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Proceedings of the 27th and 28th Northeast Pacific Pink and Chum Salmon Workshops

January 2023

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
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Northwest Fisheries Science Center

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Abstracts presented in this report were submitted by workshop participants for oral and poster presentations and do not necessarily represent the opinions of NOAA, NMFS. Only minor editorial corrections (punctuation and spelling) were made to these submissions. The editor of this report is grateful to the many contributors to these workshops who travelled from around the Pacific Rim.

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NOAA FISHERIES

Proceedings of the 27th and 28th Northeast Pacific Pink and Chum Salmon Workshops

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Proceedings of the 27th Northeast Pacific Pink and Chum Salmon Workshop 2018

William A. Egan Civic & Convention Center
555 West 5th Avenue
Anchorage, Alaska 99501
21–25 March 2018

Compiled by

Kathleen G. Neely[1] and **Peter S. Rand**[2]

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Acknowledgments

The co-chairs would like to thank The American Fisheries Society Alaska Chapter for allowing us to host this session in the AFS Western Division Annual Meeting. We would like to thank all the speakers who presented talks in the session and give a special thank you to Dr. Homel for speaking at the plenary. Finally, we would like to thank Tommy Sheridan, of Silver Bay Seafoods, for the smoked salmon at our Thursday evening Pink and Chum Salmon Workshop get-together.

Preface

This workshop series began in 1962 as the Northeast Pacific Pink and Chum Salmon Workshop, which was held in Juneau, Alaska. Since that time, it has been convened on a near biennial basis among three regions: Alaska, British Columbia, and Washington State. After a brief hiatus, we were able to resume this workshop series in 2018.

The purpose of these workshops has been to bring resource managers, researchers, and stakeholders together to review the status of pink (*Onchorhynchus gorbuscha)* and chum salmon (*O. keta)* production in and around the northeast Pacific Ocean. The workshops have provided a forum to share issues and information relevant to pink and chum salmon resource management and help maintain resource sustainably for the mutual benefit of stakeholders, thus helping to promote healthy marine and terrestrial ecosystems.

Since 1962, we have accumulated a great deal of knowledge about pink and chum salmon. These species continue to exert a strong influence on freshwater and marine food webs, serve a critical role in food security for many communities, and be of high value in commercial fisheries throughout the North Pacific. We have a growing appreciation for their life histories – while they exhibit some of the simplest life histories among Pacific salmon, we continue to learn that they are more complex than previously acknowledged. As ecosystems reorganize with climate change, pink and chum salmon in particular are poised to expand and colonize new Arctic habitats.

As in past workshops, we highlighted some key, recent advances in our state of knowledge. In keeping with the theme of the 2018 American Fisheries Society Conference (Change, Challenge, and Opportunity in Fisheries: Fishing for Solutions), we covered a broad array of topics. Dr. Kristen Homel of Oregon Department of Fish & Wildlife gave a plenary presentation on the long road to recovery of chum salmon in the State of Oregon. We had contributions on a number of important and emerging themes, including climate effects, hatcheries, range expansion, fitness-related studies, conservation efforts, and the on-going challenges of managing pink and chum salmon fisheries.

2018 Workshop Agenda

Wednesday, 23 May

Moderator: Peter S. Rand

Thursday, 24 May

Moderator: Kathleen G. Neely

Plenary

Dr. Kris Homel

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Dr. Homel has worked with the Oregon Department of Fish and Wildlife since 2012 as the Chum Reintroduction Coordinator. In that role, she is involved in planning and implementing all aspects of reintroducing functionally extirpated chum salmon to the historic range. She also serves as President of Oregon AFS and is working to expand climate initiatives in the chapter. Her current research focuses on Chum Salmon limiting factors, including determining the distribution of a salmon pathogen using environmental DNA, evaluating estuarine occupancy and survival, identifying factors affecting spatiotemporal body size of spawners, and modeling brood year returns as a function of estuary and ocean covariates. Kris received her Doctorate in Fish and Wildlife Biology from Montana State University in 2013 where she studied the spatial ecology of Snake River Finespotted Cutthroat Trout in the upper Snake River in Grand Teton National Park, WY. She received her Master's in Fisheries from Utah State University, studying the genetic population structure and movement patterns of Bull Trout in Northeast Oregon. Prior to graduate school, Kris began her fisheries career and love of Chum Salmon at Hidden Falls Hatchery in Southeast Alaska.

The History of Chum Salmon in Oregon: Collapsed Populations on the Long Road to Recovery

Historically, chum salmon *Oncorhynchus keta* represented a significant portion of the annual returns of salmon and steelhead to the lower Columbia River in Oregon and Washington; it is thought that 10–15 million salmon and steelhead returned annually (Gresh et al. 2000), of which chum may have comprised 7–10% of the return (NPPC 1986). Beginning in the early 1800s, settlement along the lower Columbia River and tributaries resulted in changes to land use and harvest of chum salmon that ultimately led to the extirpation of 90% of chum salmon populations in the LCR. By the 1950s, returns to the Columbia River numbered in the thousands, and in 1999, chum salmon were listed as 'threatened' under the Endangered Species Act (USFWS 1999).

The specific causes for decline are familiar. There has been substantial loss and degradation of spawning habitat, changes to the estuary that have reduced available rearing habitat for Chum Salmon fry, alteration of the hydrograph in the Columbia River, and predation and overharvest. Of these factors, overharvest is the only one that has been addressed. Collectively these factors represent death by a thousand cuts; no single factor explains the lack of recovery following the curtailment of harvest, but in combination, these factors can create negative feedback cycles. For example in habitats degraded by excess fine sediments, overharvest leads to decreased spawner abundance, a decreased ability to clean gravels during spawning, decreased freshwater survival, decreased fry outmigration, and a decrease in adult returns. Therefore, to achieve recovery goals, restoration must simultaneously address multiple factors at biologically relevant spatiotemporal scales.

As part of the effort to recover Chum Salmon in the Columbia River, the Oregon Department of Fish and Wildlife initiated a Chum Salmon Reintroduction Project in 2012. The goals are to: (1) restore habitat to promote natural recolonization, (2) supplement populations that have an abundance below a critical threshold, (3) reintroduce chum salmon into habitats that historically supported spawning but where they are currently extirpated, (4) construct spawning channels and create conservation broodstocks to support supplementation and reintroduction work, and (5) identify and address limiting factors.

The path to recovery is a long one. At current levels of adult reintroduction and current freshwater and marine survival rates, it could take over 100 years to reach the minimum abundance goal set in recovery planning. Certainly, addressing limiting factors would result in increased survival rates and faster population growth. However, to successful identify those factors and feasible approaches to address them, a broader perspective is needed on how we approach recovery planning and implementation.

The fisheries profession contains the expertise required to recover salmon; the profession is diverse, but also compartmentalized. Each compartment (disciplines within fisheries such as population modelers, community ecologists, pathologists, etc.) has unique ways of thinking about problems and methods for addressing them. Each also works at different spatial or temporal scales. Although there is communication among disciplines during planning, the number of disciplines involved is typically limited. For example, recovery work groups typically include harvest managers, conservation planners, hatchery managers, restoration biologists, or population modelers. However, there are other disciplines in the fisheries profession that would have valuable insight into recovery planning and implementation and identifying limiting factors. For example, social scientists provide insight into the human dimension of fisheries management and climate scientists consider how to plan at much longer time scales for conditions that may be entirely different than those to which species have adapted. Ultimately, by thinking broadly, communicating across disciplines, and diversifying recovery workgroups, a greater range of approaches are available to address salmon declines at different scales, improving the potential that efforts will be successful.

Acknowledgments

Todd Hillson and Bryce Glaser (Washington Department of Fish and Wildlife) assisted with broodstock development. ODFW staff at the Corvallis Research Lab, North Willamette Watershed District, and North Coast Watershed district assisted with broodstock collection and experimental reintroductions and ODFW staff at Big Creek Hatchery created and managed the conservation broodstock. Research and monitoring activities on the Chum Salmon Reintroduction Project are funded by Pacific Coastal Salmon Recovery Fund contract number 212-909 and Mitchell Act funds.

