PROTECTING THE FUTURE OF SALMON

ARCTIC-YUKON-KUSKOKWIM SUSTAINABLE SALMON INITIATIVE

AYK SSI JUVENILE CHINOOK SALMON WORKSHOP

April 23-24, 2014
Egan Center, Anchorage

Risks and Benefits of Using Juvenile Salmonid Research to Understand Adult Population Dynamics

www.aykssi.org

AYK SSI c/o Bering Sea Fishermen's Association
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AYK SUSTAINABLE SALMON INITIATIVE

Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative

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INTRODUCTION to the AYK SSI

An Innovative Partnership Addressing the Urgent Research Needs Facing the AYK Region

Salmon runs of the Arctic-Yukon-Kuskokwim (AYK) region have been critical to the survival of the people and wildlife for thousands of years. Over eighty communities in the region heavily depend on the harvest of salmon, which forms the foundation of their subsistence diet. However, dramatic declines in salmon runs across the AYK region over the past decade have led to restrictions on subsistence fishing and closure of many commercial fisheries.

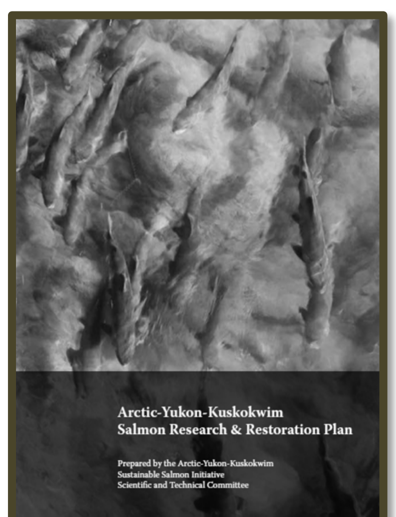
As a result, harvest restrictions have created tremendous hardships for the communities in a region with the highest subsistence dependence on salmon in the state, coupled with some of the lowest incomes in the state. In response to these declines, Bering Sea Fishermen's Association and regional Native organizations joined with state and federal agencies to create the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYK SSI), a proactive science-based program working cooperatively to identify and address the critical salmon research needs facing the AYK region.

Created via a Memorandum of Understanding in 2002, this innovative partnership includes: Association of Village Council Presidents; Tanana Chiefs Conference; Kawerak, Inc.; Bering Sea Fishermen's Association; Alaska Department of Fish and Game; National Oceanic and Atmospheric Administration; and the United States Fish & Wildlife Service. The AYK SSI is governed by an eight-member Steering Committee and advised by a six-member Scientific Technical Committee.

The first step for the AYK SSI was to collaboratively develop and implement a comprehensive research plan to address the AYK SSI's core goal:

To understand the trends and causes of variation in salmon abundance and fisheries through the assembly of existing information, gaining new information, and improving management and restoration techniques through a collaborative and inclusive process. (AYK SSI 2006)

The **AYK SSI Salmon Research & Restoration Plan** (Plan), developed with the assistance of the National Research Council of the National Academies, identifies significant knowledge gaps and establishes a set of key research priorities that complement other relevant research programs in the region without duplication of effort. Our Plan provides a science-based roadmap guiding the AYK SSI's "Invitations to Submit Research Proposals" and helps to ensure that available funds target the highest priority research questions and issues. In addition, the AYK SSI works to maintain the highest scientific standards for research by the consistent use of expert peer reviewers to evaluate competitive proposals.



Collaborative Research Supporting Sustainable Management

The AYK SSI, with the help of our member organizations and principle investigators, is different from other approaches in several important ways. It is through this unique approach and innovative partnership that the AYK SSI has created a legacy of salmon science.

- **Collaborative Problem Solving:** While funding the highest quality salmon research, the AYK SSI remains focused on harnessing that research to understand the causes of AYK salmon declines and to support improved sustainable management of these stocks. The AYK SSI Salmon Research & Restoration Plan includes a core focus on the development of new fisheries management tools and the synthesis of information for improved forecasting.

