., and steps leading to potential field investigations with interim fish passage facilities (Phase 2).

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**The importance of salmon to the Syilx – past, present, future**
Michael Zimmer, Okanagan Nation Alliance

Salmon are integral to the Syilx People. Chief Salmon represents one of the four first foods. The loss of salmon to diet and culture are immeasurable and continue today. There are opportunities to recover and restore salmon stocks, and the Okanagan River sockeye story is a great example. Conservation enhancement, habitat improvements and flow management all play an important role in the Okanagan River sockeye recovery – to a point where there are environmental, cultural, and socio-economic benefits. Salmon ceremony and celebration continues in their absence from the mainstem Columbia. Annual ritual is one of many efforts expended to bring about their ultimate return. Scientific methods, in the form of habitat modelling, donor stock screening, disease risk profiling, adult and juvenile passage and experimental release tactics, are currently being employed to work towards rebuilding anadromous salmon stocks to revitalize culture and environmental function through the remaining blocked sections of the Columbia in Canada.

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**Use of adult Pacific Lamprey passage structures at Bonneville Dam**
Nathan Zorick, Karrie Gibbons, and Kristen N. Bayley; U.S. Army Corps of Engineers

To improve adult Pacific Lamprey *Entosphenus tridentatus* passage upstream at Bonneville Dam, we operated five structures designed specifically to help them avoid dead ends or bypass bottlenecks in the traditional salmonid fish ladder. When LPS counts are included with daytime window counts, this was the largest lamprey run since counting resumed at Bonneville Dam in 1997. LPS entrance ramps are located in: the Bradford Island fish ladder's auxiliary water supply (BI-AWS), the Washington shore fish ladder's auxiliary water supply (WA-AWS) both dead ends, the Washington shore fish ladder's junction with the Upstream Migrant Tunnel (WA-UMTJ), and the Cascades Island fishway entrance (CI-ENT) which allows volitional passage to the forebay. Finally, the lamprey flume structure (LFS) is attached to the Washington shore fish ladder's north downstream entrance and has two entrances outside the fishway. The total corrected LPS passage estimate at Bonneville Dam during the 2017 monitoring season (April – October) was 122,457. This is a 115% increase in LPS use from 2016 (56,846) which is unsurprising given the increase in daytime window counts. Lamprey favored the WA-AWS 74%, the BI-AWS 24%, and then the CI-ENT, which is a single ramp at the fishway entrance, used by 2%. Due to mechanical over-counting, passage was validated using video, and a correction factor was calculated. The average correction factor was 0.72 WA-UMTJ, 1.85 WA-AWS, 0.32 BI-AWS, and 0.81 CI-ENT. Managers depend on timely, accurate counts at Bonneville Dam as an indication of the health of the Columbia Basin's lamprey population. The automated counting mechanisms use on the LPSs offer low cost, around the clock monitoring of passage, but are imperfect. To increase count accuracy we suggest trials of innovative counters such as proximity or photoelectric counters placed in line with the current paddle counters for comparison.

## *Symposium: Methods for communicating results, probability, risk, and uncertainty to managers and the general public*

**Chair: Ann-Marie Huang (Fisheries and Oceans Canada)**

Date: Wednesday, March 21st, 10:20 AM to 12:00 PM
Location: Vineyard 3

The general public does not think of probability in the same way as people with a technical background. If they did, casinos would not be so plentiful. This symposium will be a venue for people to share methods used for communicating results to people making decisions and/or feeding into the decision-making process – both methods that worked (and why) and that didn't work (and why). Methods can include, but are not limited to: choice of language, figures, and/or meeting process.

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**Communicating results with sport salmon head recovery letters**
Erika Anderson, Nicholas Komick, and Erik Grundmann; Fisheries and Oceans Canada

In Canada, the Coded Wire Tag Program depends upon the fisher-provided contributions of salmon heads by sport anglers from adipose-fin-clipped Chinook and Coho. Last year, 11 646 salmon heads were contributed to Fisheries and Oceans Canada as part of the Sport Head Recovery Program. Of these recoveries, approximately 72% of Chinook and 84% of Coho had no tag, primarily due to mass marking. Mass marking is the clipping of adipose fins from hatchery fish. This has adversely impacted angler participation and satisfaction in the program. The Mark Recovery Program (MRP)—the body responsible for administering the Canadian coded wire tag program—recognizes the importance of public involvement, therefore, letter improvements have been implemented. The underlying Oracle database makes it possible to pull comparable recoveries by date and area to allow more directed information to be communicated to the fisher. The R package, ggmap, improved the spatial display so a google-style map may be embedded in the letter. R markdown allows the code to be written for personalized letters as pdf files to email or mail to the public. Designed and tested on 2017 data, the letters have yet to be released to community participants. Example letters with various optional sections and styles will be shared during the presentation. A look at historic and current pamphlets, charts, and other publicly-communicated data will be compared and contrasted with particular attention to "lessons learned". A similar application of this data-sharing process, will be implemented for the T'aaq-wiihak fisheries on the West Coast of Vancouver Island, allowing our collaborators timely information on the origin of their catch. Your expert input and advice following the presentation would be appreciated.

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**Assessing localized habitat changes: An alternative to Habitat Suitability Index Models**

Greg Courtice, Wood Environment and Infrastructure Solutions

Habitat Suitability Index (HSI) Models have been used extensively to help assess habitat quality in aquatic systems when attempting to maintain or improve ecosystem productivity. Many habitat alterations resulting from development activities are challenging to quantify using HSI Models due to the complex and localized nature of the modifications. This issue can complicate important management decisions related to the necessity and scope of habitat compensation requirements triggered by a project and its contribution to cumulative effects. Wood (formerly Amec Foster Wheeler) has developed an ecohydraulic-based habitat assessment tool to quantify localized habitat changes, facilitating a comparison of pre- and post-modification habitat quality. This tool integrates an objective, ecohydraulic assessment with a subjective, habitat feature assessment, to provide a transparent, robust, and consistent approach to quantify likely changes to habitat quality. Modified habitats can be assessed to estimate a baseline-equivalent habitat value to provide a comparison in the context of baseline habitat quality. The assessment provides a simple, easy to communicate result for the proponent and regulator, while facilitating comprehensive ecosystem considerations “behind the scenes” to provide confidence that a thorough and robust evaluation has been considered. This tool has been successfully implemented for the City of Calgary on several complex, bioengineered bank stabilization projects on the Bow River to determine the likelihood of serious harm to fish and fish habitat.

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**Communicating results to the decision makers. Lessons learned: the good, the bad, and the intractable.**

Ann-Marie Huang, Fisheries and Oceans Canada

As biologists, we are taught how to calculate probabilities, uncertainties, variability, and sometimes even risk and performance measures. What we are taught less stringently is how to communicate these theoretical concepts to people in decision making processes who often do not have a scientific background. Without a solid background on how to interpret these concepts, reaction from the decision process can range from focusing solely on the point estimate to dismissing the entire analysis as being meaningless due to large uncertainty ranges. A sample of successful (and less successful) methods used to communicate and educate the decision process on how to read and interpret model results as well as methods used to extract technical direction from the management process will be presented. Methods discussed will include: plot types, analogies, meeting exercises, and meeting structure. Members of the audience will be invited to contribute their experiences and expertise, particularly on some of the more intractable communication objectives that remain works-in-progress.

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**Theory and practice of risk communication**
Gottfried Pestal, SOLV Consulting Ltd.

Risk is a fundamental consideration in all aspects of fisheries management. The general concept of risk is intuitive, but we face many well-documented pitfalls in our reasoning when confronted with possible alternative outcomes (e.g., risk associated with very scary rare events compared to more common, but still serious, events). Formalized decision analyses attempt to avoid these pitfalls through clear definitions and rigorous methods, but the theoretical concepts are difficult to fully implement in most fisheries settings, and risk assessments at the operational level have to work within the case-specific constraints. Communication of the results needs to bridge the gap between theory and practice, so that the audience has a proper context for the information being presented.

This talk introduces 2 conceptual maps for scoping out presentations of risk-related information (risk concepts, presentation purpose), then illustrates the approach with 4 case studies (loss of hatchery brood in a conservation program, biological benchmarks for Little Tahltan Chinook, Fraser Sockeye run size forecasts, Fraser Sockeye harvest rule simulations).

## *Symposium: Sockeye Salmon in the Pacific Northwest*

**Chair: Jeff Fryer (Columbia River Inter-Tribal Fish Commission)**

Date: Wednesday, March 21, 9:00 AM to 4:00 PM
Location: Vineyard 4

The location of this year's Washington-British Columbia AFS meeting, Kelowna, sits near the divide between two great Sockeye Salmon rivers; the Columbia and the Fraser. Fraser River Sockeye runs prior to the early 1900's were immense; the size of historic Columbia River runs are less well-documented, but were certainly in the millions. Both runs trended steeply downward in the first half of the 20th century due to dams blocking most rearing lakes in the Columbia River and a landslide partially blocking the Fraser River in 1913. More recently, the 20th century, historic abundance with record low runs occurring in the past 20 years but also a near record high in the Fraser of nearly 30 million in 2010 and over 600,000 returning to the Columbia River in 2014, primarily to the Okanagan Basin. These runs are important to fisheries in both basins, thus considerable resources have been expended on managing and seeking to improve these runs. With these runs being at the southern end of their range and high temperatures being associated with large die-offs on the upstream migration in recent years, these stocks are highly vulnerable to climate change. These stocks are also located in areas with rapidly growing human populations and their associated impacts on watersheds. This symposium will focus on impacts on salmon imposed by climate change and human population and what management actions are, or can be, taken to offset these. While this symposium is expected to focus on the Fraser and Columbia rivers, submissions from other basins in the Pacific Northwest are also welcome.