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Oral Presentations 2018

Detecting Spatial and Temporal Patterns of Covariation Between Ocean Conditions and Size at Age of Oregon Coast Chum Salmon Using Dynamic Linear Models

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Coauthor: Jeff Hard (retired)

I evaluated the relationships between 22 environmental indicators and variation in adult chum size at age between 1996 and 2014 from five wild Oregon populations to a) determine the extent of spatial variability in marine growth rate in this species and b) estimate the temporal correlations between marine growth and ocean conditions. Most of the environmental indicators have been monitored each year since 1996 in coastal waters off central Oregon. I analyzed the spatial and temporal structure of these data with dynamic linear models, which indicated that the temporal trends in marine growth differed among the populations. Correlations between chum salmon growth rate and regional environmental indicators were observed as often during the year of final ocean residence as during the year of ocean entry, suggesting that the marine environment experienced during the final year of ocean residence is as important as that experienced during the year of seaward migration for chum salmon production in this area. The environmental indicators most commonly correlated with temporal variation in Chum Salmon growth were anomalies in the Pacific Decadal Oscillation index (PDO), Oceanic Nino Index (ONI), and Coastal Upwelling Index (CUI); copepod biomass and diversity; sea surface temperature; and summer abundance of juvenile Coho and Chinook salmon sampled off the Columbia River. These patterns suggest that the influence of ocean conditions on variation in chum salmon growth are typically weak and short-lived but they are detectable. The strong environmental anomalies that were observed in 2015 and 2016 will likely have important consequences for marine survival and growth of chum salmon in this southernmost part of its range in North America.

Why We Need To Know Why Wild Alaska Salmon Taste Better

Eric Jordan
Alaskan fisherman

In thinking about this year's American Fisheries Society meeting theme, Communications and Modern Tools for Research & Management combined with the Pink & Chum Workshop, it dawned on me that Alaskans have been communicating about and doing research on a question regarding salmon for thousands of years: Which salmon taste best? Every individual, every village, and every region in Alaska has an opinion. Whether it is an opinion about white versus red king salmon in SE Alaska or Yukon versus Kuskokwim chum in Interior Alaska, or Copper River versus all other Alaska salmon, or Alaska Wild Salmon versus farmed salmon, the debate rages. But the research tools have varied little for centuries. You prepare two of the salmon identically and ask tasters which tastes the best. Because this is so important in marketing wild Alaska salmon I am humbly suggesting that individuals gathered here think about Modern Tools to research what makes Alaska salmon taste the best. I am not suggesting that we try to determine which Alaska salmon stock tastes the best. Just as I like a variety of fine wines, I love the taste of a diverse variety of wild Alaska salmon. I am often asked by crew members participating in the Crew Apprentice Program why the salmon they are eating on my boat taste so much better than the farmed salmon they have eaten. My answer is: sometimes we know the what, that salmon like to jump for example, but the why remains a mystery. In my presentation I will explain why figuring out why a whole variety of Alaska salmon taste better than farmed salmon is important. —Eric Jordan, lifelong Alaskan salmon fisherman and taster.

Who's Catching What And Where? Using Otolith Thermal Marks to Better Understand and Manage Hatchery–Wild Pink Salmon Interactions in Lower Cook Inlet Commercial Fisheries

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Pink salmon (*Oncorhynchus gorbuscha*) hatcheries in Tutka Bay Lagoon (TBLH) and Port Graham Bay (PGH) recently reopened and are expected to soon reach full production under their existing permits, releasing up to 200 million fry annually. To facilitate informed in-season management of commercial fisheries targeting wild and hatchery-produced pink salmon in the Lower Cook Inlet (LCI) area, managers with the Alaska Department of Fish and Game (ADF&G) need to distinguish between wild and hatchery fish in the commercial harvest and in spawning escapements to area streams with wild stock escapement goals. Every pink salmon raised in LCI hatcheries is marked with a series of unique thermal bands on their otoliths so returning adults can be identified to their hatchery of origin and release site. With representative spatial and temporal sampling of the commercial harvest, managers can determine where and when hatchery and wild salmon are harvested and can use that information to ensure wild stocks are not overharvested while targeting large hatchery returns. Homer staff have collected >2,800 otoliths from pink salmon harvested in commercial purse seine and set gillnet fisheries in Kachemak Bay since 2015. Preliminary results indicate LCI hatcheries contributed half of the pink salmon harvested in common property commercial fisheries in the Southern District during 2015–17. Nearly 98% of the cost-recovery harvest inside the Tutka Hatchery Special Harvest Area (SHA) derived from hatchery production, indicating limited interception of wild stocks. Overall, pink salmon index streams in the Southern and Outer districts met their respective escapement goals throughout this recent period of increased harvests targeting large hatchery returns. We will discuss various management implications associated with our preliminary results and will describe plans to strengthen our otolith sampling program to improve our understanding of hatchery-wild pink salmon interactions in LCI.

Where Did That Pink Salmon Come From? Using Thermal Marks To Identify and Enumerate Hatchery Pink Salmon Strays to Streams in Lower Cook Inlet

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With the recent reopening of the Tutka Bay and Port Graham hatcheries in Lower Cook Inlet (LCI), ADF&G staff in Homer initiated a sampling program to evaluate the potential of hatchery pink salmon (*Oncorhynchus gorbuscha*) straying into LCI area streams. Beginning in brood year 2012, thermal marks applied to the otoliths of all pink salmon raised in LCI hatcheries have allowed the department to identify returning adults to their hatchery of origin and release site. Since 2014, Homer staff have collected 6,634 otolith pairs from spawned out pink salmon carcasses on 17 streams in Kachemak Bay and along the Outer Coast. The percentage of LCI hatchery strays identified in samples ranged from 0% in many streams outside of hatchery special harvest areas, up to 100% in a stream adjacent to the Tutka Bay Lagoon Hatchery (TBLH). The high incidence of TBLH marks in the Tutka Lagoon Creek sample was not surprising given that the creek provides both the water and the brood source for the hatchery. The relative absence of LCI hatchery strays in streams greater than 6 miles from hatchery release sites is noteworthy, as is our contrasting observation that some LCI stream samples had very high percentages (30–87%) of thermally-marked pink salmon from hatcheries in Prince William Sound (PWS) that are 150–250 miles away. This latter observation may represent the first time PWS hatchery pink salmon have been documented spawning in streams well outside of PWS and should be instrumental towards considering an expanded geographic scale for future hatchery–wild interaction research.

Long-Term Productivity Trends in Natural Populations of Pink and Chum Salmon from Puget Sound, Washington, USA

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Puget Sound is home to seven anadromous Pacific Salmon (*Oncorhynchus* spp., Steller, 1743) and Trout species, including Pink (*O. gorbuscha*) and Chum (*O. keta*) Salmon. In this study, we investigated the effects of environmental variability on productivity in natural populations of Puget Sound Pink and Chum over five decades. Specifically, we used population dynamics and time series analysis to quantify temporal trends in productivity and abundance across local, regional, and basin scales. For Pink Salmon, we did not find any strong temporal trends in productivity, but there was evidence of regional covariance in productivity at fine spatial scales within Puget Sound, with populations increasing in central Puget Sound in recent years, and decreasing in south Puget Sound and the Strait of Juan de Fuca over the same period. Previous studies documented widespread declines in productivity of natural Chum stocks throughout Washington beginning in brood year 1996. Contrary to this result, we found productivity increases in Chum beginning in brood year 2006, and an overall significant increase in abundance over the time series. Increases in natural Pink and Chum populations in recent years is counter to population trajectories documented in other Pacific Salmon stocks within Puget Sound. We also found that regional and basin-scale environmental indicators, such as sea surface temperature and the North Pacific Gyre Oscillation Index, were positively associated with Pink and Chum productivity, a result that could help improve forecasts for these populations. Our results suggest that while environmental variability can drive productivity in natural populations of Pink and Chum Salmon within Puget Sound, other factors such as reduced competition during periods of poor ocean conditions may be equally important in determining productivity.

