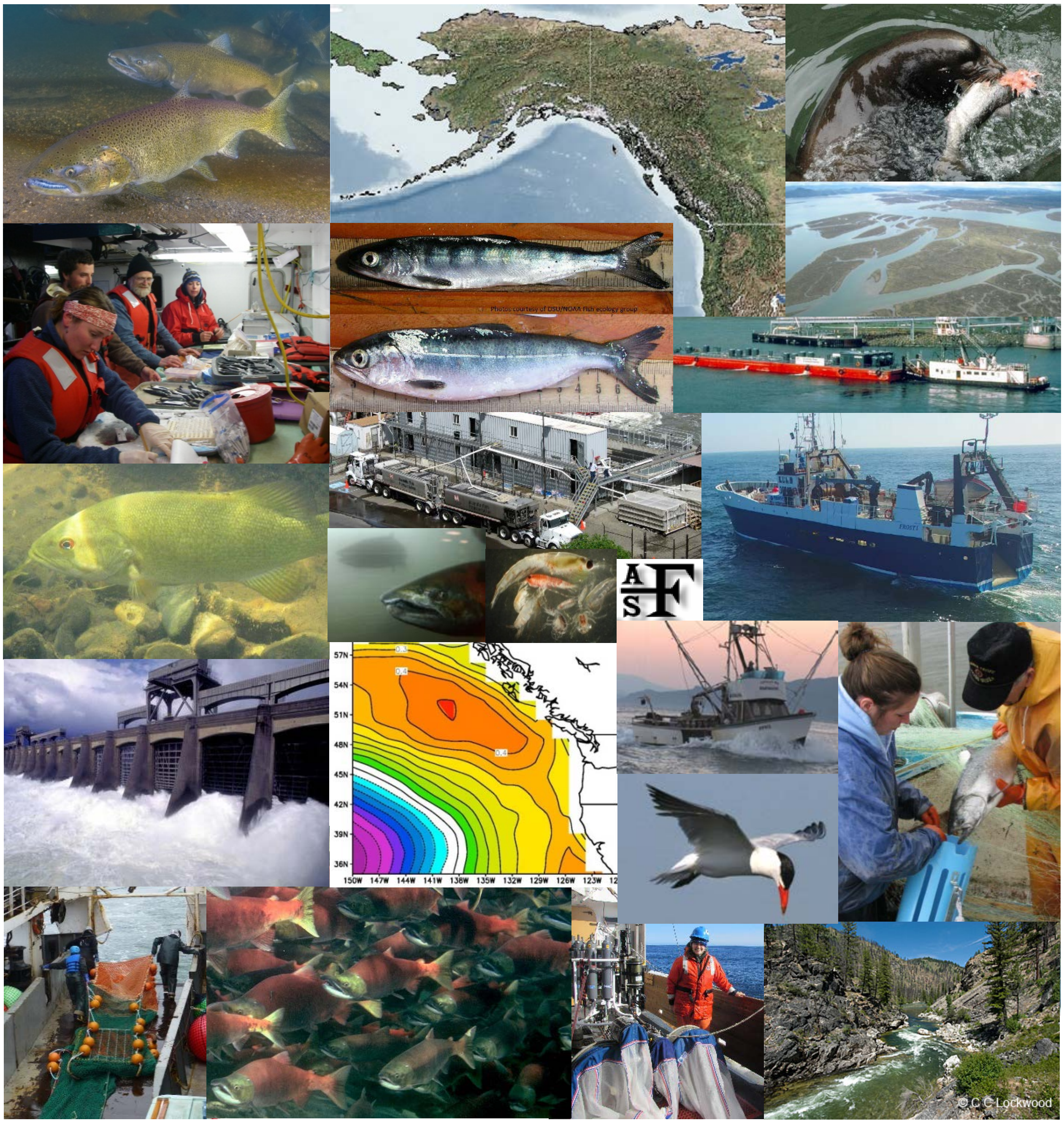
American Fisheries Society

Idaho Chapter

Fishes Without Borders Workshop
Monday, March 1st, 2021
Virtual Event



Hosted by the ICAFS Anadromous Committee

Fishes Without Borders II Workshop

Virtually-Held Annual Meeting
Monday, March 1, 2021
9:00 AM - 5:00 PM, Mountain

Sponsored by: Idaho Chapter of the American Fisheries Society Anadromous Committee

Description: The Anadromous Committee of the Idaho Chapter of the American Fisheries Society are excited to host the "Fishes Without Borders II Workshop" at the virtually-held 2021 Annual Meeting. The goal for this workshop is to expose our chapter members to research being conducted outside of the state of Idaho that is relevant to Idaho's anadromous fishes. These fish travel down the Snake and Columbia rivers to the ocean where most either migrate out to the open ocean or up along the coastline as far north as the Gulf of Alaska. They can spend multiple years in the ocean before returning back to Idaho to spawn. Consequently, a large portion of their complex life histories are subjected to harvest, predation, competition for resources, and environmental conditions outside of Idaho. Understanding these factors is important for managing our Idaho populations.

Our all-day workshop will host an array of talented researchers from various agencies, universities, and non-profits that will explore a wide range of factors influencing anadromous fish survival. Presentations in the morning will include topics on large mainstem river and hydrosystem impacts; tribal and sport harvest; and predation from fish, birds, and pinnipeds. In the afternoon, talks will focus on changing ocean conditions; and marine ecological factors affecting growth, survival, and population dynamics. In short, this workshop aims to shed light into a 'black box' of life stage-specific influences on Idaho's anadromous fishes, while also encouraging information exchange and greater communication between freshwater and downriver or ocean biologists. Please join us in exploring the exciting new research relevant to managing Idaho anadromous fish populations.