**Passage pilot for Sockeye reintroduction at Cle Elum using the Whooshh Fish Transport System**
Steve Dearden, Whooshh Innovations

Several species of anadromous fish, including Sockeye, were extirpated from the Yakama Basin in the early 1900s following the construction of irrigation dams used to supply the agricultural economy that developed in this area of Washington State. The Yakama Nations, USBR and others have agreed to a multi-year plan to reintroduce anadromy into these blocked areas. Passage solutions will need to be developed for each dam as this program progresses. As part of the initial phase of this plan, the Yakama Nations has been trucking adult sockeye into Cle Elum Lake for several years, and are now close to a point where a self-sustaining population might be possible. Another core component is construction at Cle Elum by the USBR of a downstream "Helix" system to accommodate outmigration of juvenile fish even with the dramatic reservoir level fluctuations. In 2017, Whooshh Innovations, in contemplation of future permanent upstream alternatives, installed a pilot adult fish passage system over Cle Elum Dam. The goal of this pilot was to verify the general applicability of the technology to high head dams in addition to Cle Elum specific issues. Some of the unique challenges associated with this pilot will be discussed, along with some interesting results when compared to other technologies in terms of flexibility, speed of deployment, cost, and most importantly performance and fish health. As an example, this pilot should help decision making on passage alternatives as Sockeye, and other salmonids, are considered for reintroduction programs into other blocked areas.

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**Possible adaptation of Columbia Basin Sockeye to a warming climate**
Jeff Fryer, Columbia River Inter-Tribal Fish Commission; Kim Hyatt, Department of Fisheries and Oceans Canada; Dan Selbie, Department of Fisheries and Oceans Canada; Richard Bussanich, Okanagan Nation Alliance; Skyeler Folks, Okanagan Nation Alliance; and Howie Wright, Okanagan Nation Alliance

2015 was an eye-opener for anyone concerned with the future of Columbia Basin Sockeye Salmon as a low snowpack and high temperatures resulted in unprecedented water temperatures during the stock’s upstream migration. These high temperatures occurred just past the peak of the third largest Columbia Basin Sockeye run on record, resulting in high mortality. Bonneville Dam tagging studies estimated a mortality rate to the spawning grounds of 86.7% for the Wenatchee stock and 97.2% for the Okanogan stock.

Climate models suggest that events such as occurred in 2015 may become the norm in the future. A question of concern to the region is how well Columbia Basin salmon can adapt to climate change. Data from 2015 estimate the highest survival rates were for those Sockeye Salmon which migrated past Bonneville Dam in the first 5% of the run, suggesting that a possible strategy for these fish may be to migrate early to arrive at terminal lakes prior to onset of high temperatures in migratory corridors. The trade-off would be Sockeye holding longer in natal lakes prior to spawning. Sockeye Salmon bound for the Okanagan Basin in Canada may provide insights into a stock that may be adapting to climate change. This stock is reaching the Okanagan River 12 days earlier than in the

late 1970's, possibly due to a warming Columbia River as well as habitat improvements in the Okanagan Basin that may have made an earlier migration more advantageous.

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**Stable isotopic comparison between otoliths of Chum Salmon and Sockeye Salmon**

Yongwen Gao, Makah Fisheries Management

Stable isotopes of otoliths have been used as a powerful tool in fisheries, particularly for the regions lacking of biological observation data. In this paper, we report the results of a blind test on 84 otoliths of Chum Salmon *Oncorhynchus keta* collected from three sites (Area A, B, and C) in northeast China, where all the estuaries for salmon ocean entry are located in Russia or North Korea. Two aragonite powder samples were taken from each otolith: one from the nucleus of otoliths that represents the initial 3-6 month growth; the other from the second summer growth zones. Among the samples analyzed the d13C values of Chum Salmon otoliths ranged from -10.93 to -3.75 ‰ , whereas d18O values of the same samples ranged from -6.39 to +1.93 ‰ . Based on d18O values at about -3.5 ‰ , two different spawning stocks or populations had been identified. As compared with the otoliths of Sockeye Salmon *O. nerka* from the Adams River in British Columbia, Canada, data from Chum Salmon showed similar life history from freshwater to marine but higher d18O values than those of Sockeye Salmon in the freshwater phase. Thus we concluded that the Chum Salmon in northeast China are anadromous and have the same life history as other salmon populations over the world.

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**North Fork Skokomish River Sockeye Salmon Program: Beginnings...**

Tim Hoffnagle, Tacoma Power; Andy Ollenburg, Tacoma Power; Matt Bleich, Tacoma Power; and Keith Underwood, Tacoma Power

Sockeye Salmon *Oncorhynchus nerka* became extinct in the Skokomish Basin, Washington, with construction of the Cushman Hydroelectric Complex in 1926. During relicensing in 2010, Tacoma Power was directed to develop four fisheries programs, including restoring Sockeye Salmon to the North Fork Skokomish River. Saltwater Park Sockeye Hatchery was constructed in 2016, where Sockeye Salmon will be spawned and reared for release into Lake Cushman and/or the North Fork Skokomish River below Cushman No. 2 Dam. A Juvenile Fish Collector (JFC) was constructed on Cushman Dam to capture smolts for transport and release into the North Fork Skokomish River at the base of Cushman Dam No. 2. The JFC has been tested for three years using Coho Salmon *O. kisutch* and has collected ~30% of the smolts released into Lake Cushman. The JFC has also captured large numbers of smolting kokanee (*O. nerka*; Lake Whatcom stock, which had been stocked into Lake Cushman) but were returned to Lake Cushman. Beginning in 2018, all *O. nerka* captured will be transported downstream, so kokanee will be incorporated into the restored Sockeye Salmon population, by default. So far, 252,000 and 509,000 BY 2016 and 2017, respectively, Sockeye Salmon eyed eggs have been imported from Baker River, Washington. Survival has been excellent and growth has been more rapid than expected. BY 2016 parr were released into Lake Cushman in May and September 2017 and smolts will be released this spring. We are developing a suite of rearing and release options to evaluate but want to initially maximize survival to

maturation in order for the program to quickly become self-sufficient. Future strategies will focus on rearing hatchery salmon that mimic natural Sockeye Salmon. These are the first steps toward re-establishing a self-sustaining natural Sockeye Salmon population to support recreational and tribal fisheries in the Skokomish Basin.

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**Productivity responses of Barkley Sound salmon to climate variation and change impacts in the Pacific Ocean**

Kim D. Hyatt, Howard Stiff, Diana Dobson, and Wilf Luedke; Fisheries and Oceans Canada

Salmon populations that make sea entry into the northern California Current upwelling system along the eastern rim of the Pacific exhibit variations in marine survival that co-vary with alternations in cold and warm ocean conditions. The observation that ENSO variations induce periodic oscillations in salmon marine survival in particular has served as the conceptual basis for a highly successful forecasting method (the survival stanza method or SStM) that has been used to predict variations in marine survival and annual returns of Barkley Sound Sockeye Salmon for more than twenty years. Sea-entry years associated with La Nina-like conditions (“cold ocean”) result in above average survival while those associated with El Nino-like conditions (“warm ocean”) result in below average survival. The cause and effect mechanisms behind these survival changes are now reasonably well understood and relate to ecosystem re-organization within the California Current system under warm versus cold ocean conditions. Of particular importance here, the resultant salmon survival variations are so large that total returns of Barkley Sound Sockeye may vary by more than an order of magnitude within intervals as short as 2-3 years. Consequently, First Nations, recreational and especially commercial fisheries have exhibited a decadal-scale, “boom-to-bust” character over most of their recent history. Although models of ENSO behavior under future climate regimes have not yet reached consensus, both empirical evidence and credible model projections suggest that the frequency and magnitude of El Nino-like, warm-ocean events are likely to increase with obvious implications for elevated, management challenges that Barkley Sound salmon fisheries will face within the coming decades.

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**Snake River Sockeye Salmon recovery – Historical perspective and progress towards meeting recovery objectives**

Paul Kline, Idaho Department of Fish and Game; Jesse Trushenski, EVAUA FARMS; Christine Kozfkay, Idaho Department of Fish and Game; Danny Baker, Idaho Department of Fish and Game; and Tom Flagg, National Marine Fisheries Services (Retired)

In November 1991, the U.S. National Marine Fisheries Service listed Snake River Sockeye Salmon *Oncorhynchus nerka* as endangered under the U.S. Endangered Species Act (ESA). The last known remnants of the Snake River stock return to Redfish Lake in the Sawtooth Valley in central Idaho. In the ensuing 25 years since ESA listing, many actions have been taken to conserve the Redfish Lake population and to begin rebuilding numbers of natural spawners in the wild. Guided by a three-phase Master Plan that includes captive broodstock, recolonization and local adaptation phases of effort, initial actions focused on the development of redundant captive broodstock programs at Idaho Department of Fish and Game and National Marine Fisheries Service hatcheries to prevent extinction and

preserve population genetic diversity. With the construction of Springfield Hatchery near American Falls, Idaho in 2013, the program is entering its second phase – the recolonization phase where efforts focus on rapidly rebuilding the number of adults spawning in the wild. Various complications associated with fish transport contributed to reduced smolt survival in out-migration years 2015 and 2016, but post-release success of Springfield Hatchery-reared smolts remained uncharacteristically low following optimization of fish transport protocols. Evaluation of smolts released in 2017 suggested that differences in water chemistry between the hatchery and release site may have contributed to morbidity and mortality observed after release. A variety of modified release strategies have been evaluated, including acclimation to water with an intermediate chemistry profile, water mixing at release, and in-transit water softening. The relative merits and feasibility of these strategies are still being evaluated. A general review of program history as well as results of ongoing experimentation to address post-release smolt survival complications will be discussed.