Effects of Asian Pink Salmon and Chum Salmon on the Growth of Western Alaska Chum Salmon

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Poor returns in western Alaska stocks of Chum Salmon (*Oncorhynchus keta*) have been accompanied by reductions in growth, body size, and increases in age at maturity throughout the species' range. Western Alaska Chum Salmon reside in the Bering Sea during their summer foraging months where they overlap with abundant populations of Russian Pink Salmon (*O. gorbuscha*) (primarily wild origin) and Japanese Chum Salmon (primarily hatchery origin). Spatial and diet overlap suggests that inter- and intra-specific competition may contribute to reduced growth and increased age at maturity of western Alaska Chum Salmon. We investigated the potential for such competition to influence the growth of western Alaska Chum Salmon growth using retrospective scale analysis. Chum Salmon scale samples were collected through escapement and harvest projects in Bethel, Alaska, during 1973-2014, and from incidental catches of Chum Salmon in the Bering Sea Aleutian Island Walleye Pollock *(Gadus chalcogrammus*) fishery during 2001–16. Linear mixed-effects models demonstrated a strong negative relationship between Bethel Chum Salmon growth and the abundance of Japanese hatchery Chum Salmon. Chum Salmon intercepted in the Bering Sea did not exhibit increased growth during 2012–14, despite reductions in Japanese hatchery releases of Chum Salmon in 2011 as a result of the Tohōku Earthquake. We did not observe a direct relationship between Bethel Chum Salmon growth and the abundance of wild Russian Pink Salmon. Understanding how salmon populations interact while at sea has important management implications, particularly as Pacific Rim nations consider increasing production of hatchery salmon.

Spawning Habitat Characteristics and Phenology of Fall Chum Salmon (*Oncorhynchus keta*) on the Teedriinjik River, Alaska

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Spawning site selection by Pacific salmon is influenced by physical and chemical habitat characteristics that influence embryonic developmental rates and can result in variation in hatching and emergence timing within and among species. In sub-Arctic rivers, groundwater-surface water interactions result in a wide variety of thermal habitat conditions, but the effects on early life history phenology are unknown. We measured water chemistry (conductivity, dissolved oxygen, and pH) and physical habitat characteristics (water temperature, water velocity, and substrate composition) at 11 sites representative of three geomorphic channel types (primary, flood, and spring), and used continuous water temperature data to assess overwinter thermal trends experienced by incubating fall chum salmon (*Oncorhynchus keta*) embryos along the Teedriinjik River, Alaska. Spawning habitat characteristics including mean temperature, conductivity, and vertical hydraulic gradient differed by channel type. Temperature was negatively correlated with dissolved oxygen and pH, and positively correlated with conductivity. Predicted hatching timing for primary, flood, and spring channels was 121 d, 142 (± 68 SD) d, and 149 (± 23 SD) d, respectively. The temporal extent of our data were only sufficient to predict emergence in flood channels, resulting in a mean predicted emergence of 222 (± 49 SD) d. The Teedriinjik River is a consistently strong producer of fall chum salmon in the Yukon River Basin, but nearby tributaries such as the Fishing Branch River have experienced drastic declines in fall chum numbers. Information provided by this study will assist natural resource managers in understanding the causes of this regional variation, and help them prepare for the effects of future climate and anthropogenic change in the region.

Alaska Hatchery Research Program: Overview of an Ambitious Examination of Hatchery–Wild Interactions

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Ocean-ranching, private non-profit hatcheries produce one third of salmon harvested annually in Alaska. The vast majority of this hatchery production is of Pink Salmon in Prince William Sound and Chum Salmon in Southeast Alaska. Previous research on the potential fitness consequences to wild salmon due to hatchery-wild interactions is not sufficient, as most research has been conducted outside Alaska where the magnitude of releases, habitat quality, program goals, and species cultured differ greatly from the Alaska model. Given the commercial value of hatchery production, the mandate that hatchery production be compatible with sustainable productivity of wild stocks, and the uncertainties regarding impacts on wild stocks, the Alaska Department of Fish and Game organized a science panel of experts to design a long-term research project (Alaska Hatchery Research Program; AHRP) to address this issue. The AHRP is addressing three priority issues: 1. What is the genetic stock structure of Pink Salmon and Chum Salmon in each region? 2. What is the extent and annual variability in straying of hatchery-origin Pink Salmon and Chum Salmon in each region? 3. What is the impact on fitness (productivity) of wild Pink Salmon and Chum Salmon stocks due to straying of hatchery-origin salmon in each region? The presentation will provide an overview of the AHRP in order to delineate the scope of the research and provide context for some preliminary AHRP results presented by other authors at this symposium.

Relative and Total Contributions of Hatchery- and Natural-Origin Pink Salmon and Chum Salmon Returning to Prince William Sound, Alaska, During 2013–15

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Coauthors: E. Eric Knudsen, K. Gorman, M. Buckhorn, D. Bernard

We report on results of the Alaska Hatchery Research Program (AHRP) focused on estimating the contribution of hatchery- and natural-origin Pink (*Oncorhynchus gorbuscha*) and Chum (*O. keta*) Salmon to Prince William Sound (PWS), Alaska (2013–15). Data are from ocean test fishing at 9 stations and carcass surveys in 32 streams in PWS. We explained variability in the odds ratio (OR) of observing hatchery-origin salmon using a binomial general linear model across sampling strata (ocean stations and stream districts) in addition to other covariates. We produced unbiased estimates of the fraction of hatchery-origin salmon in the run by applying measures of abundance (CPUE from test fishing and carcass counts in stream surveys). We found significant differences in OR by year, day of year, ocean station and stream districts. We found OR to be greater during 2014 for Pink Salmon that reflects lower returns of natural-origin salmon during even years. We observed greater use of the eastern-most stations by natural-origin Pink Salmon suggesting wild fish may select certain migratory paths for entering PWS. The western-most test fishing station in the eastern PWS entrance exhibited consistently high OR for Chum Salmon over the season and may be related to hatchery-origin fishing homing to the Point Chalmers remote release site (Montague Island). Results from OR for Pink Salmon across stream districts revealed a clear east-west pattern that indicates higher likelihood of observing hatchery strays in western PWS streams. The OR for Chum Salmon was highest in the Montague Island district in PWS. The hatchery fraction of the run measured by test fishing over three years was 54.9–86.4% (Pink Salmon) and 51.1–72.5% (Chum Salmon). Hatchery fractions in the escapement based on stream sampling ranged from 4.4–14.8% (Pink Salmon) and 2.8–3.2% (Chum Salmon).

Comparative Performance in Migration and Reproduction Between Natural- and Hatchery-Origin Pink Salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska Using Stable Isotope Analysis

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Coauthors: Julia M. McMahon, Peter S. Rand, E. Eric Knudsen

We report on a one season pilot project conducted in 2015 testing the null hypothesis that hatchery-origin Pink Salmon (*Oncorhynchus gorbuscha*) are similar in their at-sea foraging strategies to natural-origin conspecifics in Prince William Sound (PWS), Alaska, and therefore similar in their migratory timing, body condition, and spawning performance. Research is based on tissue-specific carbon and nitrogen stable isotope (SI) values (13C and 15N) as biogeochemical proxies of foraging. Our work is motivated by studies of interactions among PWS natural- and hatchery-origin Pink Salmon by Alaska Department of Fish & Game that have focused on quantifying fractions of hatchery salmon on spawning streams and understanding possible impacts hatchery spawning has on the survival of natural-origin offspring. This project adds a mechanistic perspective by considering at-sea foraging determinants of performance in migration and reproduction that might shape individual fitness. The at-sea life histories of Pacific salmon are not well understood and few studies have used SI techniques to test ideas about within-species variation in foraging and relationships with performance factors. We discuss results from Pink Salmon captured at the ocean entrances to PWS during migration, and on 11 streams throughout PWS during spawning. Ocean and stream analyses examined relationships between male or female body size and condition with foraging based on 13C and 15N variability in muscle and liver tissue, timing of migration, hatchery- or natural-origin status, and interactions between these variables. Ocean and stream datasets were further examined to assess relationships with fitness correlates including gonad mass, female fecundity and egg size. Our work lends insight on Pacific salmon oceanic ecology and relationships with migration and spawning performance factors. The work also provides an initial assessment of variability in life history parameters between hatchery- and natural-origin Pink Salmon in Alaska.