- **Interdisciplinary:** Expanding knowledge of the causes of these salmon declines requires research on all factors driving salmon populations. The AYK SSI is strongly interdisciplinary, drawing on and synthesizing information from diverse fields including: population biology, freshwater and marine ecology, oceanography, genetics, modeling, statistics and social science.

- **Gravel to Gravel Research:** The AYK SSI is a unique research program dedicated to understanding the causes of the declines of salmon across both the freshwater and marine ecosystems of the region, advancing research across the entire lifecycle of the salmon.

- **Capacity Building:** Our approach to conducting research includes an integrated program to expand the capacity of Native and rural organizations to participate in and lead the salmon research we fund.

Since 2002, we have funded salmon research projects implemented by a diverse array of scientists within state and federal agencies, regional organizations, universities, non-governmental organizations and the private sector. These projects address a range of high priority hypotheses and key research questions drawn from the AYK SSI Salmon Research & Restoration Plan.

Salmon research in the AYK region has been chronically underfunded. Much work remains to be done to advance the understanding of the causes of the declines and to support management of AYK salmon stocks. The AYK SSI remains committed to our mission and looks forward to working with our partners and our community of principle investigators to continue to provide the highest level of scientific integrity within our portfolio of funded projects.

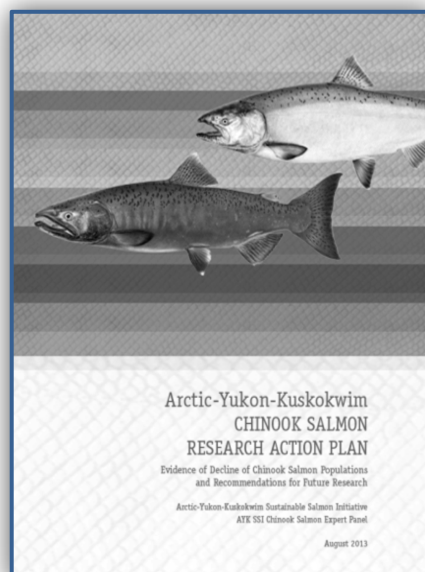
By setting aside differences and working with common purpose, we have created one of the largest, most diverse collaborative research efforts to rebuild salmon runs on the entire North Pacific coast.

AYK SSI JUVENILE CHINOOK SALMON WORKSHOP
Risks and Benefits of Using Juvenile Salmonid Research to Understand Adult Population Dynamics

April 23-24, 2014
Egan Civic & Convention Center
555 West 5th Ave, Anchorage, AK

WORKSHOP OVERVIEW

Background: Our **AYK SSI Chinook Salmon Research Action Plan** (Action Plan), released August 2013, presents a set of strategic research priorities aimed at advancing our understanding of the causes of the declines, and in turn, to support the rebuilding and sustainable management of AYK Chinook salmon stocks. Questions about mortality of juvenile salmon in their freshwater, estuarine, and early marine life phases are addressed in two of the seven hypothesized drivers of decline of AYK region Chinook salmon stocks presented in the Action Plan:



H2. Freshwater Mortality:
Hypothesis: Change in the suitability or productivity of freshwater habitats used for spawning, rearing and migration has contributed to declines in AYK Chinook salmon stocks.

H3. Ocean Mortality:
Hypothesis: Ocean conditions (physical and biological) have changed in the Bering Sea, causing an increase in mortality of Chinook salmon during the early marine portion of their life cycle and contributing to declines of AYK Chinook salmon stocks.