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**What is causing declines in the annual returns of Fraser River Sockeye Salmon?**

Mike Lapointe, Pacific Salmon Commission; Sue Grant, Fisheries and Oceans Canada; Bronwyn MacDonald, Fisheries and Oceans Canada; and Catherine Michielsens, Pacific Salmon Commission

In the late nineteenth and early twentieth century, the estimated returns of Fraser River Sockeye were large with a repeatable 4-year cycle in abundance. The largest return, in 1909, was estimated to exceed 40 million fish. Substantial landslides occurred in 1913-1914 that partially blocked the passage of the adults migrating upstream to spawn and contributed to much lower returns in subsequent years. The low returns let to decreased catches in commercial fisheries in both Canada and the United States, stimulating the formation of the bilateral IPSFC in 1937 to better understand Fraser River Sockeye populations and to coordinate harvest of the resource. To partially mitigate against the negative impacts of the slides, the IPSFC constructed fishways in a narrow part of the Fraser Canyon known as Hells Gate. The completion of the majority of the fishways in the early 1950's was followed by a prolonged period of favorable productivity. Thus, despite annual exploitation rates exceeding 70% in most years, returns increased to the point where the sum of the total returns in the four year period 1990-1993 was estimated to be the largest quadrennial return in a century. Returns have generally declined from this peak period, despite dramatic declines in fisheries exploitation rates. The most significant causal factor for declines in abundance since 1993 is decreased productivity. Limited data suggest that decreased marine survival and depressed freshwater survival in the egg to juvenile stages have both contributed to the overall declining trend in returns. The impacts of decreased productivity have been exacerbated by increased mortality in adults migrating upstream to spawn as a consequence of increased summer water temperatures in the Fraser River and the unusual upstream migration behavior of some components of the run.

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**Lake Washington Sockeye Salmon program - opportunities and challenges**
Mark LaRiviere, D. J. Warren & Associates

Sockeye Salmon were introduced into Lake Washington system in western Washington. The population became self-sustaining and generated an intense level of harvest interest by treaty Indian Tribes and sport fisherman. Urbanization, human population growth and the built environment challenge the productivity of Sockeye Salmon life history stages in the Cedar River, Bear Creek, Lake Washington and the Seattle Ship Canal. Seattle Public Utilities and regulatory agencies entered into the Landsburg Mitigation Agreement to compensate for the drinking water utility developments on the Cedar River. A hatchery program has been operated since 1991 (interim and now permanent facilities) with the goal of no reduction in fitness for the NOR population. The annual population fluctuations are attributed to variously; egg-to-fry survival, adult pre-spawning survival, in-lake presmolt survival (predation and competition), and water quality. The challenges for all parties include maintaining the population, providing for harvest opportunities and accommodating up to 200,000 spawners in an urbanized river.

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**Genetic monitoring of Sockeye Salmon reintroductions: Informed opportunities and adaptive management**
Andrew Matala, Columbia River Inter-Tribal Fish Commission; Shawn Narum, Columbia River Inter-Tribal Fish Commission; Peter Galbreath, Columbia River Inter-Tribal Fish Commission; Brian Saluskin, Yakama Nation Fisheries; Mark Johnston, Yakama Nation Fisheries; and Jeff Hogle, Confederated Tribes of the Warm Springs Reservation of Oregon

Columbia River Tribes recently initiated efforts to restore natural spawning anadromous Sockeye Salmon to regions of the Columbia River Basin where the indigenous populations were extirpated. In 2009 the Yakama Nation began out-planting adult Sockeye Salmon into Cle Elum Lake in the Yakima River Basin using genetically distinct donor stocks from Wenatchee and Osoyoos lakes in the upper Columbia River. Genetic monitoring has revealed successful reproduction by both stocks, but spatial and temporal differences in spawning behavior have restricted interbreeding, and outplant progeny have thus far remained highly differentiated. In 2016 there were ~3600 naturally produced adult Sockeye Salmon from Cle Elum Lake that returned to the Yakima River. Continued monitoring will evaluate potential reproductive and adaptive differences between 1st generation outplants and their wild counterparts. In 2010 the Warm Springs Tribe in collaboration with ODFW and PGE initiated a program to reestablish anadromous Sockeye Salmon into Lake Billy Chinook (LBC) in the Deschutes River Basin. To guard against out-of-basin disease risks, the effort involves downstream release of juvenile LBC kokanee that exhibit smolt characteristics and volunteer into a trap on a recently constructed water withdrawal structure. To present, genetic structure analyses of the LBC kokanee, which has been heavily influenced by past stocking of fish from out-of-basin hatcheries, are inconclusive regarding whether they retain a remnant of the historical Sockeye Salmon gene pool. Unfortunately, adult return numbers have been low (range 23-98), except for 2016 when 536 returned. Genetic stock identification confirmed that all but 11 fish originated from the LBC population, and 14 were confirmed as having passed Bonneville Dam. These examples will be valuable for informing possible reintroduction strategies for

other subbasins that historically supported Sockeye Salmon, including additional lakes in the Yakima River Basin, and Wallowa Lake in the Grande Ronde River Basin, etc.

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**What can we say after thirty years of PIT-tagging Sockeye Salmon?**
Joshua Murauskas, Four Peaks Environmental; Joseph Miller, Four Peaks Environmental; and Sam Haffey, Four Peaks Environmental

The application of Passive Integrated Transponder (PIT) technology to monitoring and evaluation of Pacific Salmon fundamentally changed research in the Columbia River Basin. Since the first sizable group of 1,934 wild fish in 1987, over one million PIT-tagged Sockeye Salmon have been released at 77 locations from Oregon, USA to British Columbia, Canada. We present an overview of three decades of PIT-tagging data to provide insights on migratory behavior and survival of Sockeye Salmon. An improved understanding of migratory timing, smolt survival, avian predation, adult recruits, and escapement to spawning grounds is critical for water resource and fishery managers to protect this important species.

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**Yakama Nation Sockeye Project**
Brian Paul Saluskin, Yakama Nation Fisheries

The Yakama Nation Sockeye Project (YN) is working to help provide permanent fish passage at the five large storage dams of the Yakima Project by the introduction of sockeye. These dams—Bumping, Kachess, Keechelus, Cle Elum, and Tieton, were never equipped with fish passage facilities. Four of the five reservoirs were originally natural lakes (Rimrock Lake above Tieton Dam is the exception) and historically supported local Tribal fisheries for Sockeye Salmon (*Oncorhynchus nerka*) and other anadromous and resident fish. When fish passage facilities construction is completed at the dams this would allow for better overall success of the YN reintroduction project: the reintroduction of sockeye salmon to the watershed, restoring the life history and genetic diversity of salmom. Fish passage at the storage dams is being constructed for recovery of species listed under the Endangered Species Act (ESA). The YN is able to use the downstream juvenile fish passage (flume on the spillway) to continue to reintroduce sockeye, captured at Priest Rapids Dam and in basin sockeye returnees captured at Roza Dam then transferred to Lake Cle Elum. All fish are monitored as they migrate from the reservoir to spawn, migrate downstream as juveniles, and return as adults. The interim passage allows the YN to monitor exiting juveniles at Roza Dam Collection Facilities and Chandler Juvenile Collection Facility. As sockeye adults return back to the Yakima Basin they are numerated at Prosser Dam and the trapped and hauled to Lake Cle Elum from Roza Dam.

Now that the pathway to permanent passage is progressing, the YN feel that to succeed with reintroduction of sockeye anadromous species, as well as increasing existing resident native populations, such as burbot and cutthroat trout, something needed to be done to control or preferably eliminate Mackinaw (Lake Trout; *Salvelinus namaycush*), a non-native apex predator which was introduced by Kittitas County in 1920. The YN began an aggressive Mackinaw removal program in the fall 2013 when Cle Elum Reservoir was at its lowest level due to irrigation draw down. This process involved using commercial

gillnetting equipment and techniques to capture and remove Mackinaw from the lake with the intent of collecting biological data about mature spawners and depressing their population and/or totally eradicating them from the lake in the future. Over a 1000 Mackinaw have been removed from the lake since 2013.

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**Long-term ecological change and associated environmental forcings in critical freshwater nursery habitat for Okanagan Basin Sockeye Salmon Oncorhynchus nerka: A comparative paleolimnological study of Wenatchee Lake, WA, USA, and Osoyoos and Skaha lakes, BC, Canada**

Daniel T. Selbie, Fisheries and Oceans Canada, Queen's University; Anya Köchel, Queen's University; Jeff Fyer, Columbia River Inter-Tribal Fish Commission; Kim D. Hyatt, Fisheries and Oceans Canada; Brigitte Simmatis, Queen's University; Andrea Zemanek, Queen's University; and John P. Smol, Queen's University

Columbia River Sockeye Salmon *Oncorhynchus nerka* were once relatively abundant throughout the upper Columbia and Snake River basins, but are now represented by a limited number of extant populations at the southernmost limit of their North American range. The majority of current Columbia River Sockeye Salmon production arises from stocks within the Okanagan Basin, principally those returning to Osoyoos and Skaha lakes, British Columbia, Canada, and also to a lesser extent Wenatchee Lake, WA. The xeric attributes of the Canadian watersheds supporting these fish, and projections of changing future hydrology (i.e., snow-dominated to rain-dominated) suggest these systems, their fish, and associated fisheries may be highly responsive to regional- to global-scale climatic forcings. Interactive influences on fisheries production may arise from a number landscape and in-lake stressors (e.g., lake eutrophication, anoxia/hypoxia), which contrasts with the relatively pristine, cold-water, conditions observed in Wenatchee Lake. We present comparative multi-proxy paleolimnological reconstructions within Osoyoos, Skaha, and Wenatchee lakes over the past ~150 years, to establish the range of natural variability in nursery ecosystem structure and functioning, and lake-specific responses to unique and shared environmental forcings that continue to modify the ecology of these systems. This long-term perspective highlights key sensitivities to future influences on Sockeye Salmon productive capacity within the Columbia River Basin.