Stress, Straying, and Performance on the Spawning Grounds by Hatchery-Produced Chum Salmon in Southeast Alaska

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Hatchery programs around the Pacific Rim release approximately five billion Pacific salmon each year into the North Pacific Ocean, prompting concerns about interactions with wild counterparts. Straying of hatchery-produced individuals mediates interactions with wild spawning populations, though relatively little is known about neither the proximate factors shaping straying, nor the performance of strays on the spawning grounds. In this talk, we present results that explore the potential influence of stress on homing and straying rates of hatchery-produced salmon by comparing cortisol concentrations between those that have homed (correctly returning to imprinting location) to those that strayed (returned to location other than release site). Cortisol levels were associated with fitness-proxies such as the number of days a fish lived on the spawning grounds and extent of egg retention in females. As an additional proxy for stress, we quantified the frequency of abnormal vateritic otolith development between homing and straying hatchery-produced salmon. Finally, we assessed the potential for otolith thermal marking, a widely used approach that exposes developing individuals to abrupt temperature fluctuations to induce a visible mark within the otolith, to influence rates of vaterite occurrence. No differences were found between hatchery-produced chum that had homed or strayed in cortisol concentrations of either males (stray = 113.4 ± 99.7 ng/ml; home = 124.66 ± 113.81 ng/ml) or females (stray = 329 ± 208.9 ng/ml; home = 294.12 ± 134.8 ng/ml) or rates of vaterite occurrence (stray = 40% vaterite; home = 45% vaterite). Instream lifespan was negatively correlated with cortisol concentrations, though egg retention rates were not related to cortisol concentration. There was a slight, though not statistically significant, increase in vaterite occurrence in individuals with high thermal mark intensities (low = 32%, medium = 32%, high = 39%). The lack of differences in cortisol concentrations and rates of vaterite occurrence between correctly homing and straying groups suggest that straying is not significantly linked to these physiological measures, at least on the spawning grounds. Although increasing mark complexity did not correlate with higher rates of vaterite occurrence, natural-origin fish had on average 24% lower rates of vaterite than their hatchery-produced analogs, consistent with results from other researchers.

Ecological Barriers and Bridges to Introgression of Hatchery-Produced and Natural-Origin Pink Salmon in Prince William Sound, Alaska

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Hatcheries are integral to many salmon fisheries in the North Pacific, yet straying of hatchery produced salmon is of conservation concern because of competition and reproductive interactions on the wild spawning grounds may detrimentally affect wild populations, result in lost yield to harvesters, and complicate management decisions. Enhancement hatcheries in Alaska are the largest in the world, with over 1.5 billion juveniles of all salmon species released annually, and no region releases more juvenile pink salmon (*Oncorhynchus gorbuscha*) than Prince William Sound (>630 million). Recent studies have reported consistently large numbers of strays on the wild spawning grounds of Prince William Sound, raising concerns of hybridization, outbreeding depression, and competitive interactions. While substantial work has gone into quantifying the rates of recipient straying (i.e., the proportion of a spawning population that is comprised by strays), comparably little is known about the ecology of those strays on the spawning grounds. In this talk I report on results of a pilot study in cooperation with a the Alaska Hatchery Research Project, in which I tagged 200 pink salmon in Paddy Creek; 100 in early August and 100 in late August, and recovered 77 specimens with otoliths that were distinguished to origin by post season otolith readings ($n = 31$ early, $n = 46$ late). The individuals of the early release group were all of natural origin and a Bartlett's test of in-stream life span (a phenotypic trait associated with fitness) of recovered individuals showed that in-stream life span was highly variable in the early release group ($p < 0.05$). This is most likely from increased risk of bear predation because this result is consistent with other salmon studies involving high bear predation rates in small streams. The later release group had both hatchery and natural origin individuals. There was homogenous variance of in-stream life-span and a t-test indicated that in-stream life span was significantly different by origin ($p < 0.05$), with hatchery fish living 2 days less than natural fish on average. The sample size for these results is small and un-replicated, but it provides exciting preliminary results and framework to pursue a larger tagging effort in 2018.

Population Structure of Even-Year Pink Salmon from Prince William Sound, Alaska

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Pink salmon (*Oncorhynchus gorbuscha*) are commercially and ecologically important in Prince William Sound (PWS). Along with natural production, four private non-profit (PNP) hatcheries in PWS also provide salmon for harvest. These hatcheries contribute 55–86% of pink salmon returning to PWS, and result in hatchery proportions in the escapement ranging from 4% to 15% (2013–15). The scale of the hatchery programs raised concerns that hatchery fish may influence the productivity of wild salmon through domestication selection and erosion of local adaptations. Hatchery operators proposed that ADF&G organize a science panel of experts to design and implement a long-term research project to inform future resource management decisions. The panel identified understanding population structure of PWS pink salmon as one of the primary research questions. Pink salmon have a 2-year lifecycle and thus there are 2 separate lineages in PWS. Previous examination of population structure of PWS pink salmon in an odd year (2013) found low, but significant differences among population structured by geography. Here, we used variation at 16 microsatellite loci from approximately 6,500 samples collected across time from spawning pink salmon in 30 locations in an even year (2014). Population divergence in the even-year broodline (FST = 0.0008) was less than that of the odd-year broodline (FST = 0.0020). This pattern is similar to the structure found in both even and odd-year pink salmon in British Columbia and Washington. Distinctions between early and late return timing (not tested with odd-year samples) were detected within several stream systems. Similar to the odd-year analysis, Solomon Gulch Hatchery in the northeastern region was most distinct of all regions. Future analyses will compare population structure of these contemporary samples to historic collections from the 1990s. This last phase will provide insights regarding introgression from hatchery to wild spawning aggregates.

An Evaluation of Collaborative Salmon Fishery Management in Prince William Sound, Alaska

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Collaborative decision-making is often promoted as a means to achieve socially acceptable and enduring solutions to natural resource management issues, and one that holds promise for resolving “wicked” problems. However, success rates for implementation of collaborative recommendations are unknown. The presenter’s graduate program explored challenges to collaborative salmon fishery management in Prince William Sound (PWS), Alaska, based on experience made possible through internship service on the Prince William Sound Aquaculture Corporation (PWSAC) Board of Directors. Three constraints to collaborative salmon fishery management in PWS were identified, including: (1) PWS citizens’ mistrust of public managers, (2) recent and ongoing reductions to the State of Alaska’s budget, and (3) a lack of individual and organizational capacity among the area’s prospective collaborators. The presentation then identifies several broad lessons to consider when collaborating, including: (1) the importance of selecting participants who possess relevant knowledge and who are willing to compromise, (2) an awareness and acceptance of the significant resources and time that collaborations require, (3) the availability of organizational capacity to support these endeavors, and (4) the availability of individuals with the credibility and skills required to effectively lead collaborations. The presentation concludes with some recommendations for the area’s fishery participants to consider when attempting collaborations in the future.

Discussion for Future Workshops

The Pink and Chum Salmon Workshop has found a new home with the Western Division of the American Fisheries Society. Please check out https://wdafs.org/northeast-pacific-pink-chum-salmon-workshop/ for background on the workshop and for all future meetings. We will also be adding PDFs of proceedings from past meetings.

Proceedings of the 28th Northeast Pacific Pink and Chum Salmon Workshop 2020

Bend, Oregon
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Compiled by

Kathleen G. Neely

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Acknowledgments

The Workshop chairs—Kathleen Neely, Kristen Homel, and Peter Rand—would like to thank the Oregon Chapter of the American Fisheries Society for allowing the Pink and Chum Salmon Workshop to be a full session during the Annual Meeting.