The need: In response to these hypothesized drivers of decline, a need exists to determine whether habitat variables operating during the juvenile life phase are, in fact, the dominant drivers of declines of AYK Chinook salmon stocks. However, despite great interest in new research focused on the juvenile life phases, there is reason to be cautious and deliberative in undertaking new research initiatives. Medium or long-term data sets from the Bering Sea region informing the relationship between juvenile and adult Chinook salmon productivity are very limited. Further, new investments in data collection are expensive and moderately high risk for several reasons:

- A question exists about whether it is feasible to collect data over the length of time necessary to address the above hypotheses.
- AYK freshwater and early marine habitats are difficult and expensive environments in which to collect data.
- The possibility exists that medium to long-term datasets on juvenile population dynamics may not inform our hypotheses or advance and improve forecasting and management.

Workshop Aims: This juvenile Chinook salmon workshop is designed as a forum to explore, evaluate and weigh the potential benefits and risks among a range of approaches to create the long-term data sets required to address our hypotheses and better inform AYK region Chinook salmon forecasting, conservation and management. The aims of this two day workshop are two-fold:

1. Explore what we know about juvenile Chinook salmon ecology, especially the evidence for the scope and scale of juvenile Chinook salmon mortality in their freshwater and early marine life phases informed by case studies from the AYK region and elsewhere.
2. Compile and review the best science advice available and then propose new strategic research investments to improve our understanding of juvenile Chinook salmon mortality as determinant of brood-year strength.

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AGENDA

Day 1: Wednesday, April 23, 2014
SESSION 1: 9:00 AM – 10:45 AM
Introduction

Welcome / Introductory Remarks
Art Nelson, Chair, AYK SSI Steering Committee

Introduction to the Workshop
Workshop Co-Chairs:
Chris Zimmerman, USGS Alaska Science Center, Anchorage
Daniel Schindler, University of Washington School of Aquatic & Fishery Sciences, Seattle

Overview Presentations
Summary of AYK Regional Chinook Salmon Declines / Presentation of Selected Hypotheses from the AYK SSI Chinook Salmon Research Action Plan
Chinook Salmon Expert Panel Co-Chairs:
Daniel Schindler, University of Washington School of Aquatic & Fishery Sciences, Seattle
Chuck Krueger, Great Lakes Fishery Commission, Ann Arbor

Review of Ongoing and Completed Juvenile Chinook Salmon Research in the AYK Region
Chris Zimmerman, USGS Alaska Science Center, Anchorage

Correlation, Inference and Causality - Challenges to Understanding Linkages between Juvenile and Adult Salmon Population Dynamics
Franz Mueter, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau

BREAK (15 min.)

SESSION 2: 11:00 AM – 5:00 PM
Lessons from Long-Term Juvenile Salmon Research and Monitoring Programs
(Each presentation ~45 min., including questions)

Freshwater Research: Research on Freshwater Habitats and Juvenile Salmonid Ecology in the Columbia River Basin - Lessons and Applications
Pete Bisson (Ret.), US Forest Service, Pacific Northwest Research Station, Olympia

LUNCH 11:45 AM – 1:00 PM

<u>Technological Approaches</u>: Review and Synthesis of the Costs and Benefits of Tagging Programs in the Columbia River Watershed
Chris Jordan, NOAA, NW Fisheries Science Center, Seattle

<u>Freshwater Research</u>: Landscape Ecology and Watershed Processes - Long-Term Studies to Understand the Freshwater Drivers Affecting Anadromous Salmonids
Gordon Reeves, US Forest Service, Pacific Northwest Research Station, Corvallis

<u>Marine Research</u>: Risks and Benefits of Research on the Estuarine and Marine Ecology and Survival of Juvenile Salmonids in the California Current
Laurie Weitkamp, NOAA, NW Fisheries Science Center, Newport

BREAK (20 min.)