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**Pacific salmon responses to climate variation and change in freshwater ecosystems**

Howard Stiff, Kim Hyatt, and Diana Dobson; Fisheries and Oceans Canada

Recent investigations in British Columbia and the Pacific Northwest have demonstrated regional temperature shifts of about +0.8°C over the past century, with projected temperature increases of 1.5-3.2°C in near-future decades. Temperature effects on migrating adult Sockeye salmon *Oncorhynchus nerka* have been well documented in many Pacific Northwest river systems. Temperatures in the range of 21-24°C can be lethal, and water temperatures in excess of 18°C affect migration speed, cause timing delays, and result in secondary effects such as increased disease, pre-spawn mortality, reduced gamete viability, and decreased egg-to-fry survival rates.

Seasonal precipitation has also changed markedly in the recent past, and future projections point to wetter winters and drier summers, with a high likelihood that extreme events will become more frequent. Associated changes in stream discharge levels may result in physical limits to fish passage during low flows, while high flows may generate velocity barriers that reduce or prohibit upstream migration at key locations along the migratory route (such as canyons, rapids and falls, but also man-made fish-ways and weirs).

Interacting temperature and discharge stressors exert annual to decadal-scale influences on economically valuable salmon stocks returning to Sproat and Great Central lakes in the Somass River system on the west coast of Vancouver Island. Historically challenging locations for upstream passage at Sproat Falls and Stamp Falls have been largely mitigated by fish-way construction projects since 1927, but recent studies indicate that daily transit rates through these fish-ways are still influenced by seasonal variations in environmental conditions. Extreme high early summer flows appear to delay onset of upstream migration, while daily mean water temperatures exceeding 19-21°C may impede or even stop migration. The latter climate induced effects are associated with an increased frequency and magnitude of pre-spawn mortality, especially during extended elevated temperature and low flow periods.

Climate change projections portend an increase in the frequency and duration of extreme flow and high temperature conditions, with negative implications for the sustainable production of Somass Sockeye Salmon beyond 2050. Mitigation via human intervention (e.g., engineering of “cold-water” release structures for the Somass, Stamp and Sproat rivers and/or creation of additional water storage) will most certainly be necessary to ensure future migration success, high productivity and sustainable fisheries for adult Sockeye salmon originating from this B. C. watershed.

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**Divergence of the condition of Sockeye Salmon fry among lake and river rearing habitats***

Elissa Sweeney-Bergen*, Simon Fraser University, Lake Babine Nation Fisheries; Donna Macintyre, Lake Babine Nation Fisheries; and Jonathan W. Moore, Simon Fraser University

Freshwater rearing habitat for young Pacific salmon provides opportunity for growth and survival, such as lake habitat for juvenile Sockeye. However, access to these habitats differs between populations and even individuals. For example, in Sockeye populations that spawn downstream of lake outlets, it may be challenging for fry to successfully access lake rearing habitats. Yet, despite the potential consequences of this difference in habitat availability, relatively little work has been done to investigate the condition of young salmon where individuals have different early life habitat experiences. Here we investigated whether Sockeye fry rearing in lake and river habitat types had different body conditions through the spring and summer. This project took place in the Babine River mainstem, a large tributary of the Skeena River in north-central British Columbia, just downstream of Babine Lake, one of the largest Sockeye Salmon rearing lakes in BC. Systematic sampling following spring emergence allowed for tracking of size and condition of individuals who had swam upstream to access lake rearing grounds and comparison with those who were swept downstream and found in backwater areas of the river.

Initially, both lake and river fry were comparable in condition, but at later samplings, lake fry were consistently larger in both length and weight. These data indicate that fry in the river were occupying lower quality habitat, or that smaller or weaker fry were being displaced downstream. Poorer condition of river fry could have implications on other health parameters (i.e., competitive ability, pathogen resistance, etc.) and ultimately survival. Thus, the spatial arrangement and accessibility of habitats could exert strong control on the condition and fitness of juvenile salmon.

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**Developing and implementing adaptation strategies through upgrading and re-purposing existing in-stream infrastructure for conservation and sustainable production of salmon originating from the Somass watershed in British Columbia**
Alan Lill, BC Conservation Foundation; Craig Wightman (presenter), BC Conservation Foundation; Barry Chillibeck, Northwest Hydraulic Consultants; and Kim Hyatt, Fisheries and Oceans Canada

The Somass watershed supports several high value wild as well as hatchery-origin salmon stocks. Independent research indicates that climate change places important economic and social values associated with salmon production from this watershed at serious risk of loss. Sustainable salmon production in the Somass Watershed depends, in part, on existing in-stream infrastructure including three DFO fish-ways and a major salmonid enhancement facility as well as two privately owned dams at the outlets of two large nursery lakes that produce Sockeye Salmon. Adaptation options that might be employed by fisheries and water managers to mitigate future impacts of climate change on salmon production have been identified during the course of several years of investigation and planning, coordinated by the BC Conservation Foundation in partnership with various levels of government, two First Nations, private sector interests and the stewardship community. Specifically, engineering feasibility assessments and stream modelling were undertaken and a number of possible adaptation infrastructure and management alternatives were developed - all designed to reduce high water temperature and low flow impacts that will increasingly threaten sustainable production of Sockeye Salmon and Chinook Salmon in this watershed in the face of future climate change.

## *Symposium: Contributed papers*

**Chair: Benjamin Cross (Colville Confederated Tribes)**

Date: Wednesday, March 21, 1:20 PM to 3:00 PM
Location: Vineyard 3

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**Dynamic prey landscapes for four fishes foraging in the Skeena River estuary***
Michael Arbeider*, Simon Fraser University; Charmaine Carr-Harris, Skeena Fisheries Commission; Ciara Sharpe, Simon Fraser University; and Jonathan W. Moore, Simon Fraser University

Estuary food webs and habitat support many fishes, including juvenile salmon (*Oncorhynchus* sp.) and forage fish, whose population dynamics and habitat preferences may be controlled by prey abundance and distribution. Yet estuarine diets of many species are either unknown or highly variable between regions. Improving understanding of the identity of key prey species, as well as their spatio-temporal dynamics, could help improve understanding of a dimension of estuary habitat importance of these fishes, particularly relevant for regions with continued industrial development. For example, the Skeena estuary is the second largest in British Columbia and has high pressure from anthropogenic developments, but little is known about the food web of juvenile Sockeye Salmon and Coho Salmon, Pacific Herring, nor Surf Smelt. On-going collaborative research between First Nations fisheries programs and SFU are investigating juvenile salmon and forage fish food webs and habitat use in the estuary of the Skeena river. We surveyed zooplankton and fish communities and their diets across the estuary. Coho Salmon consumed terrestrial insects and larval fish most but decapod zoea, harpacticoid copepods, and pteropods were also substantial diet contributions. Sockeye Salmon primarily consumed harpacticoid copepods, similarly to Pink Salmon and Chum Salmon in other systems. In contrast, both forage fish species, Pacific Herring and Surf Smelt, primarily consumed calanoid copepods, which were the most abundant prey species but are also much more evasive than harpacticoid copepods. Thus, estuary fishes integrate differently with their dynamic prey landscapes. Multiple prey varied through either space or time in relation to biophysical factors. For example, higher harpacticoid copepod abundance was associated with sites over eelgrass and calanoid copepod and decapod zoea abundance increased with salinity. This research is a step towards understanding the food-web foundation of juvenile salmon and forage fish habitat use in an estuary under pressure from anthropogenic development.

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**Holy smolts it's time to go! Modelling age at seaward migration in juvenile steelhead***
Colin Bailey*, Simon Fraser University; Douglas Braun, Department of Fisheries and Oceans; Donald McCubbing, Instream Fisheries Research Inc. (deceased); John Reynolds, Simon Fraser University; Bruce Ward, BC Ministry of Environment (retired); Trevor Davies, BC Ministry of Forests, Lands and Natural Resource Operations; and Jonathan Moore, Simon Fraser University

Steelhead trout display more life-history variation than any other Pacific salmon; up to 36 distinct life-histories have been recorded in one watershed. Steelhead life-histories include variation in the number of years spent as juveniles in a stream, the number of years spent as adults in the ocean, and the number of spawning migrations an adult completes. While we understand that genetics and environment play strong roles in steelhead life-history expression, we still understand relatively little about the effects of multiple simultaneous environmental factors on life-history variation. Using a 4-decade dataset, we examined the simultaneous effects of pink salmon spawning, artificial nutrient addition,

density dependence, temperature, and precipitation on the age-specific probability of juvenile steelhead migrating to sea. With these results, we further demonstrate how the consistent difference in abundance between odd and even-year Pink Salmon runs may structure the proportions of different-aged steelhead smolts within brood groups. Understanding life-history variation in steelhead can improve our understanding of how environmental variation may affect their population stability, productivity, and persistence.

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**History of salmon marine netpen aquaculture in Washington State**
Orlay Johnson, WABC Chapter AFS, Seattle Aquarium

The history of netpens in Washington has not followed a smooth path, and recently has suffered a devastating setback. However, initially netpens were seen as a positive force for wild fish survival and an alternative to over-fishing and habitat destruction.