Preface

The theme of the 2020 Oregon Chapter AFS Annual Meeting was "Beyond Resilience." This theme was to encourage attendees to consider how to "create, support and sustain integrated systems (social, political, economic and ecological) that can benefit and thrive under increasing disturbance and disorder." The 28th Pink and Chum Salmon Workshop was integrated into this meeting with the understanding that the workshop would be permanently connected with the Oregon Chapter. There was a fair amount of discussion as to whether or not this meeting would occur as the beginning of the COVID-19 pandemic was shutting down in-person activities across the country. In keeping with the theme, participants exhibited a resilient nature, and the meeting did occur in person.

Our keynote presenter was Dr. Karen Dunmall who presented on a program, called "Arctic Salmon," that is guided by community-driven and community-led monitoring and research of freshwater and coastal ecosystems. This program monitors abundance and distribution trends for salmonids and also notes the presence of unusual fishes across the Canadian Arctic. Dummall's research includes working with community groups and harvesters in Canada, Alaska, and Norway and can be followed on social media: www.facebook.com/arcticsalmon.

Other topics in the workshop included methods to understand abundance and productivity in Puget Sound Chum Salmon, population structure of Pink Salmon from Prince William Sound, reintroduction programs, escapement calculations, recovery strategies, and survival in a warming climate. The workshop culminated in a roundtable discussion to brainstorm on various topics related to pink and chum salmon, exchange information on data collections, and strike up conversations on possible collaborations. This workshop was well attended, and it is the hope of the organizers that the Pink and Chum Workshop will continue in the future.

2020 Workshop Agenda

Wednesday, 4 March

Moderator: P. S. Rand

Thursday, 5 March

Moderators: K. G. Neely and K. Homel

Plenary

Karen Dunmall, Ph.D.

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Karen received her Master of Science from University of Waterloo, and her PhD in biology from the University of Manitoba. She now works as an Arctic Aquatic Biologist for Fisheries and Oceans Canada, studying coastal ecosystems and biodiversity shifts of fishes in the Canadian Arctic.

Arctic Salmon: Community-Led Initiatives Bridge to an Arctic "Beyond Resilience"

Karen Dunmall

Coauthors: Darcy McNicholl, Zander Chila, Colin Garroway, Trevor Lantz, Jim Reist

Anthropogenically driven climate change is altering habitats, fish distributions, and ecosystem relationships in the Canadian Arctic at an unprecedented rate. Accordingly, adaptation to changes by developing responses that promote understanding and sustainability in the context of ongoing change is required. Monitoring, understanding, and adapting to these changes, however, is exceedingly difficult given the remote and harsh Arctic environment, the rates of change, the lack of basic information about aquatic species and their habitats at high latitudes, and absence of clear end points associated with the changes. Knowledge, informed responses, and delivery of responses by local communities is essential to effective adaptation by Arctic resource users. Here we present several examples of community-based and community-led initiatives developed to monitor changing fish biodiversity, key freshwater habitats, and coastal ecosystems in the Canadian Arctic, and which facilitate local adaptive responses. A Canadian Arctic-wide community-based monitoring project, called Arctic Salmon, is documenting increasing abundances and distributions of Pacific salmon, Atlantic salmon *Salmo salar*, and other "unusual fishes" in subsistence harvests, and is providing appropriate samples to understand biological and related ecosystem responses to climate change. We describe a novel framework to successfully apply citizen science to monitor rapidly shifting fish biodiversity in the Canadian Arctic. We also describe an approach, which can be community-led, to monitor key environmental parameters in critical freshwater habitats for native fishes, and to predict watersheds vulnerable to colonizations by salmon. We have also begun to document local and traditional knowledge about salmon and the changing aquatic environments to

better understand factors influencing biodiversity shifts. Finally, we extend this approach to "Arctic Coast" to assess coastal ecosystems across trophic levels in a transferrable way to transition into a community-led, year-round initiative for the Canadian Arctic. By coordinating, sharing, and building upon local, traditional, and scientific knowledge in a rapidly changing environment, we can better adapt to changes, manage fishery development opportunities, and predict the conservation impacts in a future Arctic.

Oral Presentations 2020

Patterns of Occurrence of Hatchery-Origin Pink Salmon in Five Streams in Western Prince William Sound, Alaska

Peter S. Rand
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Since 2013, a collaborative field project in western Prince William Sound, Alaska, has focused on sampling the origin of adult pink salmon in five small spawning streams. Here we report on patterns in P(H) (probability of occurrence of hatchery-origin pink salmon on the spawning grounds) observed during 2013–17. Result of analysis of 57,626 otoliths over 5 years will be presented. We analyzed the probability of occurrence of hatchery-origin fish using a generalized linear model with the following covariates: year of sampling, day of sampling, and distance upstream of the low tide line. A stream on southern Knight Island near Montague Entrance was found to have the highest overall P(H) (mean = 0.5), whereas the other 4 streams exhibited lower occurrence probabilities (<0.25). The year 2014 was marked with the highest occurrence of hatchery-origin fish (mean = 0.78), and there appears to be a trend of lower P(H) in more recent years in the time series. Hatchery-origin pink salmon tended to arrive later in the season, and were found disproportionately present in upstream, freshwater habitat (as opposed to intertidal habitat), which likely has consequences for reproductive fitness. Recent years have been marked by pre-spawning mortality resulting from drought conditions. I will emphasize the importance of this study and how it might affect the management of wild and hatchery pink salmon in Prince William Sound and elsewhere.

Relative Fitness of Hatchery and Natural Pink Salmon in Prince William Sound: Part I, Methods

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Coauthors: Emily Lescak, Heather Hoyt, Tyler Dann, Chris Habicht

Private non-profit hatcheries practice extensive ocean-ranching aquaculture of Pacific salmon in Alaska. Most of the 1.8B juvenile salmon released annually by hatcheries are Pink Salmon (*Oncorhynchus gorbuscha*) in Prince William Sound (PWS) and Chum Salmon (O. keta) in Southeast Alaska. While policies exist to reduce risk to natural stocks, the scale of these hatchery programs and documented hatchery straying into streams has raised concerns regarding the long-term impact of hatchery-origin fish on the productivity and sustainability of natural stocks. We used genetic parentage analysis to estimate the relative reproductive success (RRS) of stray hatchery-origin versus natural-origin Pink Salmon for the first time in two streams in PWS for one generation in both odd- and even-year lineages. We reconstructed pedigrees for brood years 2013 and 2014 for Hogan Bay and Stockdale Creek by combining origin information from thermal otolith marks with parentage information from genetic data analyses of > 17,000 fish for 298 single nucleotide polymorphism amplicons. This research is part of the larger Alaska Hatchery Research Program that seeks to better understand hatchery and natural-origin interactions and inform resource management decisions regarding future hatchery production in Alaska.

Relative Fitness of Hatchery and Natural Pink Salmon in Prince William Sound: Part II, Results

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We present the first study to directly measure the relative reproductive success (RRS) of hatchery- and natural-origin Pink Salmon (*Oncorhynchus gorbuscha*). We examined both odd- and even-year lineages for two streams in Prince William Sound, Alaska (PWS) to provide pseudo-replicate measures of RRS. Reproductive success, measured as adult progeny that return and die in the stream, was significantly lower for hatchery-origin versus natural-origin parents from both lineages. However, while reproductive success was significantly lower for hatchery females in both streams and lineages, the reductions in male reproductive success were not always statistically significant. Generalized linear modeling indicated that reproductive success was lower in hatchery-origin fish after accounting for covariates such as sample date (run timing), sample location within the stream, and fish length. These are the first in a series of RRS analyses under the Alaska Hatchery Research Program (AHRP), which will ultimately include replicate analyses in other streams that will provide more power to investigate cross-type effects (matings between natural- and hatchery-origin fish), and the potential to explore inter-generational effects to determine whether decreased reproductive success is ephemeral (effects a single generation) or long-term (effects multiple generations). If reductions in fitness are replicated, important questions will remain regarding the mechanisms driving the effect and its persistence into future generations. Identifying driving mechanisms behind reductions in fitness and the potential for persistent effects across generations will be important to inform policy makers on how best to balance the economic value of hatchery programs with the potential for risk to wild stocks.