American Fisheries Society

Idaho Chapter

Fishes Without Borders II Workshop

Virtually-Held Annual Meeting
Monday, March 1 2021
9:00 AM - 5:00 PM, Mountain

09:00 Welcome

09:10 Introduction: Anadromous life history and importance to consider the complexities of fish management in large mainstem river and ocean environments

09:30 **Does Passage through Snake River Dams Cause Latent Mortality?**
Tiffani Marsh — NOAA Fisheries, NW Fisheries Science Center — Seattle, WA

09:50 **Distribution of genetic variation underlying migration timing in steelhead of the Columbia River.**
Dr. Erin Collins — Columbia River Inter-Tribal Fish Commission — Hagerman, ID

10:10 **Observed trends in the summer steelhead stock composition from yearly genetic analysis of harvest in Columbia River tribal and sport fisheries during 2011-2019.**
Alan Byrne — Idaho Department of Fish and Game — Boise, ID

10:30 **Nonnative fish distribution model reveals a potentially overlooked predation threat to native salmonids.**
Dr. Erika Rubenson — Four Peaks Environmental — Seattle, WA

10:50 **Measuring the cumulative and additive effects of colonial waterbird predation on steelhead survival in the Columbia River Basin.**
Dr. Quinn Payton — Real Time Research, Inc. — Bend, OR

11:10 **Association between pinniped abundance and survival for individual populations of adult spring/summer Chinook salmon in the lower Columbia River.**
Mark Sorel — WA Coop Fish & Wildlife Research Unit — Seattle, WA

11:30 **Estimating pinniped predation on Columbia River salmon while staying one step ahead of a natural born fisher.**
Dr. Michelle Rub — NOAA Fisheries, NW Fisheries Science Center — Hammond, OR

11:50 **Questions on all previous talks**

12:00 **LUNCH BREAK**

13:00	**Warming ocean conditions relate to changes in salmon prey field and juvenile salmon trophic requirements.**			
	Elizabeth Daly	Oregon State University	Newport, OR	
13:20	**Nonstationary effects of ocean temp on Pacific salmon productivity.**			
	Dr. Michael Litzow	NOAA, NMFS	Kodiak, AK	
13:40	**Two anomalously warm years in the northern California current: impacts on early marine Steelhead diet composition, morphology, and potential survival.**			
	Hillary Thalmann	Oregon State University	Newport, OR	
14:00	**Effects of the North Pacific Current on Pacific salmon productivity vary across time and space.**			
	Dr. Michael Malick	NOAA Fisheries, NW Fisheries Science Center	Manchester, WA	
14:20	**Climate change threatens Chinook salmon throughout their life cycle.**			
	Dr. Lisa Crozier	NOAA Fisheries, NW Fisheries Science Center	Seattle, WA	
14:40	**Record-setting abundances of pink salmon impact Pacific salmon and other marine species, including southern resident killer whales.**			
	Dr. Greg Ruggerone	Natural Resource Consultants, Inc.	Seattle, WA	
15:00	**Questions on previous talks/Break (10 mins)**			
15:10	**Utilizing open access salmon trophic ecology data to understand spatial and interspecies dynamics across the North Pacific Ocean.**			
	Caroline Graham	International Year of the Salmon	Vancouver, B.C.	
15:30	**Climate and competition influence sockeye salmon population dynamics across the Northeast Pacific Ocean.**			
	Dr. Brendan Connors	Fisheries and Oceans Canada	Sidney, B.C.	
15:50	**Density-dependent marine survival of hatchery-origin Chinook salmon may be associated with pink salmon.**			
	Dr. Neala Kendall	Washington Department of Fish and Wildlife	Olympia, WA	
16:10	**Ecological thresholds and temporal patterns in Chinook Salmon forecast performance.**			
	Dr. William Satterthwaite	NOAA Fisheries, SW Fisheries Science Center	Santa Cruz, CA	
16:30	**Questions on previous talks**			
17:00	**Wrap-up and adjourn**			

American Fisheries Society

Idaho Chapter

Fishes Without Borders Workshop
Monday, March 1st, 2021
Virtual Meeting

ABSTRACTS:

Does Passage through Snake River Dams Cause Latent Mortality?

Tiffani Marsh[1]*

[1] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA, USA; tiffani.marsh@noaa.gov**

From 2005 to 2011, NOAA Fisheries conducted a study designed to test whether smolt passage through the lower three Snake River dams and reservoirs resulted in mortality that was not expressed until after fish completed migration through that section of the hydrosystem ("latent mortality"). The study design used replicate groups of hatchery stream-type Chinook salmon collected at Lower Granite Dam and implanted Passive Integrated Transponder (PIT) tags. Fish were assigned to one of three treatments: trucked from Lower Granite Dam and released below Ice Harbor Dam (reference group); trucked for an equivalent time and returned to Lower Granite Dam for release into the tailrace (dam-passage group); and released into the tailrace of Lower Granite Dam without having been trucked (truck-effects group). The period from mid-April to mid-May each year was divided into two-day tagging periods. From each period, a set of three groups was released, with up to 10 replicates per year. The response variable was smolt-to-adult return rate (SAR). To compare survival over a common portion of the post-treatment life-cycle, SAR was estimated from smolts from each treatment that survived to the tailrace of McNary Dam, and returning adults were counted upon detection at Bonneville Dam. The primary comparison was between dam-passage groups, which experienced passage through Little Goose, Lower Monumental, and Ice Harbor Dams, and reference groups, which did not. Key results were: (1) fish that arrived at McNary Dam earlier had higher SAR; (2) dam-passage groups arrived at McNary Dam later, on average, and had lower SAR than reference groups; (3) after accounting for migration timing (and fish size at tagging), there was no significant difference in SARs between dam-passage and reference groups; i.e., no significant evidence of latent mortality.