Salmon hatcheries began in Washington State in the late 1895. Netpen culture was only initiated in 1970s when the researchers at NMFS Manchester Field Station used the MV Brown Bear, as floating fish hatchery that released smolts into Puget Sound. Fish were held in nets around the ship to be transported, and gradually researchers realized these netpens could be used to raise salmon to pan-sized adults on site. In the 1970s, researchers at NMFS, developed a pilot-scale floating netpen system and formed a joint NMFS/Union Carbide Company (Global Systems). This company under the direction of John Lindbergh sold pan-sized Pacific Salmon. Soon, 16 different netpens operations flourished in the state.

However, a variety of issues, doomed these operations, including poor siting, environmental and legal concerns, replacement of Pacific salmon with Atlantic salmon, and the rise of large scale netpen operations in Canada, Chile, and other countries.

By 2007 netpen operations had been consolidated into one U.S.-owned company, Icicle Seafoods, which up to 2016, had the largest salmon aquaculture industry in the U.S. with eight marine farms producing approximately 17 million pounds of Atlantic salmon annually.

The industry has also expanded to rear native species such as sablefish, steelhead, and cutthroat trout as well as experimenting with closed deep water ocean pens.

In May, 2016, Icicle's operation was sold to the Canadian firm Cooke Aquaculture. In the spring of 2017 the company experienced a catastrophic collapse of a netpen structure at the Cypress Island facility. The results and implications of this disaster are yet to be determined.

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**Balancing seasonal food web interactions to manage kokanee production in a mixed fishery***

Brian Lanouette*, Washington State University; Barry C. Moore, Washington State University; and Benjamin K. Cross, Colville Confederated Tribes

Complex food web interactions in mixed warm- and coldwater fisheries can directly impact fish production. Buffalo Lake, located on the Colville Confederated Tribes Reservation in north-central Washington State, has a mixed fishery primarily managed for a sustainable, naturally reproducing kokanee population. Secondary management goals are to provide Largemouth Bass and stocked Rainbow Trout fisheries. Kokanee and hatchery Rainbow Trout may both exploit a common zooplankton food resource; excess trout stocking may reduce the production of both species through competitive interactions. In addition, predation from Largemouth Bass could decrease kokanee and Rainbow Trout production but increase bass production. Food web interactions for all Buffalo Lake fish species have been studied through quarterly fish collections from 2014 to 2017. We employed stomach content analysis to examine seasonal diet overlap and interspecific predation. Largemouth Bass diets were dominated by crayfish. However, predation on kokanee and Rainbow Trout occurred during October and May when kokanee and Rainbow Trout occupied shallower waters to spawn and feed. Rainbow Trout were generalists feeders with macroinvertebrates and crayfish consumption representing a dominate part of their diet for most of the year. During winter months (February) and times of peak summer stratification (July and August), Rainbow Trout diets shifted to consumption of *Daphnia* and other zooplankton also consumed by kokanee. The sharing of zooplankton resources provided evidence for significant biological overlap between the diets of kokanee and Rainbow Trout. To balance predator prey interactions within the lake's food web, we are currently developing bioenergetics consumption models to quantify the competitive fish interactions (i.e., production trade-offs between species) to guide future management strategies.

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**Phenological mismatch reduces survival in wild steelhead trout *Oncorhynchus mykiss* population**

Samantha M. Wilson, Thomas Buehren, Jennifer Fisher, and Jonathan W. Moore; Simon Fraser University

Climate change is shifting the timing of juvenile salmon migrations and prey availability at different rates and it is unclear what repercussions this may have on individual survival or persistence of a population (match/mismatch hypothesis). We tested the match/mismatch hypothesis by studying how the temporal 'match' between prey availability and ocean entry of passive integrated transponder tagged juvenile Wind River steelhead trout influences ocean survival. We found that the most parsimonious model predicting ocean survival included size, and the number of days between ocean entry and the bloom of cold-water zooplankton near the Columbia River estuary. The probability of wild juvenile steelhead trout ocean survival is related to a match between ocean entry and high-quality zooplankton availability.

## *Symposium: The future of bull trout populations and management in British Columbia and Washington*

**Chairs: Nikolaus Gantner (BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development - FLNRORD), Shawna Warehime (Eastern Washington University), and Rachel Chudnow (University of British Columbia)**

Date: Wednesday, March 21, 3:20 PM to 5:00 PM
Location: Vineyard 3

Environmental and anthropogenic stressors pose threats to Bull Trout *Salvelinus confluentus* populations in both British Columbia and Washington. Climate change is one major stressor, as water temperature is often the most important environmental parameter delineating the distribution of Bull Trout. In addition, land use practices, such as hydroelectric dams, forestry practices, and fisheries management practices can further affect Bull Trout populations directly and indirectly.

Bull Trout are federally listed with some level of conservation concern throughout their range. If the species is to thrive, it is necessary to examine causes for decline and evaluate pathways to recovery in the face of existing and emerging threats. This includes studying recovery initiatives currently underway as well as emerging technologies and policies. For example, applications such as the Cold-Water Climate Shield model by the U.S. Forest Service Research and Development Branch and the advances in the utility of environmental DNA have been successfully employed to identify shifts in stream water temperatures and subsequent effects on salmonids, including Bull Trout. The promising method of environmental DNA appears to provide an alternative to traditional approaches.

This symposium is welcoming submissions from academia, government agencies, and the private sector on both sides of the border to share lessons learned and success stories from the past, as well as to jointly discuss future strategies to assess and manage Bull Trout populations. Submissions as platform presentations and poster presentations are welcome and a wrap-up panel discussion may be held to conclude the symposium. A summary report may be written with contributions from all participants.

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**Hierarchical Bayesian meta-analysis to characterize cross-population variation in the stock-recruit relationship for Bull Trout***

Rachel E. Chudnow*, Institute for the Oceans and Fisheries, University of British Columbia; Brett T. van Poorten, British Columbia Ministry of Environment British Columbia and Institute for the Oceans and Fisheries, University of British Columbia; and Murdoch K. McAllister, Institute for the Oceans and Fisheries, University of British Columbia

This investigation develops a hierarchical Bayesian meta-analysis to estimate the recruitment compensation ratio (CR) and characterize the functional form of stock-recruitment for Bull Trout *Salvelinus confluentus*. The Goodyear compensation ratio (comparable to steepness) quantifies density-dependent compensatory increases in juvenile survival when stock size is reduced to low abundance, which allows populations to

persist despite changing mortality rates. Understanding the functional form, and estimating the parameters of a population's and species' stock-recruitment relationship is crucial for estimation of key parameters used to aid recovery efforts and develop sustainable fisheries policies. Results of this investigation show Bull Trout to have a high scope for density-dependent compensation evidenced by CR estimates generated in this study, which is also supported by multiple lines of evidence. However, due to lack of data, variance is high. This investigation demonstrates that changes in habitat quality and quantity are likely limiting the recovery of many Bull Trout populations. Difficulty in finding data for this study and the high variance of results highlights the importance of collecting data on both stock and recruitment in the same fashion across regions to facilitate investigations of this type, and reduce variance in estimates for Bull Trout and other species.

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**Predator-prey interactions between Bull Trout and juvenile Sockeye Salmon in Chilko Lake, British Columbia**

Nathan Furey, University of British Columbia and University of New Hampshire; Scott G. Hinch, Department of Forest and Conservation Sciences, University of British Columbia; Adam Kanigan, Department of Forest and Conservation Sciences, University of British Columbia; Arthur L. Bass, Department of Forest and Conservation Sciences, University of British Columbia; Kristi M. Miller, Fisheries and Oceans Canada; and Andrew G. Lotto, Department of Forest and Conservation Sciences, University of British Columbia

Both Bull Trout and Sockeye Salmon are species of ecological, economic, and cultural importance in British Columbia and the Pacific Northwest and are of great conservation concern. Predator-prey interactions between species of conservation concern can make management difficult. We conducted a series of studies investigating the relationships between Bull Trout and juvenile Sockeye Salmon smolts in Chilko Lake, British Columbia, one of the largest Sockeye Salmon-producing systems in the Fraser River watershed. Over three years (2013–2015) we examined stomach contents of Bull Trout during the period of Sockeye Salmon smolt outmigration in the spring. During this period, Bull Trout feed exclusively on smolts and the degree of consumption is intense, with stomach contents representing 5–10% of Bull Trout's body mass. By binge-feeding, Bull Trout can dramatically increase smolt consumption and growth. Consistently across three years, Bull Trout selected for small smolts. In addition, Bull Trout also selected for smolts with a specific viral infection in one year in which the virus was present. Using fine-scale acoustic telemetry in 2014, it appears Bull Trout move each night in response to pulses of outmigrant smolts. In addition, Bull Trout returned to the lake outlet the following year (2015) to exploit the smolt outmigration, and we are currently working to understand Bull Trout movements relative to Sockeye Salmon life history at broader spatial scales across the landscape. These results potentially suggest an important reliance between these two species of conservation concern. In addition, Bull Trout select for factors expected to be selected for by other predators (size and infection), likely limiting the efficacy of any management actions aimed at reducing exposure of smolts to Bull Trout.