Investigation of Contemporary Population Structure of Pink Salmon from Prince William Sound, Alaska

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Pink salmon (*Oncorhynchus gorbuscha*) support a valuable commercial fishery in Prince William Sound (PWS). Private non-profit hatcheries in PWS contribute approximately 90% of the returning pink salmon and these fish are harvested at higher proportions than wild fish. Despite this high harvest level of hatchery-origin fish, hatchery proportions in wild streams range from 0.0% to 91.5% in wild drainages. The impact of hatchery fish on wild fish is of concern. These hatcheries used local fish as broodstock to seed the hatcheries in the late 1970's and early 1980's. An understanding of contemporary population structure of pink salmon is a first step in assessing the potential genetic interaction of hatchery fish spawning in the wild. In this study, we examined variation at 16 microsatellite loci from approximately 10,000 samples. Those samples were collected from 27 locations in the odd-year broodline (years of 2013 and 2015) and from 30 locations in the even-year broodline (year of 2014). Only natural-origin fish were examined from wild systems. The structure among populations at fine-and broad-spatial scales and between early and late return timing was investigated. A fixation index, FST, in the odd-year broodline was 0.002, whereas it was 0.001 in the even-year broodline. Distinction between early and late return timing was observed within several, but not all, streams. Collections from the only hatchery in northeastern PWS, located at the head of a long fjord, were distinct from other collections from other PWS districts in both broodlines. Early returning fish from Snug Harbor Creek, a location close to one large hatchery and likely along the migration corridor for all other hatcheries in PWS, were the most divergent collections in both odd-year and even-year broodlines. This last finding was unexpected and we look forward to exploring hypotheses at the workshop.

Revealing Patch Attractiveness to Straying Hatchery Chum Salmon in Southeast Alaska

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The straying of hatchery salmon produced in harvest enhancement programs results in lost yield to fishermen and mediates interactions between strays and wild fish on the spawning grounds. Previous work has revealed a strong influence of distance between release locations and sites where hatchery fish ultimately stray, but other evidence suggests additional features of recipient sites may similarly attract hatchery strays. In this talk, I review what is known and not known about site-specific attractiveness to hatchery salmon and describe a new project seeking to further elucidate patterns of dispersal within Southeast Alaska chum salmon metapopulations. I describe a modeling approach that considers collective movement ecology as well as site-specific streamflow models while accounting for hydrological distances among sites. Understanding and identifying the biotic and abiotic factors shaping site-specific attractiveness to strays with this model will allow for more accurate accounting of wild fish escapement and facilitate planning of release locations to avoid locations of highly attractive streams. Taken as a whole, this project seeks to support Alaska's intention to avoid interactions of hatchery and wild fish on the spawning grounds because of the well-known detrimental ecological and evolutionary impacts on wild fish.

Intertidal Influences on Winter Stream Temperatures and Duration of Incubation for Pink and Chum Salmon Eggs in Coastal Alaska

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Projections of climate change impacts on Pink and Chum Salmon should consider changes in the thermal regimes of both freshwater streams as well as the near-shore ocean environment. Freshwater spawning habitat in the steep-walled fiords of Alaska's Prince William Sound (PWS) is limited because, within short distances from the ocean, streams become steep and the bed sediment becomes too coarse for spawning. Previous research has shown that, in some PWS streams, more than half of the Pink Salmon spawn in the intertidal zone, even when freshwater spawning habitat is accessible and uncrowded. Water temperature monitoring in streams throughout PWS showed that temperatures in non-glacial, freshwater streams closely followed air temperatures, but in both the surface and subsurface of intertidal reaches, temperature periodically spiked during winter high tides -often rising from near 0 °C to 4 °C. Surface ocean temperatures do not follow air temperatures because of deep mixing of ocean waters. Thus, PWS functions as a large thermal reservoir and maintains ocean surface temperatures close to 4 °C. When ocean water floods intertidal reaches, relatively warm ocean water intrudes into the streambed sediment, displacing colder freshwater. The height of a redd above the low tide line determines the duration of tidal inundation and the salinity, temperature, and dissolved oxygen concentration of water in the redd.

We modeled incubation of Pink and Chum Salmon eggs from daily temperature data, comparing intertidal reaches with adjacent freshwater reaches. We found periodic warming from ocean water intrusion increased the over-winter accumulation of thermal units leading to shorter incubation duration and earlier emergence. The tidal interactions between surface ocean water and freshwater create steep environmental gradients over a few 100's of meters of stream. Over the long-term, selection for freshwater versus intertidal spawning locations will lead to very different pressures from climate change.

Rethinking Survey Life Values for Use in Annual Chum Salmon (*Oncorhynchus keta*) Escapement Calculations

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Coauthors: Lea Ronne, Marisa Litz

Area-Under-the-Curve (AUC) calculations using live-counts of salmon is a common method used by fisheries managers to estimate escapement of spawning salmon species such as Chum (*Oncorhynchus keta*), Pink (*O. gorbuscha*), and Sockeye (*O. nerka*). Escapement is derived by dividing AUC abundance by a survey life value, which is the duration a spawner can be detected in a survey area. Throughout Washington, a standard survey life of 10 days is assumed for Chum salmon. However, survey life can vary within and between watersheds and from year-to-year. Ideally, unique survey life estimates should be calculated each year for varying stream sizes to determine if stream conditions are leading to shorter or longer residence times for spawning salmon. Over the three years of this study (2017-2019), we collected weekly live counts of Chum salmon in a range of stream reaches in Grays Harbor tributaries in Washington. Live chum were designated as either spawners or holders. A carcass mark–recapture effort was conducted and analyzed using a Jolly-Seber open population approach to determine unbiased abundance estimates of total chum spawners in a subset of the stream reaches. Unique survey life estimates delineated by stream size were derived using live-fish counts and mark-recapture abundances. Survey life estimates varied from as low as 7.5 days in a medium stream to as high as 13.4 days in a small stream. The survey life estimates were sensitive to the spawner vs. holder designation used for live fish, resulting in a difference of up to 3.9 days depending if survey life was calculated with spawner only or total live counts. Using spawner only counts resulted in shorter survey life values and higher abundance estimates than when using total live counts. We recommend using spawners only counts as it reduces the likelihood of double counting the same fish in multiple survey areas. In addition, using unique survey life values could result in more accurate spawning abundance estimates that account for differences in stream size, flow regimes, or other sources of interannual variation.

Fraser River Pink Salmon: Comparing Run Size Estimates Based on Two Different Methods

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Fisheries targeting pink salmon (*Oncorhynchus gorbuscha*) returning to the Fraser River in British Columbia are managed bi-laterally by Canada and the United States under the Pacific Salmon Treaty. Making decisions regarding fishing opportunities for pink salmon can be challenging because pink salmon returns are highly variable from year to year, and occur in a relatively short time period. The Pacific Salmon Commission (PSC) is responsible for providing both countries with in-season estimates of the Fraser River pink salmon daily abundances in marine areas and in the lower river, as well as updates for the expected total run size and timing of the run. Two methods are used to produce these estimates: a test-fishing-based method and a hydroacoustics-based method. Catch-per-unit-effort data from marine test fisheries provide an early prediction of the pink salmon return, but assessments are uncertain due to low catchability and highly variable estimates of historical catchability. A hydroacoustics program in the lower Fraser River provides higher precision estimates of daily escapement and is used to produce marine reconstructions of the pink salmon run, but this information is often not timely enough to inform fisheries management decisions for marine areas. We compare several years of Fraser River pink salmon run size estimates using test-fishing-based and hydroacoustics-based methods. We discuss strategies to overcome challenges in producing timely, accurate, and precise in-season pink salmon run size estimates, as well as what can be learned from comparing these two methods.