Distribution of genetic variation underlying migration timing in steelhead of the Columbia River.

Erin E. Collins[1]*, John S. Hargrove[2], Thomas A. Delomas[2], Shawn R. Narum[1]

*[1] Columbia River Inter-Tribal Fish Commission, Hagerman Genetics Lab; 3059-F National Fish Hatchery Road, Hagerman, ID 83332, USA; ecollins@critfc.org**

2 Pacific States Marine Fisheries Commission, Idaho Department of Fish and Game, Eagle Fish Genetics Lab, 1800 Trout Road, Eagle, ID 83616, USA

Migrations are energetically costly, especially when moving between fresh and saltwater, but are a viable strategy for Pacific salmon and trout (*Oncorhynchus spp.*) due to the advantageous resources available at various life stages. Anadromous steelhead (*Oncorhynchus mykiss*) migrate vast distances and exhibit variation for arrival migration phenotypes that have a genetic basis at candidate genes known as *GREB1L* and *ROCK1*. We examined the distribution of genetic variation at 13 candidate markers versus 246 neutral markers for 113 populations (n = 9,471) of steelhead from inland and coastal lineages in the Columbia River. Patterns of population structure with neutral markers reflected genetic similarity by geographic region as demonstrated in previous studies, but candidate markers clustered populations by predominate phenotypes of early vs. late arrival migration. Alleles for late arrival migration had the highest frequency overall in steelhead populations, with only 9 populations that had a majority of frequency of alleles for early migration. We identified two haplotype blocks within the candidate region that included one block of markers within the *GREB1L* gene and another block with markers in the intergenic region upstream of *GREB1L*, but haplotype frequencies had similar patterns of geographic distribution as single markers. Redundancy analyses were used to model environmental effects on allelic frequencies of candidate markers and significant variables were migration distance, minimum temperature of the warmest month, 20-year average August water temperature, annual mean temperature, isothermality, and annual precipitation. This study elucidates the distribution of genetic variation underlying migration timing in steelhead to assist with conservation management of this species.

Observed trends in the summer steelhead stock composition from yearly genetic analysis of harvest in Columbia River tribal and sport fisheries during 2011-2019.

Alan Byrne[1]*, Thomas Delomas[2], Ken Keller[3], Megan Begay[4], Stuart Ellis[5], Roger Dick II[4]

[1] *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID 83707, USA; alan.byrne@idfg.idaho.gov**

[2] *Pacific States Marine Fisheries Commission, Idaho Department of Fish and Game, Eagle Fish Genetics Lab, 1800 Trout Road, Eagle, ID 83616, USA*

[3] *Pacific States Marine Fisheries Commission, 5525 South 11th Street Ridgefield, WA 98642, USA*

[4] *Yakama Nation, PO Box 151 Toppenish, WA 98948, USA*

[5] *Columbia River Inter-Tribal Fish Commission, 700 NE Multnomah, Suite 1200 Portland, OR 97232, USA*

The Columbia River sport fishery downstream of Bonneville Dam and the tribal fishery from Bonneville Dam to McNary Dam has been sampled yearly to estimate the stock composition using genetic methods since 2011. Currently, nearly all summer steelhead broodstock from hatcheries upstream of Bonneville Dam are genotyped allowing hatchery origin fish to be identified using parental based tagging (PBT) techniques. Steelhead with an unclipped adipose fin that were not assigned with PBT (putative wild fish) were then assigned using Genetic Stock Identification (GSI) markers. Although the number of harvested fish has been declining in recent years, the proportion of harvest from the Snake basin has shown consistent trends in each fishery. In general, as the year progresses from June to October the proportion of the harvest from Snake basin stocks increases. Both tribal and non-tribal Columbia River fisheries for chinook, coho, and sockeye must not exceed allowable impacts on steelhead as defined by the U.S. v. Oregon Management Agreement. These impacts are sized based and "B-Index" steelhead, defined as fish $\geq$ 78cm, may constraint fisheries. Although these large steelhead are present throughout the Columbia basin, most hatchery and wild origin large fish are from stocks within Idaho.

Nonnative fish distribution model reveals a potentially overlooked predation threat to native salmonids.