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**Climate change influence on Upper Fraser Watershed and Bull Trout habitat**
Nikolaus Gantner, Vanessa Foord, John Rex, Ian Spendlow, and Ray Pillipow; BC Ministry of Forest, Lands, Natural Resource Operations and Rural Development, Fisheries and Wildlife, Omineca Region

Climate change poses a threat to Bull Trout populations in the Omineca region as water temperature is the most important environmental parameter delineating the distribution of Bull Trout. Mean annual temperature in the Omineca region have increased by 1.3°C in approximately the last 100 years and is projected to increase an additional 3.5°C by 2055. The Omineca region has recently experienced below average snowpacks coupled with warm, dry summers may be contributing to increasing stream temperatures. Investigating the relationship between climate change and stream temperatures as they relate to Bull Trout habitat is necessary as climate models project these trends to continue. The objectives of this new study are to identify areas of potential risk to Bull Trout from climate change as well as areas of potential climate refugia for Bull Trout. The Bowron watershed, one of 51 Bull Trout-Designated Watersheds identified in the Bull Trout Management Plan for the Middle and Upper Fraser River Watershed, lends itself to serve as a case study due to the availability of relevant model input data and its relative proximity to Prince George, BC. We propose to apply the USFS Cold-Water Climate Shield tool to the Bowron watershed to identify future areas of high risk as well as refugia to Bull Trout. Air and water temperature loggers will be deployed and Bull Trout presence confirmed using electrofishing and eDNA analysis in August of 2018. Results will aid the identification of Upper Fraser Basin watersheds most sensitive to stream and riparian air temperature increase. Once identified, watershed-specific forestry and riparian management practices to mitigate projected temperature increases can be identified and implemented to lower risk of future bull trout habitat loss. We will discuss how the information generated by this project can inform fisheries habitat, water management, as well as conservation planning and management activities that will be influenced future climatic conditions.

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**Evaluating the effectiveness of fish passage operations for resident Bull Trout at a flood storage dam in Southeastern British Columbia**
Katy Jay, BC Hydro

The Duncan Dam, a Columbia River Treaty dam located near Kaslo, BC, has operated upstream passage of adult Bull Trout *Salvelinus confluentus* from Lower Duncan River to the Duncan Reservoir since 1968. A weir downstream of the Low Level Outlet Gate (LLOG) was installed in the 1990's after observations that Bull Trout access to the LLOG flip bucket might be impeded at certain operating levels. Because the transfer requirements are operationally intensive and the weir was deemed a safety risk during annual installation, two studies were undertaken to evaluate its effectiveness. One study enumerated and measured fork length and weight of fish within the flip bucket during transfers with the weir installed. The weir was removed and sampling was repeated for comparison. The presence of the weir increased the ability of smaller Bull Trout (<65cm) to access the flip bucket by 71% (28%, 128%; 80% CI). A second study was conducted to determine the transfer programs contribution to recruitment of Bull Trout to Duncan Reservoir and Kootenay Lake (downstream of Duncan Dam). Juvenile otolith (n=354) and

natal stream (n=13) chemistries were analyzed and, using linear discriminant analysis (LDA), a model was developed to predict natal origin of adult Bull Trout captured in Kootenay Lake (n=46), Duncan Reservoir (n=12) and at Duncan Dam (n=67). Upper Duncan River was predicted to have been the rearing grounds of 26% and 23% of adult Bull Trout captured at Duncan Dam and Kootenay Lake, respectively. These studies indicate the importance of the Bull Trout transfer program in maintaining diversity within the migrating spawn population and contributing to Bull Trout recruitment below Duncan Dam. Results have been used to guide recommendations for future improvements to Bull Trout passage.

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**Bull Trout in the Yakima Basin: A proposal to prevent future declines**
Todd Newsome, Yakama Nation; Gabriel Temple; Pat Monk; Mark Johnston; and Dave Fast

Bull Trout abundance and distribution has become substantially reduced over much of the species native range over the last hundred or more years. This reduction prompted listing under the Endangered Species Act (ESA) in 1998 but despite their listing, many populations continue their struggle for existence. The Yakima Basin, located in Central Washington State currently has 15 Bull Trout populations identified and at least two of those have become functionally extirpated in recent memory while several others remain at critically low abundance levels. In response, we developed a plan to spearhead and initiate recovery measures to halt further declines. We propose a small-scale experimental translocation study to relocate juvenile Bull Trout from a depressed population in a stream that regularly dewaters thereby stranding fry, to a natures type captive rearing environment temporarily before being returned to the stream, or to another suitable stream. Briefly, fry will be grown in captivity for a short period to overcome the large survival impact associated with the fry stage dewatering (approximately one growing season) at which point the majority of the fish will be returned to the stream of origin. A small number of fish will also be translocated to a presumably suitable stream to protect the abundance and genetic legacy of the source population and to act as a refuge and source for future translocations or reintroductions. The results from this study will be used to inform future large-scale recovery efforts in the Yakima Basin. In this presentation, we illustrate the current depressed status of Bull Trout in the Yakima and propose one strategy to aid their recovery.

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## *Symposium: Okanagan salmon restoration*

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**Chair: Chad Fuller (Okanagan Nation Alliance)**

Date: Thursday, March 22nd, 9:00 AM to 11:40 AM
Location: Vineyard 4

Topics for our symposium will cover habitat, hydro, hatchery, health, and harvest.

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**Okanagan River restoration initiative**
Karilyn Alex, Camille Rivard-Sirois, and Colette Louie; Okanagan Nation Alliance

The health of the q̓awsitkw (Okanagan River) has been severely impacted by the channelization works that occurred in the mid-1950's. Only 16% (5 km) of the river remains in a natural (3 km) or semi-natural state (2 km). 84% (30 km) of the river has been channelized, straightened, narrowed and dyked.

In an effort to regain the habitat quality and quantity that has been lost, the Okanagan River Restoration Initiative (ORRI) concept was conceived in 2000. ORRI is an ecosystem based collaborative approach assembling provincial (MoFLNRO), federal (DFO, EC), First Nations (ONA, CCT, OIB, PIB) and various local authorities and funders via a Steering Committee.

In our presentation we will review the ORRI process and vision, key design elements, construction phases to date, monitoring highlights, and next steps.

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**Results from large-scale experiments to test the effectiveness of stream restoration: Is restoration working and can we increase restoration effectiveness?**
Stephen Bennett, Utah State University; Nicolaas Bouwes, Eco Logical Research, Inc.; Joseph Wheaton, Utah State University; and Scott Shahverdian, Anabranch Solutions, LLC

Key watershed processes such as sediment routing, riparian function, and wood recruitment have been impaired across the Pacific Northwest. These impaired processes have led to poor spawning and rearing conditions for anadromous and resident fish populations. Since the 1990's, hundreds of millions of dollars have been invested in stream restoration actions to improve stream conditions and recover fish populations. However, the effectiveness of stream restoration at increasing fish production has rarely been evaluated, or has only been evaluated in small, short-term studies. To overcome these issues, long-term, large-scale restoration experiments have been initiated in the Pacific Northwest, referred to as Intensively Monitored Watershed (IMW) studies. We describe the results of the Bridge Creek IMW in Oregon and the Asotin Creek IMW in Washington that used beaver dam analogs (Bridge) and low-cost, high-density wood structures (Asotin) to improve stream and riparian habitat. In each IMW, we monitor abundance, growth, movement, and seasonal survival of juvenile steelhead, spawning distribution, and collect detailed stream habitat and topographic data. Each IMW has at least five years or pre and post- restoration data. We demonstrate that these restoration alternatives can be cost-effective and significantly improve stream and riparian habitat, and increase wild juvenile steelhead abundance and production. However, we caution that although IMWs are providing important insights into the effectiveness of stream restoration, the scope of stream habitat degradation is large and the data on fish response is still relatively limited (i.e., 1-3 life cycles post-restoration). Results from these two studies provide insight into restoration effectiveness and the potential to mitigate the influence of climate change on imperiled salmon and steelhead populations.

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**Okanagan Nation Alliance's Skaha Lake Sockeye Salmon Reintroduction Program**
Ryan Benson, Okanagan Nation Alliance

Historically, the Okanagan Basin was a major contributor to salmon stocks in the Columbia River system. Traditionally, salmon have been essential to Syilx People in the Okanagan Territory for subsistence, culture, and commerce. Due to human caused factors such as harvest, hydro-electric dam construction, river channelization, and introduction of invasive species, salmon stocks in the Okanagan system experienced a precipitous decline during the last century. Specifically, construction of McIntyre Dam in 1953 downstream of Skaha Lake blocked Sockeye Salmon migration, resulting extirpation in Skaha and Okanagan lakes. In the mid-1990's returning Sockeye were estimated to be less than 3,000, and Syilx People of the Okanagan Nation were extremely alarmed by the potential loss of the Okanagan Sockeye stock. The Okanagan Nation Alliance (ONA), in partnership with the Department of Fisheries and Oceans, the BC Ministry of Forests, Lands, and Natural Resource Operations, and Grant and Chelan County Public Utility Districts implemented a 12-year experimental reintroduction of Sockeye Salmon into Skaha Lake in 2004. The experimental reintroduction entails collection of adult brood stock from the Osoyoos Lake population (directly downstream of Skaha Lake), harvest of gametes from donor stock, fertilization of eggs, hatchery rearing, and outplanting of fry the following spring. Since 2014, fry have been reared at the ONA owned kɬ cp̓ə̓lk̓ stim̓ Hatchery, located on the Penticton Indian Reserve. In addition to hatchery supplementation, ONA has been conducting intensive monitoring and evaluation consisting of adult Sockeye/kokanee counts, in-lake fry enumeration and sampling, mysis, zooplankton, and limnological monitoring, and bio-energetic analysis. The on-going monitoring is part of the adaptive management process to ensure the re-introduction is not negatively impacting the aquatic ecosystem. Since the program was initiated, Skaha and Osoyoos lakes currently support self-sustaining Sockeye populations, and comprise 70-90% of the total Columbia Sockeye run.