Competition Between Pink and Chum Salmon Is Mediated by Environmental Variability in Natural Populations from Washington

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Natural populations of Pink (*Oncorhynchus gorbuscha*) and Chum (*O. keta*) Salmon make up the highest abundances of Pacific salmon in Washington, USA and in many cases spawn in the same watersheds. Pink Salmon predominantly return in odd years, and for Chum Salmon, stocks interacting with Pink Salmon exhibit strong even- and odd-year variations in size, age-at-maturity, and productivity. In this study, we investigated the effects of competition between natural populations of Washington Pink and Chum Salmon during all life history phases over five decades. Chum run sizes were <50% lower in pink years compared to non-pink years and productivity was more likely to be negative in odd (pink) brood years, even along the coast, where there are no Pink Salmon populations, suggesting that competition during the overlapping marine period may be most critical for establishing the distinct even- and odd-year patterns. We used dynamic factor analysis to evaluate long-term observable and hidden trends in Pink and Chum productivity. We also evaluated the influence of marine survival indicators such as sea surface temperature, Pacific Decadal Oscillation (PDO), and North Pacific Gyre Oscillation (NPGO) on productivity trends and whether Pink exerted competitive control over Chum productivity through time. Our results indicate that Chum may be showing a long-term, multi-decadal decline in productivity starting in the mid- to late 1990s, while Pink are showing a more recent decline in productivity occurring over the past decade. These trends were strongly associated with PDO in both salmonids, however, NPGO and Pink abundance may be playing a weaker role, suggesting that productivity patterns, and hence marine survival, are likely determined by a suite of temporally varying oceanographic and ecological processes that occur during the first few years of growth.

Linking Scale Growth to Variation in Puget Sound Chum Salmon Abundance and Productivity

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Coauthors: Andrew Claiborne, Marisa Litz, Mickey Agha, Lance Campbell

An improved understanding of the mechanisms that influence productivity and abundance of Puget Sound (PS) Chum Salmon is critical for accurately determining the number of harvestable fish and for identifying years of conservation concern. Recent research has found environmental factors (e.g., Pacific Decadal Oscillation) and the abundance of potential competitors (Pink Salmon) during the first few years of marine life are related to trends in age-at-maturity and productivity of PS Chum Salmon. Relatively little, however, is known about how marine growth varies in relation to environmental factors and population productivity for PS Chum Salmon. The two primary objectives of this study are A) to identify the relationship between environmental factors, population productivity, and marine growth in PS Chum Salmon, and B) to develop stock-specific indicators of survival and productivity that utilize marine growth and environmental factors for forecasting. The study is focused on 3 spatially distinct stocks: Skagit River, South Sound, and Hood Canal fall-run Chum Salmon that exhibit decreasing, stable, and increasing productivity, respectively. We analyzed n = 4,320 scale samples of fish from brood years 1997–2012 to estimate growth during each year at sea for returning age classes 31, 41, and 51. We will present relationships between marine growth, population productivity, population abundance, and a variety of abiotic and biotic indices including Pacific Decadal Oscillation, North Pacific Gyre Oscillation, sea surface temperature, and Pink Salmon abundance. Indices will be incorporated into a multivariate framework and models that best capture variation in productivity will be ranked after undergoing hind-casting validation. The results of this study lead to better understanding of the ocean ecology of Chum Salmon and could improve pre-season forecast performances, as current estimates are largely derived from naive models of recent year recruit-per-spawner averages that are insensitive to years of unusually low and high survival.

Pink and Chum Salmon on the High Seas: New Insight from a Winter Expedition to the Gulf of Alaska

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Pacific salmon spend the majority of their life in the ocean, but many details are poorly understood. For example, we only have a vague sense of where they go, what they eat, or how fast they grow during the 1–5 years that salmon typically spend in marine waters. We know the least about winter, when there may be so little to eat that fish risk starving to death. To begin to understand this winter period, the International Gulf of Alaska Expedition spent a month in late winter 2019 in the Gulf of Alaska studying salmon on board the Russian Research Vessel Professor Kaganovskiy. This expedition was a signature event for the International Year of the Salmon (yearofthesalmon.org/). Laurie was fortunate to serve as one of 21 scientists representing U.S., Canada, Russia, Japan, and South Korea on the expedition. This talk will describe the initial findings from the expedition (with many more to come once 1,000s of collected samples are analyzed), with an emphasis on the winter ecology of pink and chum salmon.

Predicting the Freshwater Range of Occurrence for Chum Salmon to Guide Restoration Efforts in the Chehalis River Basin, WA

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Understanding the factors influencing the distribution of species in time and space is a fundamental goal of ecology and a crucial component for effectively managing and recovering populations. The fragmentation of habitat restricts the ability of local populations to exploit heterogeneous patches of habitat that shift in suitability over time and space, and is an on-going threat to the persistence of freshwater fishes. A large-scale restoration effort of salmonid habitats in the heavily altered Chehalis River basin in southwest Washington requires science-based guidance to maximize restoration effectiveness. The current study will provide a robust model of freshwater distribution, allowing habitat gains from restoration actions to be more accurately represented in the planning process. Freshwater fish distribution can be described by identifying the upper limit of occurrence, whereas all habitat downstream is potentially exploited during different life history stages. The objectives of this study are to (i) document the upper limit of occurrence of adult Chum Salmon (*Oncorhynchus keta*), (ii) identify the relationship between landscape characteristics and the range of occurrence, and (iii) estimate the potential freshwater range of occurrence of adult Chum Salmon in the Chehalis River basin based on observed distributions rather than relying on professional opinion. To do so, we fit a GIS-based logistic regression model parameterized with available landscape and environmental spatial data along with fish occurrence data collected from terminal streams in three sub-basins in 2017 and 2018 ($n = 59$). In this talk, I will discuss preliminary model results, which identify elevation and drainage area as important covariates for predicting chum range of occurrence (PCC = 0.88 ± 0.01; AUC = 0.95 ± 0.01). Our model estimates 3,221.4 km of potential habitat in the absence of anthropogenic obstructions. These results will inform discussions on the prioritization of restoration efforts by providing a quantitative description of chum habitat suitability.

Detecting Spawning of Threatened Chum Salmon over a Large Spatial Extent Using eDNA: Implications for Monitoring Recovery

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Chum Salmon were historically abundant in the Columbia River with estimated returns exceeding 1 million adults. Following rapid declines in the 1940s, Columbia River Chum Salmon were listed as threatened in 1999. Oregon and Washington developed recovery strategies aimed at increasing the viability of the species throughout their historical range in the Columbia River. Above Bonneville Dam, dam counts provide spawner abundance data but little is known about where spawning occurs. Spawning ground surveys may underestimate distribution and abundance, particularly for rare species, as they often have a limited spatial and temporal scope and are hampered by survey conditions. Trapping is costly and spatially constrained. In contrast, environmental DNA (eDNA) allows for the collection of samples across a broad spatial extent in a short period of time, and is cost effective and accurate, which makes it well-suited for identifying the presence of a rare species. In this study, we used eDNA to identify the spawning distribution of Chum in tributaries between Bonneville Dam and The Dalles. We successfully detected Chum Salmon DNA in four streams and in our positive control. We also conducted a pilot study examining potential contamination by surveyors. We walked in a small stream with contaminated waders and collected water samples before and after contamination. Chum Salmon DNA was detected up to 11 days after contamination. These results demonstrate that eDNA is a useful tool to improve our understanding of spawning distribution across a broad spatial extent. However, the potential for contamination from surveyors or anglers must be explicitly incorporated in the sample design. With these constraints, eDNA is useful for rapidly understanding distribution at a fraction of the cost that would be required with surveyors or trapping methods, and may serve as a companion to those techniques by refining the extent where surveyors could focus their efforts.