Erika S. Rubenson[1]*, Julian D. Olden[2]

[1] *Four Peaks Environmental Science & Data Solutions; 1300 North Northlake Way, Suite 102; Seattle, WA 98103; erubenson@fourpeaksenv.com**

[2] *University of Washington, School of Aquatic and Fishery Sciences, 1122 NE Boat Street, Seattle, WA 98195, USA*

Nonnative fish species are a leading threat to native salmonid species throughout the Columbia River Basin, and climate change, illegal introductions, and habitat alteration are contributing to expanding distributions. Recent research shows an increase in diversity, abundance, size, and voracity of nonnative fish predators in key outmigration corridors, but little is known about fish predators in upstream habitats where juvenile salmonids rear. Protecting critical salmonid rearing habitat from invasion can be greatly enhanced by predictive models that highlight regions most at risk, especially when paired with tools that enable early detection. Unfortunately, management-relevant distribution data are largely lacking for most invasive species, and early detection is complicated by the geographic scale. To address this, we combined species distribution modeling with environmental DNA (eDNA) to locate range boundary regions of Smallmouth Bass (*Micropterus dolomieu*), a widespread nonnative predator in the Columbia River Basin. We predicted that Smallmouth Bass is currently distributed across approximately 18,000 river kilometers and overlaps with 3–62% of rearing habitat of salmonids (species dependent). Under a moderate climate change scenario, Smallmouth Bass is predicted to expand its range by two-thirds, totaling approximately 30,000 river kilometers by 2080. Basin-wide models were sufficiently accurate to identify upstream invasion extents to within 15 km of the eDNA-based boundary, and including eDNA data improved model performance at critical range boundary regions. Our research calls attention to potential predation threats previously understood to be isolated to downstream or reservoir habitats. While management of predators in outmigration corridors remains a top priority, incorporating techniques to detect upstream invasions is key to protect native salmonid species.

Measuring the cumulative and additive effects of colonial waterbird predation on steelhead survival in the Columbia River Basin.

Quinn Payton[1], Allen F. Evans[1]

[1] *Real Time Research, Inc.; 1000 S. W. Emkay Drive, Bend, OR 97702; quinn@realtimeresearch.com*

We investigated to what degree predation by Caspian terns limited the survival of Upper Columbia River (UCR) and Snake River (SR) steelhead over an 11-year study period (2008–2018). The dataset included passive integrated transponder tagged smolts that were exposed to varying levels of predation during out-migration to the Pacific Ocean. We used a hierarchical, multinomial state-space model to jointly estimate weekly and annual predation and survival probabilities (proportion of available fish) among time-stratified cohorts to explicitly measure the strength, magnitude, and direction of the relationship between these processes. The spatial-scales investigated included (1) smolt out-migration from Rock Island Dam (for UCR smolts) or Lower Monumental Dam (for SR smolts) to Bonneville Dam and (2) smolt out-migration from Bonneville Dam to their return to Bonneville Dam as adults. Results indicated that increases in tern predation probabilities on both SR and UCR steelhead smolts upstream of Bonneville Dam were associated with statistically significant decreases in survival probabilities to Bonneville Dam. We estimated the average annual difference in observed survival versus baseline survival (i.e., survival in the absence of tern predation) were 0.05 (95% credible interval = 0.03–0.07) for SR steelhead and 0.20 (0.14–0.26) for UCR steelhead. Results also indicated that higher levels of tern predation on smolts in the Columbia River estuary were associated with lower adult returns to Bonneville Dam. Results suggested that for every 100 SR and UCR steelhead smolts consumed by terns in the estuary 6 (3–9) and 14 (6–23) fewer adults, respectively, returned to Bonneville Dam on average. Results provide strong evidence that tern predation on steelhead smolts was an additive source of mortality during the smolt life-stage and was a partially additive source of mortality to the adult life-stage, findings that have important implications for steelhead management in the Columbia River basin.

Association between pinniped abundance and survival for individual populations of adult spring/summer Chinook salmon in the lower Columbia River.

Mark H. Sorel[1,2]*, R. Zabel[1], D. Johnson[3], A.M. Wargo Rub[4] and S. Converse[5]

[1] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112, USA; marks6@uw.edu**

[2] *University of Washington; School of Aquatic and Fishery Sciences; Seattle, WA 98105, USA*

[3] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115, USA*

[4] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division, 520 Heceta Place, Hammond, OR 97121, USA*

[5] *U.S. Geological Survey; Washington Cooperative Fish and Wildlife Research Unit; University of Washington; Seattle, WA 98105, USA*

The recovery of many marine mammals has resulted in new management challenges, such as increasing predation by pinnipeds on threatened salmon. Seemingly, pinniped conservation is now in conflict with the recovery of threatened salmon, creating a dilemma for managers. We examined the relationship between seasonal California sea lion (*Zalophus californianus*) abundance and survival of adult spring/ summer Chinook Salmon (*Oncorhynchus tshawytscha*). To quantify mortality associated with increasing sea lion abundance, we examined the effect of seasonal sea lion abundance on adult salmon survival during migrations through the Lower Columbia River. We integrated data on survival with data on population-specific migration timing, allowing quantification of the relationship between sea lion abundance and survival in 18 threatened populations of spring/ summer Chinook salmon. Of the 18 populations examined, earlier migrating populations experienced the greatest reduction in survival associated with increased sea lion abundance. We estimated that in years with high sea lion abundance, the nine earliest-migrating populations experienced an additional 21.1% (95% CI = 16.3–26.1) mortality compared to years with baseline sea lion abundance, while the nine latest migrating populations experienced an additional 10.1% (7.5–13.0). Integrating datasets on seasonal survival and migration timing made it possible for us to estimate population-specific mortality associated with increased sea lion abundance in the Lower Columbia River, highlighting the utility of data integration approaches. The mortality experienced by early migrating Chinook salmon suggests the potential for demographic and evolutionary consequences. Identifying the management actions that will allow for socially and legally acceptable tradeoffs between multiple conservation and other social values will be facilitated by development of explicit multi-species management frameworks. Continued monitoring could help to reduce the substantial uncertainty about the effect of pinnipeds on salmon and the predicted outcomes of alternative management actions.

Estimating pinniped predation on Columbia River salmon while staying one step ahead of a natural born fisher.