<u>Marine Research</u>: Ocean Life of Chinook Salmon - Synthesis of Research on Juvenile Chinook Salmon in British Columbia
Dick Beamish (Ret.), Pacific Biological Station, DFO, Nanaimo, British Columbia

<u>Marine Research</u>: Review and Synthesis of Southeast Alaska Marine Juvenile Chinook Salmon Research Programs and Findings
Alex Wertheimer (Ret.), NOAA, Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau

Wrap-Up and Brief Review of Schedule for Day 2: 5:00 PM

DAY 2: Thursday, April 24, 2014
SESSION 2 (Cont.): 9:00 AM – 2:45 PM
Lessons from Long-Term Juvenile Salmon Research and Monitoring Programs
(Each presentation ~45 min., including questions)

<u>Technological Approaches</u>: Risks and Benefits of Using Acoustic Telemetry to Quantify Freshwater, Estuary and Early Ocean Survival of Juvenile Salmonids
Michael Melnychuk, University of Washington School of Aquatic & Fishery Sciences, Seattle

<u>Landscape Approaches:</u> From Reach to Region - Activities to Advance our Understanding of Climate Change Impacts on Western Alaska's Freshwater Systems
Joel Reynolds, USFWS Western Alaska Landscape Conservation Cooperative, Anchorage

BREAK (15 min.)

Marine Research: Bristol Bay Sockeye Salmon Early Marine Ecology Ed Farley, NOAA, Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau
Freshwater Research: Risks and Benefits of Long-Term Research across Multiple Life Stages - UW's Alaska Salmon Research Program Daniel Schindler, University of Washington School of Aquatic & Fishery Sciences, Seattle
LUNCH 12:15 PM – 1:30 PM
Freshwater Research: Juvenile Chinook Salmon Research in Yukon and BC Mike Bradford, DFO and Simon Fraser University, School of Resource and Environmental Management, Vancouver
Marine Research: Evolving Yukon River Juvenile Chinook Salmon Research in the Northern Bering Sea - Addressing Information Needs and Improving Uncertainty James Murphy, NOAA, Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau Katherine Howard, Alaska Department of Fish & Game, Division of Commercial Fisheries, Anchorage
BREAK (15 min.)

SESSION 3: 3:00 PM – 5:00 PM
SYNTHESIS: Discussion of Best Science Advice to Guide New Research Investments

Overview of Process / Guidance to Break-Out Groups	Workshop Co-Chairs	3:00 PM
Break-Out Group Discussions	3 Break-out Groups Organized by Topic: • Freshwater • Estuarine • Marine	
Plenary Round Table Discussion with Input from Break-out Group Leaders	Facilitated by Workshop Co-Chairs	
Concluding Comments	Workshop Co-Chairs	5:00 PM

ABSTRACTS

Alphabetical, by Author

Marine Research: Ocean Life of Chinook Salmon - Synthesis of Research on Juvenile Chinook Salmon in British Columbia

Dick Beamish (Ret), Pacific Biological Station, DFO, Nanaimo, British Columbia

Abstract:

In British Columbia, there have been changes in the population dynamics of Chinook salmon that mostly resulted in substantial declines in abundance despite a large hatchery program. In the 1970s, the major commercial and sports fisheries for Chinook salmon were in the Strait of Georgia. An average annual commercial catch of about 400,000 fish in the 1970s, declined to low numbers until the commercial fishery was closed in 1998. In the 1970s over 90% of the sports fish effort in British Columbia was in the Strait of Georgia, resulting in a catch in some years of over 400,000 Chinook salmon. Today, the catch is less than 20,000 annually. A recent exception to the declining trend in production has been the stock aggregate in the South Thompson area of the Fraser River drainage. Chinook salmon smolts in this area enter the Strait of Georgia 6 to 8 weeks later than most other smolts and as a consequence are having much better marine survival. The better survival of these late ocean entering and smaller smolts is an indication that prey availability and abundance in the early marine period, probably is a major reason for the changing trends in abundance. This presentation will include a summary of the results of the ocean studies of Chinook salmon over the past two decades in the Strait of Georgia and off the west coast of British Columbia. I will also include a description of a new, five-year coordinated effort within Puget Sound and the Strait of Georgia to determine the causes of the decline in Chinook salmon production. I will also describe the proposals by NPAFC to focus international efforts on identifying the fundamental mechanisms that regulate Pacific salmon production.