Distribution of *Ceratonova shasta* in the Lower Columbia River Basin and Effects of Exposure on the Survival of Juvenile Chum Salmon

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Chum Salmon populations in the Columbia River basin were listed as threatened under the Endangered Species Act and are the target of recovery efforts in Oregon and Washington. Despite those efforts, marine survival rates have remained depressed; marine survival averages 0.34%, as compared to the average of 1.8% observed in Chum Salmon populations from the remainder of the range. It is thought that the majority of mortality contributing to those rates occurs during the 2-3 month period of time beginning when fry leave the natal stream and extending through the first 1-2 weeks in the ocean. One potential mortality source for juvenile Chum Salmon is the parasite *Ceratonova shasta*. This parasite is endemic to the Pacific Northwest and has caused sometimes fatal infections in juvenile Chum Salmon outside of the Columbia Basin. The goal of this study was to assess the potential of *C. shasta* to limit the survival of juvenile Chum Salmon by identifying: (1) the spatiotemporal distribution and density of *C. shasta*, (2) the susceptibility of Chum Salmon fry to ambient levels of *C. shasta* in the Columbia River and tributaries, and (3) susceptibility to low and moderate levels of *C. shasta* under controlled conditions. In 2018 and 2019, we collected water samples from throughout the Columbia River and tributaries during the outmigration of juvenile Chum Salmon and used genetic-techniques to determine if the parasite was present. In 2019, we used sentinel exposures at three locations where *C. shasta* is present to determine infection rates across ambient spore densities. Lastly, we conducted lab experiments to determine infection and mortality rates under different exposure durations and spore densities *of C. shasta*. Results from these studies demonstrated spatio-temporal overlap between *C. shasta* and juvenile Chum Salmon and high susceptibility of Chum Salmon to infection (and death) from *C. shasta*.

Chum SNP Baseline Development and Implementation

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Population genetic baselines provide a foundation for fisheries research and management. Employing new advances in genome science, the WDFW Chum Salmon baseline now characterizes 73 populations throughout the northeastern Pacific with 350 single nucleotide polymorphisms (SNPs). With the high resolution of this baseline, researchers explore production and out-migration timing of different run groups in the same rivers in Hood Canal and Strait of Juan de Fuca, identify parents of returning spawners in the Columbia River to assess recovery strategies, and estimate components of mixed stock fisheries in Puget Sound to inform harvest allocation, especially for populations of conservation concern, and to improve run reconstruction. We are currently collaborating with Department of Fish and Oceans, Canada to expand the Chum SNP baseline to resolve mixed stock fisheries in the Southern Boundary region. The expanding SNP baseline for Chum Salmon is useful to multiple agencies managing Chum Salmon throughout the northeastern Pacific.

Washington Department of Fish and Wildlife's Lower Columbia River Chum Salmon Recovery Strategy

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WDFWs recovery strategy focuses first on protecting existing populations by protecting and/or enhancing existing habitat with high incubation survival & hatchery production if needed. For extirpated populations, the first priority is restoration or creation of high quality, off main-channel spawning and incubation habitat until natural process can create high-quality, off-channel habitat. Promote natural recolonization and/or use hatchery releases from genetically appropriate donor stocks to jump start populations. Initiate monitoring programs (Viable Salmonid Parameters, habitat, and hatchery effectiveness) to track progress and adaptively manage.

Washington Department of Fish and Wildlife's Lower Columbia River Chum Salmon Viable Salmonid Parameter Monitoring Program

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In response to their listing under the ESA in 1999, WDFWs Southwest Region Fish Program developed and implemented a robust Viable Salmonid Parameter (VSP) monitoring program for Washington State populations of lower Columbia River chum salmon. VSP monitoring is essential to evaluating population viability status and tracking recovery progress. The program includes Fish-in/Fish-out monitoring in multiple primary recovery populations to estimate productivity. An expansive stream survey program was initiated to document temporal and spatial diversity. Whenever possible, mark/recapture tagging programs are incorporated with stream surveys to generate unbiased and precise estimates of abundance. Tissue samples are collected annually from all populations and hatchery programs to be used for current and future genetics analyses. All hatchery-origin chum salmon produced in the lower Columbia River are marked prior to release via either thermal marks on their otoliths or through parental based tagging. Origin determinations based on these marks, scale ages, and population estimates are combined for run-reconstruction, as well as annual estimates of pHOS and pNOS by population and estimates of pHOB and pNOB for the hatchery programs.

Duncan Creek Chum Salmon Reintroduction Program: Results and Lessons Learned

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After nearly 40 years of absence, the replacement of a failing private dam in the late 1990s and the construction of a spawning channel in 2001 provided a unique opportunity to evaluate three reintroduction strategies simultaneously: natural straying from nearby populations, direct adult releases into the spawning channel, and releases of hatchery-origin fed-fry.

Poster Presentation

Warm and Wormy: The Climate Change Forecast Fish Fear!

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Coauthors: Kris Homel, Julie Alexander

As fisheries professionals, we tend to apply the techniques we are most familiar with to the problems we see, and then look for relationships. This approach can be improved upon by traveling outside of our lanes and examining other forces that affect ecosystems. Climate change is here and is changing the paradigm. One such shift is the balance between parasites and hosts. For example, ongoing studies have shown that *Ceratomyxa shasta* has expanded its range in the Columbia River Basin and that it is affecting salmonids negatively (Miller et al. 2014). This poster will outline life cycles of several parasites in a warming Pacific Northwest climate, and address the overarching questions on how these organisms may affect the success of host species, and how these changing dynamics may affect fisheries, recovery, and restoration planning. The focus will be on, but not limited to, investigations with salmonids and *C. shasta* in the Fraser River System and in the Puget Sound Region.

Northeast Pacific Pink and Chum Salmon Workshops

Year	Location	Chair(s)	Organization(s)
1962	Juneau, AK	T. Merrell	BCF
1964	Juneau, AK	D. Bevan	FRI
1966	Ketchikan, AK	C. Meacham	ADFG
1968	Juneau, AK	T. Merrell	BCF
1970	Prince Rupert, BC	A. Hartt	FRI
1972	Sitka, AK	R. Roys	ADFG
1974	Vancouver, BC	T. Bird	CDE
1976	Juneau, AK	J. Helle, K Koski	NMFS
1978	Parksville, BC	J. Mason	FMS
1980	Sitka, AK	A. Kingsbury	ADFG
1983	Orcas Island, WA	K. Fresh, S. Schroeder	WDFW
1985	Harrison Hot Springs, BC	B. Shepherd	CDFO
1987	Anchorage, AK	P. Mundy, K. Tarbox	ADFG
1989	Port Ludlow, WA	D. Phinney	WDFW
1991	Parksville, BC	D. Bailey, J. Woodey	CDFO, PSC
1993	Juneau, AK	B. Smoker	UA-Fairbanks
1995	Bellingham, WA	G. Graves, H. Fuss	NWIFC, WDFW
1997	Parksville, BC	P. Ryall	CDFO
1999	Juneau, AK	S. Hawkins	NMFS
2001	Seattle, WA	J. Hard, O. Johnson, K. Myers	NMFS, UW
2003	Victoria, BC	B. White, G. Bonnell	PSC, CDFO
2005	Ketchikan, AK	S. Heinl, R. Focht, A. Wertheimer	ADFG, DIPAC, NMFS
2008	Bellingham, WA	O. Johnson, K. Neely, L. Weitkamp, J. Hard, K. Adicks	NMFS, WDFW, UW, NWIFC
2010	Nanaimo, BC	J. Candy, M. Trudel	CDFO
2012	Juneau, AK	J. Orsi, E. Fergusson, S. Heinl	NMFS, ADFG
2015	Vancouver, BC	K. Neely, J. Hard	NMFS, AFS-WA/BC Chapter
2018	Anchorage, AK	K. Neely, P.S. Rand	AFS Alaska Chapter
2020	Bend, OR	K. Neely, K. Homel, P.S. Rand	AFS Oregon Chapter

ADFG: Alaska Department of Fish and Game; AFS: American Fisheries Society; BCF: Bureau of Commercial Fisheries (U.S.); CDE: Canada Department of Environment; CDFO: Fisheries and Oceans Canada; DIPAC: Douglas Island Pink and Chum, Inc.; FMS: Undefined acronym; FRI: Fisheries Research Institute; NMFS: National Marine Fisheries Service; NWIFC: Northwest Indian Fisheries Commission; PSC: Pacific Salmon Commission; UA-Fairbanks: University of Alaska-Fairbanks; UW: University of Washington; WDFW: Washington Department of Fish and Wildlife.

U.S. Secretary of Commerce
Gina M. Raimondo

Under Secretary of Commerce for
Oceans and Atmosphere
Dr. Richard W. Spinrad

Assistant Administrator for Fisheries
Janet Coit

January 2023

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