Michelle A. Wargo Rub[1]*, Benjamin P. Sandford[2], Nicholas A. Som[3,4], Mark J. Henderson[5], Donald M. Van Doornik[6], David J. Teel[6], Matthew J. Tennis[7], Olaf P. Langness[8], Bjorn K. van der Leeuw[9], and David D. Huff[10]

[1] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division, 520 Heceta Place, Hammond, OR 97121, USA; michelle.rub@noaa.gov**

[2] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division, Ecosystem Analysis Program, 3305 E. Commerce Street, Pasco, WA 99301, USA*

[3] *U.S. Fish and Wildlife Service; Arcata Fish and Wildlife Office; 1655 Heindon Road, Arcata, CA 95521, USA*

[4] *Humboldt State University, Fisheries Biology Department; 1 Harpst Street, Arcata, CA 95521, USA*

[5] *U.S. Geological Survey; California Cooperative Fish and Wildlife Research Unit; Humboldt State University, 1 Harpst Street, Arcata, CA 95521, USA*

[6] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division, Manchester Research Station, 7305 Beach Drive East, Port Orchard, WA 98366, USA*

[7] *Pacific States Marine Fisheries Commission; Astoria, OR 97103, USA*

[8] *Washington Department of Fish and Wildlife, Columbia River Management Unit, Sturgeon and Smelt Projects, 5525 South 11th Street, Ridgefield, WA 98642, USA*

[9] *U.S. Army Corps of Engineers, Portland District; Fisheries Field Unit, P.O. Box 150, Cascade Locks, OR 97014, USA*

[10] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112, USA*

Prompted by increasing pinniped abundance and concerns about predation on salmon, NOAA Fisheries initiated a study in 2010 to measure survival of adult spring-run Chinook salmon (*Oncorhynchus tshawytscha*) through the lower CR and estuary. Over the next nine years, researchers implanted adult salmon with Passive Integrated Transponder (PIT) tags as they arrived within the estuary and estimated their survival to Bonneville Dam (Rkm 234). Based on PIT tag detections within the fish ladders at Bonneville, we estimated 51 751 - 224 705 salmon died annually within the study reach from sources other than harvest. Mixed-effects logistic regression modelling identified pinniped predation as the most likely source of this mortality. In addition to the main PIT-tagged study group, we also tested active transmitters such as acoustic and VHF for their ability to provide reach level survival estimates between the estuary and Bonneville Dam. This talk will summarize the information gained from the main PIT tag group as well as present some of the challenges encountered with the use of active transmitters. For example, the apparent ability of pinniped predators to use the soundwaves produced by acoustic transmitters to locate tagged fish.

Warming ocean conditions relate to changes in salmon prey field and juvenile salmon trophic requirements.

Elizabeth A. Daly[1]*, Richard D. Brodeur[2], and Toby D. Auth[3]

[1] *Oregon State University, Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, OR 97365, USA; elizabeth.daly@noaa.gov**

[2] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon, 97365, USA*

[3] *Pacific States Marine Fisheries Commission; Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, OR 97365, USA*

Feeding conditions for out-migrating spring and early summer juvenile salmon have been observed to change between a winter-spawned ichthyoplankton community dominated by nearshore taxa during cooler winter ocean conditions and offshore taxa during warmer winter ocean conditions. The biomass of the coastal ichthyoplankton is positively related to measures of adult salmon returns the following years, as well as an ichthyoplankton community increasingly comprised of coastal taxa. The diet composition of the juvenile spring Chinook salmon collected in the ocean in May reflect similar cool/warm ocean taxonomic changes as observed in the winter ichthyoplankton community. Using a 19-yr time series, we have observed that ocean-caught juvenile spring Chinook salmon are thinner, shorter, eat more food, are more piscivorous, and subsequently return as adults in lower numbers during warm ocean conditions. Similar-sized juvenile fish caught in 2015, one of the warmest years in the time series, weighed 17.6% less than juvenile Chinook salmon caught during 2008, a cold ocean year. While the juvenile salmon consumed significantly more food in warmer ocean conditions, when there is generally less prey available, preliminary data suggests that the food consumed is of lower energy density and that bioenergetically, the fish grow slower and return as adults in fewer numbers during warmer ocean conditions. We also present some preliminary 2020 field results, and address the current state of the ocean for juvenile salmon.

Nonstationary ocean climate effects on salmon productivity.

Mike Litzow[1]*, Lorenzo Ciannelli[2], Curry J. Cunningham[3], Bethany Johnson[4], and Patricia Puerta[5]

[1] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, NOAA Fisheries, Kodiak Laboratory, 301 Research Court, Kodiak, AK 99615, USA; mike.litzow@noaa.gov**

[2] *Oregon State University, College of Earth, Ocean, and Atmospheric Sciences, 104 CEOAS Administration Building, Corvallis, OR 97331, USA*

[3] *Alaska Pacific University, Fisheries, Aquatic Science and Technology Laboratory, 4101 University Dr., Anchorage, AK 99508, USA*

[4] *University of California Santa Cruz, Department of Applied Mathematics, Santa Cruz, CA 95064, USA*

[5] *Instituto Español de Oceanografia, Centro Oceanográfico de Baleares, Palma de Mallorca, 07015, Spain*