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**The five H's (hydro, hatcheries, habitat, harvest, health) of Okanagan anadromous fishes**
David Duvall and Tom Dresser, Grant County Public Utility District

Grant PUD's closest hydroelectric project is over 360 kilometers from the current anadromous barrier at the outlet of Okanagan Lake and yet this distance doesn't prevent active participation and involvement with the remaining four H's of this symposium. There is a three-prong approach with implementing mitigation programs to achieve no-net impact by hydroelectric dams: project survival, hatchery supplementation, and habitat restoration. Survival studies which evaluate fish passage survival and mortality associated with avian and piscivorous predation conducted at Priest Rapids and Wanapum dams show species specific survival by Chinook (86.7%), steelhead (87%) and sockeye (91%) are meeting performance standards. Survival rates consistently fall within the target range whether fish use bypass systems, spill gates, or even turbine passage. Dam survival rates for each individual species are in the mid to upper 90 percent. Grant PUD produces up to 1,619,666 million hatchery summer Chinook, spring Chinook, steelhead, and sockeye that are released in the Okanagan basin annually to mitigate for unavoidable loss at hydroelectric projects, with robust monitoring and evaluation programs in place to assess

effects on natural origin anadromous populations and non-target taxa. As a way to monitor fish health before release into the natural environment, a new laboratory operated by Okanagan Nation Alliance performs disease testing and other analyses associated with the program. For the final prong, 100 habitat projects have been presented, reviewed and approved for implementation by a multi-membered habitat committee, nineteen in the Okanagan basin, to help natural origin stocks continue recovery and expansion within the watershed since 2006. Although more difficult to measure, these combined activities have certainly led to harvest opportunities for tribal, commercial, and recreational fisheries in both marine and freshwater areas.

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**Have invasive mysids *Mysis diluviana* altered the capacity of Osoyoos Lake, British Columbia to produce Sockeye Salmon *Oncorhynchus nerka*?**

Kim D. Hyatt,Fisheries and Oceans Canada; Donald J. McQueen, York University (Emeritus); and Athena D. Ogden, Fisheries and Oceans Canada

During 2005-2013, at Osoyoos Lake, British Columbia, we investigated trophic relationships among fry of *Oncorhynchus nerka* (Sockeye and kokanee), a suite of limnetic planktivores including *Mysis diluviana*, and their zooplankton prey. Our goal was to quantify the impacts that a recently introduced population of *Mysis* would have on density, growth and survival of resident age-0 Sockeye Salmon. Results from this 9-year study indicate that the Osoyoos Lake food-web was strongly influenced by external events. These included: large annual variations in river discharge, an earthen dam failure and effluent input from an Okanagan River tributary and highly variable recruitment of *O. nerka* fry given out-of-basin factors (harvest, marine survival) controlling adult salmon returns. Surprisingly, large annual variations in *O. nerka* recruitment (0.63–7.00 million fry), did not induce significant, “top-down” associations in growth, survival or subsequent production among the macro-planktivores (pelagic fish and *Mysis*) and their zooplankton prey. A single significant correlation ($p < 0.05$) between *O. nerka* fry abundance and their von Bertalanffy $W\infty$ emerged from a set of 14 potential “top- down” associations tested. By contrast, we identified several strongly positive, “bottom-up” effects in which survival of *O. nerka* fry was significantly associated ($p < 0.01$) with annual variations in total zooplankton biomass, *Daphnia* biomass and *Epischura* biomass. Our results indicate that *Mysis* played a dual role in the Osoyoos Lake pelagic food web. As predators, they accounted for an average (June-October) of 64% of the total prey biomass consumed by fish and *Mysis*. As prey, *Mysis* contributed an average of 35% of the prey biomass consumed by fish. Consumption by fish and *Mysis* together accounted for daily losses of only 4.5% of non-mysid zooplankton biomass and 34% of daily zooplankton production. We conclude that in all years, total prey consumption by *Mysis* and fish was never high enough, acting alone, to reduce the availability of their potential zooplankton forage base. However, we also estimate that in the absence of *Mysis*, *O. nerka* fry could experience a 43% increase in their daily food intake and that fish and *Mysis* might control their principal prey taxa when exogenous factors (e.g., annual discharge) induced major reductions in zooplankton biomass. Finally, although *Mysis* has clearly altered energy flow pathways from plankton to fish in the Osoyoos Lake food-web, mysids have not precluded rebuilding *O. nerka* abundance to levels at or exceeding historic maxima.

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**An assessment of impacts of the 2010 Testalinden Dam breach on aquatic food webs and planktivores (*Oncorhynchus nerka* and *Mysis diluviana*) at Osoyoos Lake, British Columbia, Canada**

Athena Ogden, Fisheries and Oceans Canada; and Kim Hyatt, Fisheries and Oceans Canada

An earthen-fill dam, located above the floor of the Okanagan Valley in British Columbia's southern interior, failed and sent a debris flow of more than 200,000 $m^3$ of materials down the course of Testalinden Creek and into the Okanagan River on June 13, 2010. Extensive property damage from this event included the destruction of homes, agricultural machinery and vineyards. Outflows from Testalinden Creek entered the Okanagan River and eventually Osoyoos Lake. Local authorities launched coordinated emergency responses to the Testalinden Dam breach and mass-wastage event (hereafter the Testalinden event) as it developed. Immediately after the event, provincial agencies conducted formal reviews including: a description of events, a review of dam and water licensing policy, analysis of the incident and the community recovery effort. However, assessment of the effects of the dam failure and debris-flow events on aquatic biota has been missing. In this paper we attempt an assessment of the Testalinden event impacts on lacustrine food-webs from phytoplankton, to zooplankton, to a planktivorous macro-invertebrate (*Mysis diluviana*) and finally to planktivorous fish (*Oncorhynchus nerka*). To achieve this, we subjected paired data sets collected from two valley-bottom lakes (Skaha and Osoyoos lakes) to either before-and-after (BA) or paired before-and-after controlled impact (BACI) analyses. Our results provide evidence for a trophic cascade of significant responses by several aquatic taxa as follows. First, short-lived biomass pulses of four genera of phytoplankton occurred simultaneous with, or immediately after, the Testalinden events and then were accompanied by a persistent reduction in total phytoplankton biomass (chlorophyll-a) during 2010-2013 relative to 2005-2009. BA and BACI statistical comparisons of zooplankton abundance across these same intervals indicated significant multiyear reductions of *Daphnia* spp., *Epischura* sp., *Leptodiaptomous* sp. and increases of *Bosmina* sp., in Osoyoos but not Skaha Lake. These zooplankton species were important prey of *M. diluviana* and *O. nerka* fry, and subsequent BACI testing revealed that (a) the biomass of *Mysis* in Osoyoos Lake exhibited significant reductions in the year following the Testalinden events, and (b) anomalously low survivals of *O. nerka* fry began in Osoyoos Lake in 2010 and persisted for 3 or 4 years thereafter. Finally, because our studies included assessments over the entire life history of *O. nerka*, we were able to provide a conservative estimate of a $10 million U.S. economic loss from follow-on effects of Testalinden events to fisheries interests in Canada and the U.S.

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**A brief history of the kł cp̓əlk̓ stim̓ hatchery 2014-2018**

Dan Stefanovic, Okanagan Nation Alliance; and Norm Johnson, Okanagan Nation Alliance

We looked at the kł cp̓əlk̓ stim̓ hatchery's past, present and future of Sockeye enhancement in the Okanagan by analyzing techniques to improve survival percentage from broodstock to fry release. Sockeye Salmon eggs have been transported back to the kł cp̓əlk̓ stim̓ hatchery since 2014, with over 8.5 million Sockeye eggs. Survival percentages were monitored throughout different stages of development for the past 4-5 years until fry release (and beyond-in lake). Differences among survival percentages were

found each year, as well as, an increase in survival percentages from year to year. Changes made in technique and methods during broodstock and egg takes were key factors leading to increases in survival percentages.

## *Contributed posters*

Date: Tuesday, March 20, 6:00 PM to 8:00 PM
Location: Ballroom – Salon A

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**Seven years of monitoring and evaluating Rufus Woods Lake Rainbow Trout**
Jeff Caisman, Colville Confederated Tribes; and Benjamin K. Cross, Colville Confederated Tribes

Rufus Woods Lake, an 82 km long reservoir of the Columbia River, has emerged as a destination triploid Rainbow Trout *Oncorhynchus mykiss* fishery over the past two decades, primarily due to supplementation by the Colville Confederated Tribes (CCT) and aquaculture net pen escapements. Since 2011, an average of 32,343 Rainbow Trout have been released into Rufus Woods annually by CCT with an additional 117,500 escaping from aquaculture net pens in 2011. In 2015, CCT established management objectives to maintain an annual angler harvest exceeding 40,000 trout with an average length greater than 400 mm. In order to assess supplementation effectiveness and management objectives, a creel survey was implemented. During 2011–2017, the mean annual angler effort averaged 201,530 angler hours with an average annual harvest of 56,932 trout. Mean annual catch rates ranged from 0.23–0.53 fish/h, while the majority of stocked fish were harvested within three months of release. Return to creel estimates for different release groups were estimated to be 41–84% in the eight months following stocking. A preliminary regression analysis showed a positive relationship between the number of fish stocked and angler catch by year ($P = 0.025$), suggesting the fishery was largely dependent on CCT stocking efforts. Additionally, previous research showed entrainment of released trout was likely associated with spill rates over the downstream dam (Chief Joseph Dam), and utilization of available prey was likely insufficient to sustain growth of trout stocked below target harvest size. Based on these findings, CCT focuses supplementation efforts during periods of high angler effort prior to springtime spill and directly releases trout at target size to meet management objectives.