Dick Beamish *retired from the Pacific Biological Station, DFO in 2011, but continues with a few projects. He and colleagues just finished a book on the Strait of Georgia that is written for the general public. He and other colleagues are completing a book on the ocean life of Pacific salmon that will be published by the American Fisheries Society. He continues as an Editor of the Transactions of the American Fisheries Society and authors or coauthors a paper or two every year. He is a Fellow of the Royal Society of Canada, a member of the Order of Canada and Order of British Columbia and one of the several thousand* *recipients of the Nobel Peace Prize for work with the IPCC. A large rhododendron garden, grandchildren and talking about rugby over a beer keep him busy in his spare time.*

Freshwater Research: Research on Freshwater Habitats and Juvenile Salmonid Ecology in the Columbia River Basin – Lessons and Applications

Pete Bisson (Ret.), US Forest Service, Pacific Northwest Research Station, Olympia

Abstract:

As the two largest river systems in western North America, the Columbia and Yukon Rivers are roughly similar in terms of length, drainage area, and average discharge. Both rivers possess salmon runs that support important aboriginal, commercial, and recreational fisheries both in-river and at sea. Despite these similarities, the freshwater environments of the two drainages are profoundly different. In addition to the obvious climate differences, the Columbia River Basin has been extensively altered by a variety of human impacts resulting in a widespread loss of formerly productive habitats and a native fauna that faces substantial imperilment to a much greater extent than in the AYK region. Nearly half of the currently ESA-listed west coast salmon and steelhead stocks reside in the Columbia Basin, including five distinct Chinook salmon population units. Much of the funding for freshwater habitat improvement and habitat monitoring comes from the Bonneville Power Administration, as guided by the Northwest Power and Conservation Council. Millions of dollars are spent each year to protect streams, improve fish survival through a maze of tributary and mainstem dams, purchase water rights, control pollutants, and operate numerous hatcheries. This very ambitious ecological restoration program includes considerable funding for freshwater habitat research and juvenile salmonid studies. Although some important monitoring programs occur in the AYK area, the scope and magnitude of research on juvenile salmon ecology in the Columbia Basin likely surpasses other west coast river systems. What has been learned and applied from these studies? We have learned that although volumes of habitat data have been collected by various organizations over the years, differences in measurement protocols and inadequate data archiving have hampered data sharing and analysis. We have learned that technological advances (e.g., geospatial mapping and PIT-tagging) have facilitated real improvements in understanding habitat status and trends at large geographic scales, as well as more detailed insights into juvenile salmonid movements, survival patterns, and environmental limiting factors. We have learned that quantitative relationships between juvenile abundance and specific habitat properties have been very difficult to determine due to many sources of variation; this has been problematic for establishing the efficacy of habitat restoration projects. We have learned that there are major categories of habitat factors such as food webs and environmental contaminants that are incompletely monitored and whose influence on juvenile salmonid abundance and survival are poorly understood. Finally, we have learned that new insights from freshwater habitat research and monitoring have not been fully considered in other aspects of salmon management, e.g., adjustments in hatchery releases that could be based on annual variation in habitat quantity and quality. Recently, some scientists have called for a shift in biological objectives for salmon and steelhead in the Columbia River Basin to a strategy based on protecting and restoring habitat diversity and environmental resilience. To assist in accomplishing these objectives four steps have been suggested to improve freshwater monitoring strategies: (1) support the development of high level indicators of habitat condition and fish population performance; (2) implement

monitoring to evaluate progress against new quantitative objectives such as environmental diversity metrics, life stage-specific survival goals, and habitat restoration benefits; (3) implement social monitoring to better evaluate and improve acceptance of restoration programs at local scales, and develop opportunities for citizen engagement in monitoring activities; and (4) design monitoring to support adaptive management and structured decision making by providing data to test current knowledge and revise management programs.