The inverse effect of coastal ocean temperature anomalies on Alaskan and more southern salmon stocks has been recognized for decades. But in many cases the mechanisms underlying this broad pattern remain poorly understood. One factor that may complicate our understanding of ocean climate effects on salmon productivity is nonstationarity (change over time) in relationships between temperature and other climate variables. The Aleutian Low synchronizes variability between ocean temperature and a range of other important physical variables in the North Pacific. However, interannual variability in the Aleutian Low declined after the late 1980s. Apparently as a result, covariance between temperature and other physical properties in the Gulf of Alaska declined, and covariance between temperature and salmon productivity also declined. Nonstationary climate-salmon relationships may also be important for understanding the effects of anthropogenic climate change. Since the onset of anthropogenic temperature extremes in 2014, the set of climate variables mapping onto the Pacific Decadal Oscillation Index (PDO) has changed, and the sign of PDO-salmon relationships in the Gulf of Alaska has reversed. Recognizing and accounting for nonstationarity in climate-salmon relationships may be broadly important for understanding the consequences of changing ocean conditions for Pacific salmon. However, the degree to which changing Aleutian Low variance explains nonstationary climate-salmon relationships beyond the Gulf of Alaska remains an open question.

Two anomalously warm years in the northern California Current: impacts on early marine Steelhead diet composition, morphology, and potential survival.

Hillary L. Thalmann[1]*, Elizabeth A. Daily[2], Richard D. Brodeur[3]

[1] *Oregon State University, Department of Fisheries and Wildlife, Coastal Oregon Marine Experiment Station, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon, 97365, USA; hillary.thalmann@oregonstate.edu**

[2] *Oregon State University, Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon, 97365, USA*

[3] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon, 97365, USA*

Juvenile Steelhead *Oncorhynchus mykiss* enter the northern California Current ecosystem from the Columbia River and other northwest coastal rivers and include several populations listed under the US Endangered Species Act. However, relatively little is known about the response of these populations to interannual variability in ocean conditions. In 2015 and 2016, anomalous ocean conditions, called the warm 'Blob', persisted in the northern California Current, increasing ocean temperatures by >2.5°C. To determine how Steelhead respond to such major shifts in temperature, we compared juvenile Steelhead diet composition, stomach fullness, size, and body condition from 2015 and 2016 to a subset of Steelhead collected from previous surveys (2001, 2002, 2004, 2006-2011) that included warm, cool, and neutral ocean years. In addition, we used bioenergetics models to assess the importance of the marine environment in contributing to changes in Steelhead condition under different ocean temperature scenarios. Steelhead from 2015 and 2016 exhibited some of the poorest body conditions but were the largest sizes across all years evaluated. Steelhead diet composition varied between warm and cold years and between warm and average years, with Steelhead consuming more insects, juvenile rockfishes, and rare and unidentified fish in warm years. Unusual taxa including gelatinous salps (2015 and 2016) and juvenile smelts (2016) were consumed during Blob-influenced years. Bioenergetics models indicated that interannual variability in growth is influenced by changes in temperature and feeding conditions in the marine environment, with significant differences in growth between warm and cold ocean years apparent by day two of the simulated marine residence. These findings highlight the potential for warm ocean years to influence the diet composition and morphology of Columbia River Steelhead populations and may lead to a better understanding of factors influencing survival of juvenile Steelhead in the early marine residence.

Effects of the North Pacific Current on Pacific salmon productivity vary across time and space.

Michael J. Malick[1]*, Sean P. Cox[1], Franz J. Mueter[2], Brigitte Dorner[3], and Randall M. Peterman[1]

*1 National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Manchester Research Station; 7305 Beach Dr. East, Port Orchard, WA, 98366, USA; michael.malick@noaa.gov**

2 *University of Alaska, School of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801, U.S.A*

3 Driftwood Cove Consulting, GD Lasqueti Island, BC V0R 2J0, Canada

Horizontal ocean transport can influence the dynamics of higher-trophic-level species in coastal ecosystems by altering physical oceanographic conditions, predation, or the advection of food resources into coastal areas. In this presentation, I will examine the effects of two modes of variability in the North Pacific Current (NPC) on productivity of North American salmon stocks to better understand how pathways of horizontal ocean transport could influence population dynamics of Pacific salmon. In particular, I used Bayesian hierarchical models to estimate how strongly productivity of 163 pink, chum, and sockeye salmon stocks was influenced by (1) the north-south location of the NPC bifurcation (BI) as it hits the west coast of North America and (2) the NPC strength, which was indexed by the North Pacific Gyre Oscillation (NPGO). Results revealed that the effects of the BI and NPGO on salmon productivity varied across space and time. The association between the BI and NPGO and salmon productivity was strongest for stocks located in Washington (WA) and British Columbia (BC) and weaker for stocks in Alaska. Further investigations showed that for sockeye salmon, the relationship between the NPGO and productivity shifted from negative to positive over the past 5 decades for WA and BC stocks. Taken together, these results provide some evidence that the relative importance of horizontal transport pathways may differ between northern and southern areas and may change across time periods.

Climate change threatens Chinook salmon throughout their life cycle.

Lisa G. Crozier[1]*, Brian J. Burke[1], Brandon E. Chasco[1], Daniel L. Widener[2], and Richard W. Zabel[1]

*1 National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division, 2725 Montlake Blvd E., Seattle, WA 98112, USA; Lisa.Crozier@noaa.gov**

2 Ocean Associates, Inc., under contract to National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112, USA

Widespread declines in Atlantic and Pacific salmon (Salmo salar and Oncorhynchus spp.) have tracked recent climate changes, but managers still lack quantitative projections of the viability of any individual populations in response to future climate change. To address this gap, we assembled a vast database of survival and other data for eight wild populations of threatened Chinook salmon (O. tshawytscha). For each population, we evaluated climate impacts at all life stages and modeled future trajectories forced by global climate model projections. Populations rapidly declined in response to increasing sea surface temperatures and other factors across diverse model assumptions and climate scenarios. Strong density dependence limited the number of salmon that survived early life stages, suggesting a potentially efficacious target for conservation effort. Other solutions require a better understanding of the factors that limit survival at sea. We conclude that dramatic increases in smolt survival are needed to overcome the negative impacts of climate change for this threatened species.