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**Impacts of temperature on life history strategies of invasive Eastern Brook Trout *Salvelinus fontinalis****
Kaeli Davenport* and Paul Spruell, Eastern Washington University

Instances of invasive fish are expected to increase with global climate change, making it critically important to determine how these invaders will respond to environmental variation. The goal of this project is to understand how varied life history strategies may contribute to overall invasive success and survival of Brook Trout *Salvelinus fontinalis* in

variable stream temperatures. This will allow me to predict how brook trout might respond to changing temperatures that are expected to result from climate change. The objective of this project is to determine how different stream temperatures impact growth and timing to maturity in invading fish species using Brook Trout as my model. In September 2017, Brook Trout were collected using backpack electrofishing from six different streams located within the Pend Oreille River basin: three warmer water streams and three colder water streams. Streams include Sullivan Creek (10-16°C), Cee Cee Ah Creek (10-14°C), Le Clerc Creek (10-13°C), Cusick Creek (18-20°C), Calispell Creek (18-20°C), and Ruby Creek (18-20°C). Temperatures presented are average maximum temperature for each stream. Fish were euthanized immediately after capture and measured for length (mm) and weight (g). Otoliths were removed to determine size at age as well as age at maturity. Gonads were measured to determine gonadosomatic index (GSI = [Gonad Weight / Total Tissue Weight] x 100). In order to compare the impacts of temperature on length, weight, and age of fish I will run an ANOVA. Although data analysis is ongoing, preliminary results suggest interesting differences in size at age between warmer and colder stream temperatures.

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**Implications of food type on the effectiveness of a syringe method for gastric lavage of Largemouth Bass***

Brian Lanouette*, Washington State University; Barry C. Moore, Washington State University; and Benjamin K. Cross, Colville Confederated Tribes

The gastric lavage method for non-lethally extracting stomach contents is commonly utilized by fisheries biologists to determine fish diets. The technique involves using a device to flush water through a fish's stomach, thereby removing the contents. It is often cited as having near 100% efficiency. However, we noted that some food items, particularly crayfish, were difficult to remove from the stomach contents of Largemouth Bass using gastric lavage techniques. In May 2017, we conducted a pilot study where 54 Largemouth Bass ranging from 200 to 500 mm TL were sampled from North Twin Lake, Washington using pulsed-DC electrofishing. Largemouth Bass stomachs were flushed repeatedly with filtered water using a 60cc syringe until the contents came back empty three consecutive times. Bass were then sacrificed, and their stomachs removed for laboratory analysis of any remaining food items. Of the bass sampled, 15 had contents remaining in their stomachs post lavage for an inefficiency of 28%. Whole and partial crayfish were among the most common prey item not removed by gastric lavage. An average crayfish weight of 0.8 g was removed by gastric lavage versus 1.61 g remained in stomachs post lavage. In many cases, other prey items including dragonfly larvae were found amongst crayfish indicating that crayfish parts potentially prevented these food items from being extracted. The potential for gastric lavage ineffectiveness warrants further investigation into food type limitations associated with the technique.

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**Using stable isotopes to investigate the trophic status of an invasive crayfish in a temperate, oligotrophic lake***

John Loffredo*, Washington State University; Brian Lanouette, Washington State University; Barry C. Moore, Washington State University; and Benjamin K. Cross, Colville Confederated Tribes

The ecological role of crayfish has traditionally been over-simplified when describing aquatic food webs. Recent studies have documented crayfish exhibiting multiple functional roles among endemic and exotic populations in lentic or lotic habitats. The indiscriminate diet and adaptive behavior of crayfish has allowed multiple invasive crayfish species to thrive when introduced into novel habitats. Crayfish invasions have the potential to rapidly re-shape benthic invertebrate assemblages; affecting littoral community processes, and warrants investigation.

Northern Crayfish *Orconectes virilis* were introduced more than fifteen years ago into Buffalo Lake, an oligotrophic lake in north-central Washington, managed by the Confederated Tribes of the Colville Reservation. Northern Crayfish inhabit a novel ecological niche among the wholly-introduced Buffalo Lake fishery. In Buffalo Lake, crayfish are critical summer food source for sport fish and serves as a standalone fishery. Despite the importance of this invertebrate to the Buffalo Lake food web, the dietary requirements of this crayfish population remain unknown. As a result, the long-term sustainability of this species as a prey source and harvestable fishery is a question for resource managers.

Utilizing hepatopancreas (liver) tissue that has a short isotopic turnover rate, we can document near real-time trophic position and ontogenetic diet shifts of this crayfish population. We hypothesize that northern crayfish follow resource waves: targeting epiphytic algae, benthic invertebrates, largemouth bass eggs, and detritus opportunistically throughout the year. Seasonal $\delta^{15}N/\delta^{13}C$ values of possible crayfish food sources were compared to $\delta^{15}N/\delta^{13}C$ values of crayfish liver tissue collected bi-weekly from Buffalo Lake May through October 2017.

This project will benefit the body of knowledge for freshwater ecology by quantifying the feeding behavior of an invasive crayfish in a novel system. Furthermore, this project will address management questions for Buffalo Lake's crayfish population regarding diet niche overlap or intraguild predation between crayfish and littoral fish species.

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**Investigating mystery *O. nerka*: Comparative analysis of three non-anadromous *O. nerka* populations***

Quinn Moldestad*, Jeffrey Jensen, and Brianna Wrightson; University of Washington, Bothell

Non-anadromous populations of Sockeye Salmon *Oncorhynchus nerka* (kokanee) are known historically to have been present in Lake Washington, Lake Sammamish and their associated tributaries. Currently these populations are either in sharp decline (Lake Sammamish late-run), extirpated (Lake Sammamish early-run), or possibly extirpated (Sammamish river and Lake Washington). The Sammamish river and its tributaries

contain a poorly understood population of *O. nerka* that differs phenotypically from Lake Sammamish native kokanee and anadromous and residual Sockeye Salmon elsewhere in the basin. These mystery *O. nerka* appear to have little overlap in spawning time with residual/anadromous Sockeye Salmon. Average fork length of this population (370 mm) is larger than likely residual Sockeye Salmon (300 mm) and native kokanee (335 mm), but substantially smaller than anadromous Sockeye Salmon (500 mm). Here we report morphological comparative analysis of gill rakers, total body length, otoliths, and scale analysis of this population with known native kokanee and likely residual Sockeye Salmon. This mystery *O. nerka* population may be the last genetic remnants of local non-anadromous kokanee populations found in Lake Washington or may represent recently evolved freshwater populations evolved from introduced anadromous ancestors. Native genes in Lake Washington would represent an important focus for conservation efforts (as are currently underway in Lake Sammamish), and finding a population that has evolved in Lake Washington within the last century would provide additional insight mechanisms underlying Sockeye Salmon life history variation.

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**Rainbow Trout *Oncorhynchus mykiss* habitat utilization in Lake Spokane, Washington***

Shawna Warehime*, Eastern Washington University; Chris Moan, Avista Corp; and Paul Spruell, Eastern Washington University

Dams influence water quality and available habitat leading to changes in conditions such as water residence time and habitat types for native fish species. The construction of Long Lake Dam in 1915 created the Lake Spokane Reservoir on the Spokane River downstream of Spokane, WA. The reservoir now experiences stratification, warmer temperatures, increases in nutrient loading, and low dissolved oxygen. My objective is to determine summer habitat utilization by triploid Rainbow Trout *Oncorhynchus mykiss* in relation to temperature and dissolved $O^2$ (DO). During year one of this two year study I inserted internal acoustic transmitters into 20 Rainbow Trout. These transmitters contain sensors for temperature and depth. They were released into Lake Spokane and tracked weekly (6/1-11/6) until location, temperature, and depth were pinpointed. Additional temperature and DO data of the reservoir were provided by Avista. These data will be used to determine how fish movement/selection is influenced by water quality. Habitat where fish were located will be compared to habitat where they were not found to determine if there is a significant difference in selection. Preliminary data resulted in 19 of the 20 fish being located, five mortalities over the season, and 14 actively moving in the reservoir. The Rainbow Trout made individual long distance movements throughout the reservoir during the summer period with surprising temperature selections and variable depths (14-23.6ºC & 0-16 m respectively). However, late summer to early fall showed schooling within 3 m of the surface at 20.4ºC, and staying at these depths until the last tracking event in early November. An additional 25 individuals will be tagged in 2018 to increase sample size and investigate annual variation in habitat selection.

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**Temperature effects on consumption: Bioenergetic implications for management of Dungeness and graceful crabs***

Grace Workman*, University of Washington; Patrick Sean McDonald, University of Washington; Kirstin Holsman, National Oceanic and Atmospheric Administration; and David Armstrong, University of Washington

To predict the effects of climate change on Puget Sound crab fisheries, ecology, and distribution, we will conduct consumption experiments held in temperature controlled aquaria at 4 temperatures (5, 15, 20, 25 C) across multiple sizes (70-100mm carapace width) of Dungeness and graceful crabs. This data will help investigate their feeding rates, egestion, and excretion via a basic mass balance bioenergetic equation in which consumption must equal respiration, egestion, excretion, and growth. We will obtain data on feeding rate by conducting feeding trials across temperature and size treatments for both species, as well as investigate the egestion and excretion components of consumption by collecting untouched and unconsumed food material before analyzing fecal pellets. This multi-species comparison may result in size and temperature-dependent feeding patterns and have implications for future spatial distributions and energy requirements of Dungeness and graceful crabs across Puget Sound, which is important for future management of the fishery and understanding their ecology.