Pete Bisson *is an emeritus scientist at the Forest Service's Pacific Northwest Research Station in Olympia, Washington. He worked as an aquatic biologist for the Weyerhaeuser Company for 21 years prior to joining the Forest Service in 1995. His research has included stream habitats and food webs, riparian zone management, and a variety of conservation issues related to freshwater ecosystems. He holds affiliate faculty appointments at the University of Washington and Oregon State University. Pete recently completed two terms as vice-chair of the Independent Scientific Review Panel for the Northwest Power and Conservation Council, which provides guidance to fish and wildlife recovery in the Columbia River Basin.*

<u>Freshwater Research:</u> Juvenile Chinook Salmon Research in Yukon and BC

Mike Bradford, DFO and Simon Fraser University, School of Resource and Environmental Management, Vancouver

Abstract:

Over half of total egg-adult mortality for stream-type Chinook salmon occurs in the freshwater stages; thus there is potential for this stage to contribute significantly to adult returns. Managers have identified three major uses for research and monitoring of this segment of the life cycle:

1. Setting of escapement goals or other population targets. Freshwater habitats usually limit overall population size and understanding the mechanisms of population limitation has value to support, or replace, traditional stock-recruitment analysis.
2. Understanding variation in survival in the freshwater stages. Natural or human-induced changes in freshwater habitats can cause variation in survival and ultimately smolt production. Understanding linkages between land use, stream flow, temperature or other variables may be useful in understanding production dynamics.
3. Partitioning survival in freshwater and marine environments by estimating smolt production.

The relative role of each life history stage can be evaluated if a reliable smolt index is available. Smolt abundance measures can be used as forecasting tool; additional information on size, condition, timing or stock composition may be of value in conditioning ocean survival or abundance studies.

For stream-type Chinook salmon the challenge for providing management advice is the diversity of life history types and habitat use that is observed in large basins, and the logistics of working in large unregulated rivers. I will describe efforts to understand the freshwater life history and potential limiting factors for Fraser and upper Yukon River stream-type Chinook salmon that emphasize the interaction between life history, habitat availability and hydrology. I will also describe a long- (Fraser) and short term (Yukon) downstream migrant studies that characterize

the migration of juveniles from each basin towards the sea. These results will form a basis for evaluating different options for research into the freshwater stages of AYK Chinook salmon.

Mike Bradford *is a Research Scientist with the Salmon and Freshwater Ecosystems Division of DFO's Science Branch, and Adjunct Professor, School of Resource and Environmental Management, Simon Fraser University, near Vancouver BC. He has a wide range of interests, including the freshwater ecology and population dynamics of Chinook salmon. In the 1990s he conducted a multiyear study of the life history and habitat use of stream-type Chinook salmon in the Fraser River watershed and in the early 2000s he managed a similar study of Chinook salmon in the upper Yukon River basin. He has participated in a range of expert panels, commissions and inquiries on the status of salmon and other species in Alaska, Canada and the US. Currently Mike is working at the Science-Policy interface, developing assessment protocols and decision tools for the new Fisheries Protection Provisions of Canada's Fisheries Act.*

Marine Research: Bristol Bay Sockeye Salmon Early Marine Ecology

Ed Farley, Alaska Fisheries Science Center, Auke Bay Laboratories, NOAA, Juneau

Abstract:

The link between climate variability and marine survival of salmon is believed to be strongest during their first year at sea. The hypothesis is that survival of salmon during this period is a function of size and energetic status they gain during summer. This presentation will review our current understanding of the impact of climate variability on early marine ecology of Bristol Bay sockeye salmon. Data come from annual fish and oceanographic surveys conducted during late summer and fall in the eastern Bering Sea. Utilizing these data, an assessment on the applicability of juvenile sockeye salmon early marine ecology research to Chinook salmon will be reviewed. In addition, these data will be used to determine whether or not there is a potential to incorporate salmon early marine ecology survey data into forecasts of future salmon returns.