Record-setting abundances of pink salmon impact Pacific salmon and other marine species, including southern resident killer whales.

Greg Ruggerone[1]*, Brendan Connors[2], James R. Irvine[3]

[1] *Natural Resources Consultants, Inc. 4039 21st Avenue West, Suite 404, Seattle, WA 98199, USA; GRuggerone@nrccorp.com**

[2] *Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 W. Saanich Rd., Sidney, BC V8L 5T5, Canada*

[3] *Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia V9T 6N7, Canada*

In 2018, to the surprise of many people, we reported that there were more Pacific salmon returning from the North Pacific Ocean during 2005-2015 than any time since 1925 when detailed record keeping began. Updated estimates, still preliminary, indicate that even more Pacific salmon returned during 2018 and 2019 than in any previous two-year period (more than 900 million salmon per year). In contrast, the NWPCC salmon abundance goal for the entire Columbia Basin is 5 million fish, primarily Chinook, coho, sockeye, and steelhead. However, more than 70% of the North Pacific salmon in 2018 and 2019 were pink salmon, which is arguably the least desirable species to humans and a species that has been shown to cause a trophic cascade in the North Pacific, leading to adverse effects on sockeye, Chinook, coho, chum, and steelhead, marine fishes, seabirds, and even southern resident killer whales. Our research since 2000 to uncover the effects of pink salmon on other marine species has relied upon their biennial pattern of abundance, which is typically highest in odd-numbered years. Physical oceanographic conditions cannot explain the biennial patterns observed in the vital metrics of affected species. Our presentation provides an overview of this research. Pacific salmon, especially Chinook and steelhead, migrate thousands of kilometers at sea, leading us to ask whether pink salmon may affect Columbia Basin salmon as they migrate into the Gulf of Alaska and beyond.

Utilizing open access salmon trophic ecology data to understand spatial and interspecies dynamics across the North Pacific Ocean.

Caroline Graham[1,2]*, Evgeny A. Pakhomov[1,2,3], Brian P. V. Hunt[1,2,3]

[1] *University of British Columbia, Institute for the Oceans and Fisheries, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada; mcarolinegraham@gmail.com**

[2] *University of British Columbia, Department of Earth, Ocean, and Atmospheric Sciences, 2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada*

[3] *Hakai Institute, PO Box 25039, Campbell River, British Columbia V9W 0B7, Canada*

The North Pacific Marine Salmon Diet Database (NPMSDD) is an open-access relational database built to centralize and make accessible salmon diet data. The creation of this database is aligned with efforts by the International Year of the Salmon and other organizations to make salmon data standardized and accessible. Using data from the NPMSDD, we examined spatial patterns in diet, trophic niche width and niche overlap for chum, pink and sockeye salmon across the North Pacific during 1959–1969. This is a baseline period before major hatchery enhancement occurred coinciding with a negative phase of the Pacific Decadal Oscillation. Large-scale (between regions) and fine-scale (within regions) spatial and interspecies differences were apparent. In the Western Subarctic, all species tended to consume zooplankton. In the Bering Sea, chum consumed zooplankton, while sockeye and pink alternated between zooplankton and micronekton. In the Gulf of Alaska / Eastern Subarctic, chum and sockeye specialized on gelatinous zooplankton and cephalopod prey, respectively, while pink consumed a mixture of zooplankton and micronekton. The highest diet overlap across the North Pacific was between pink and sockeye (46.6%), followed by chum and pink (31.8%), and chum and sockeye (30.9%). Greater diet specialization was evident in the Gulf of Alaska / Eastern Subarctic compared to the Western Pacific. In addition to the large-scale trophic patterns, our data revealed novel fine-scale spatial patterns, including latitudinal, onshore-offshore, and cross-gyre gradients. Our results showed that pink tended to be more generalist consumers, and their diets may be a better reflection of overall prey presence and abundance in the environment. Conversely, chum and sockeye tended to be more specialist consumers, and their diets may provide a better reflection of interspecies dynamics or prey availability. This study provides a baseline for comparison with current and future changes in salmon marine ecology and North Pacific ecosystems.

Climate and competition influence sockeye salmon population dynamics across the Northeast Pacific Ocean.

Brendan Connors[1*], Michael J. Malick[2*], Gregory T. Ruggerone[3*], Pete Rand[4], Milo Adkison[5], James R. Irvine[6], Robert Campbell[4], and Kristen Gorman[4, 5]

[1] *Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 W. Saanich Rd, Sidney, BC V8L 5T5, Canada; Brendan.Connors@dfo-mpo.gc.ca**

[2] *National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA*

[3] *Natural Resources Consultants, Inc., 4039 21st Avenue West, Seattle, WA 98199, USA*

[4] *Prince William Sound Science Center, PO Box 705, 300 Breakwater Avenue, Cordova, Alaska, 99574, USA*

[5] *University of Alaska Fairbanks, College of Fisheries and Ocean Sciences, Juneau, AK 99801, USA*

[6] *Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo BC V9T 6N7, Canada*

[*] *contributed equally to this work*

Ocean conditions and inter- and intra-specific interactions are well known to influence salmon growth and productivity. However, their combined effects are poorly understood. Using data from 47 sockeye salmon (*Oncorhynchus nerka*) populations across the eastern North Pacific Ocean, along with information on ocean climate conditions and indices of potential salmon competitors, we present evidence that the magnitude and direction of climate and competition effects vary over large spatial scales. In the south, a warm ocean and abundant salmon competitors combined to reduce sockeye productivity, whereas in the north, a warm ocean substantially increased productivity and offset the negative effects of competition at sea. From 2005-2015, the approximately 82 million adult pink salmon (*O. gorbuscha*) produced annually from hatcheries were estimated to have reduced the productivity of southern sockeye salmon by ~15%, on average. In contrast, for sockeye from the Gulf of Alaska and Bering Sea, the same level of hatchery production was predicted to have reduced sockeye productivity by ∼6% and ∼5%, respectively. These findings reveal spatially dependent effects of climate and competition on sockeye productivity and highlight the need for international discussions about large-scale hatchery production.

Density-dependent marine survival of hatchery-origin Chinook salmon may be associated with pink salmon.

Neala W. Kendall[1]*, Benjamin W. Nelson[2], and James P. Losee[1]

[1] *Washington Department of Fish and Wildlife, 1111 Washington St. SE, Olympia, Washington 98501, USA; neala.kendall@dfw.wa.gov**

[2] *University of British Columbia, Institute for the Oceans and Fisheries, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada*

Understanding how protected species influence the population dynamics of each other is an essential part of ecosystem-based management. Increasing releases of hatchery Chinook salmon has been proposed to aid recovery of endangered southern resident killer whales (SRKWs). We analyzed 30 years of data and found that density-dependent survival of hatchery Chinook salmon released into the central and southern parts of the Salish Sea (Washington, USA and British Columbia, Canada) may be associated with the presence of naturally-produced pink salmon, which are highly abundant as juveniles only in even-numbered years. We first modeled hatchery Chinook salmon marine survival as a function of the numbers of juvenile Chinook released and the presence of emigrating juvenile pink salmon between 1983 and 2012. Then we related reconstructed numbers of hatchery Chinook salmon returning to Puget Sound to the abundance of juvenile Chinook released in even (pink emigration) and odd (non-pink emigration) years from 1980 to 2010. We found that in some regions of the Salish Sea, both hatchery Chinook salmon marine survival and adult Chinook returns varied depending on the number of hatchery Chinook released and the presence of juvenile pink salmon. Specifically, in some regions survival of hatchery Chinook salmon decreased when greater numbers of juveniles were released into the Salish Sea in even years, when large numbers of pink salmon were present, but increased or remained stable when pink salmon were not present in large numbers (in odd years). This suggests lower, density-dependent survival of juvenile Salish Sea Chinook salmon during even outmigration years. Our analyses suggest that scientists and managers should further investigate potential mechanisms for density-dependent survival of hatchery Chinook salmon from Salish Sea hatcheries when designing strategies to maximize adult returns.

Ecological Thresholds and Temporal Patterns in Chinook Salmon Forecast Performance.

William H. Satterthwaite[1]*, Jennifer L. Gosselin[2], Kelly S. Andrews[3], Correigh M. Greene[4], Chris J. Harvey[3], Stuart H. Munsch[5], Michael R. O'Farrell[1], Jameal F. Samhouri[3], and Kathryn L. Sobocinski[6]

[1] *National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division, 110 McAllister Way, Santa Cruz, CA 95060 USA;* will.satterthwaite@noaa.gov*

[2] *University of Washington, School of Aquatic and Fishery Sciences, Seattle, WA 98105, USA*

[3] *National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division, 2725 Montlake Boulevard East, Seattle, WA 98112, USA*

[4] *National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division, 2725 Montlake Boulevard East, Seattle, WA 98112, USA*

[5] *Ocean Associates Inc., Under Contract to National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA*

[6] *Long Live the Kings, 1326 5th Ave. #450, Seattle, WA 98101, USA*

Preseason abundance forecasts heavily influence management of ocean salmon fisheries along the U.S. West Coast, yet little is known about how environmental variability influences forecast performance in comparison to current approaches (i.e., sibling-based, production-based, or averaged over recent years). We investigated forecast performances for key California/Oregon ocean fishery stocks in (Sacramento and Klamath Fall Chinook), and high priority stocks of prey for endangered Southern Resident Killer Whales (multiple stocks in Puget Sound). We explored how well environmental indices (at multiple locations and time lags) explained variation in forecast performance, and tested for nonlinearities and thresholds. For the California stocks, no environmental index could explain >50% of the variation in forecast performance, but spring PDO and winter NPI of return year had R^2>40% for the sibling-based Sacramento Fall Chinook forecast, with nonlinearity and apparent thresholds. This suggests that conditions experienced after jacks return have the most impact on sibling-based forecast performance. For Puget Sound stocks employing various forecast methods, we detected nonlinear and threshold relationships (with R^2>50%) with multiple indices and time lags. These results suggest environmental influences on preseason forecasts may create biases that unwittingly render salmon fisheries management more or less conservative, and therefore warrant further study and consideration. Ongoing work on temporal patterns in Chinook forecast performance shows no obvious improvement over time, possibly greater risk of overforecasting at low abundance, and an increase in synchrony since the early 2000's which may reflect shared effects of winter conditions across stocks.