Ed Farley *is the Program Manager for the Ecosystem Monitoring and Assessment (EMA) Program at the Alaska Fisheries Science Center, Auke Bay Laboratories in Juneau, AK. The EMA program conducts regular fish and oceanographic research in Alaska's large marine ecosystems (Gulf of Alaska, Bering Sea, and Chukchi Sea). Data from these surveys are utilized in 'end to end' ecosystems models as an Integrated Ecosystem Assessment to understand the relative role of climate on groundfish recruitment and salmon marine survival. In that regard, Ed's current research is focused on addressing hypotheses that link climate change and variability to ecosystem function and to link ecosystem function to fish growth, fitness, and survival at critical life history stages.*

Technological Approaches: Review and Synthesis of the Costs and Benefits of Tagging Programs in the Columbia River Watershed

Chris Jordan, NOAA, NW Fisheries Science Center, Seattle

Abstract:

In the Columbia River basin, there are extensive, on-going tagging programs that support the management of ESA listed anadromous salmonids. In particular, for stream-rearing populations of chinook and steelhead, tagging of rearing and out-migrating juveniles and returning adults is

undertaken to support population status assessments as well as effectiveness evaluations of a wide range of management actions. Among the major factors for decline for Columbia River salmonid populations are the impacts of mainstem hydropower projects, and upland and stream habitat degradation due to human activity. Large-scale adaptive management programs are in place to evaluate the impact of management strategies both in the arena of hydropower project operation and tributary habitat rehabilitation. A key component to the success of the experiments that underlies the adaptive management process is the ability to track individual fish as they move through the hydropower system, and to be able to associate differential life-stage and full life-cycle survival across a gradient of natural and manipulated conditions. A wide-range of tag types are currently being utilized for these management evaluation studies, including radio, acoustic, and RFID. There are risks and benefits to all tagging methods that must be carefully considered, especially for work on ESA listed organisms. However, what is probably most important to consider when evaluating the application of tagging technologies to address these types of fisheries management questions are the limitations imposed by the tags themselves. The limitations to consider are tag cost ($2.00 - $200 per tag), detection cost ($500 - $50,000), detection range (0.2 – 500m), tag life span (30d – infinite) and fish size at tagging (>60mm). Rarely will a single tag type meet all programmatic objectives and unfortunately a single tag type may not be ideal for any one objective, nonetheless, an enormous amount has been learned through tagging salmonids in the Columbia River basin in the support of management decision making, both in terms of basic salmonid biology as well as the impacts of management actions on fish population processes.

Chris Jordan *is a Research Fisheries Biologist with NOAA/NMFS's Northwest Fisheries Science Center and Program Manager for the Mathematical Biology and Systems Monitoring Program. His current work focuses on the design and implementation of large-scale monitoring programs to assess anadromous salmonid freshwater habitat and population status as well as the watershed-scale effect of management actions on salmonid habitat and population processes. The research component of these projects is the development of novel monitoring methods, including sampling designs, metrics and indicators, to address specific data and information needs for the management of ESA listed Pacific Northwest salmonid populations. Specifically, he manages several large research and monitoring programs funded by the Bonneville Power Administration and NOAA-Fisheries in the Wenatchee, John Day and Salmon (ID) River basins that serve as the on-the-ground test beds for design and implementation research.*

<u>Technological Approaches</u>: Risks and Benefits of Using Acoustic Telemetry to Quantify Freshwater, Estuary, and Early Ocean Survival of Juvenile Salmonids

Michael Melnychuk, School of Aquatic and Fishery Sciences, University of Washington

Abstract:

In this talk I will draw from experiences with the Pacific Ocean Shelf Tracking Project (POST) to address some of the advantages and common criticisms of using acoustic tracking technology for quantifying mortality of migrating juvenile salmonids in freshwater and coastal marine waters. Acoustic telemetry paired with mark-recapture models can be very useful for estimating mortality during the downstream migration and in many cases during the early ocean migration, and thus for partitioning these components from the remainder of marine mortality. Studies attempting to quantify tagging effects on salmon survival or behavior typically lead to

prescriptions of a minimum body size above which no tagging effects occur. Such recommendations are likely unrealistic, and researchers could instead assume that tagging effects always occur across all body sizes, and shift the focus to determine how these effects vary with tag size:body size ratios. Given that absolute tagging effects are not easily estimable (for survival especially), acoustic tagging studies that involve experiments or comparisons among release groups are less likely to provide biased estimates compared to studies with objectives of providing absolute survival estimates. When absolute survival estimates are desired for partitioning total mortality into habitat-specific or phase-specific components, integrating these studies with others (e.g. life-cycle models using smolt counts and adult returns) could improve the bounding for mortality estimates in successive life-history phases. Estimating survival of migrating juvenile salmon with mark-recapture models involves assuming that smolts do not stop migrating in between acoustic receiver stations where they cannot be detected. Freshwater residualization, local residency in coastal waters, and direct movement offshore without passing by coastal detection stations are important considerations in designing and interpreting results from acoustic telemetry studies. I will discuss the above lessons in relation to the potential applicability of acoustic telemetry to the AYK region for juvenile Chinook salmon.

Mike Melnychuk *completed his PhD at UBC, working with Carl Walters and Villy Christensen, and collaborating with the POST Project. His doctoral work involved quantifying movement and mortality patterns of juvenile salmon during the migration from rivers in southern B.C. through the Strait of Georgia system. Part of his focus was on using mark-recapture models to estimate survival rates of migrating salmon populations, and another part was in developing new methods for estimating detection probabilities. He is currently a post-doctoral research scientist as the University of Washington's School of Aquatic and Fishery Sciences, working with Ray Hilborn. His current research focuses on quantifying the variability in fisheries management systems around the world and assessing the consequences of that variability for fish stocks and fisheries.*

Overview Presentation: Correlation, Inference and Causality - Challenges to Understanding Linkages between Juvenile and Adult Salmon Population Dynamics

Franz Mueter, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau

Abstract:

Salmon face a gauntlet of biological and physical challenges on their journey from egg to spawning adult. Identifying the conditions that cause fewer or more individuals to survive the various stages of this gauntlet requires an understanding of the most important processes acting on salmon during the freshwater and marine stages, as well as long-term measures of variability in survival and in key biological and physical drivers. Linking these drivers to overall survival and ultimate recruitment is the holy grail of much fisheries research but is fraught with difficulty. The literature is littered with "false positives" and spurious associations. Here I review some of the pitfalls in such studies, including multi-collinearity among different explanatory variables and among the same variables measured at different temporal and spatial scales, large-scale spatial auto-correlation in environmental drivers, and temporal autocorrelation at seasonal and interannual time scales. I will provide examples and strategies for avoiding these pitfalls, including mechanistic-based modeling, pre-screening of environmental variables to identify appropriate spatial and temporal scales for analysis, and multi-stock analyses to increase

statistical power. Given current data limitations, there simply are no strategies that can prove causality, but these approaches can greatly narrow the range of plausible explanations for observed variability in salmon survival and recruitment.

Franz Mueter *began biological studies in Aachen, Germany, before pursuing graduate degrees in biological and fisheries oceanography, as well as biostatistics, in Fairbanks, Alaska. His research initially focused on the early life history of pollock and flatfishes in nearshore waters of the Gulf of Alaska, and gradually expanded to include spatial dynamics and recruitment dynamics of fishes throughout the Gulf of Alaska, Being Sea and – more recently – the Chukchi Sea. He has also modeled recruitment processes of salmon in relation to temperature variability throughout the Northeast Pacific and has worked on other anadromous species in Alaskan waters, including the Beaufort Sea. He is currently Associate Professor at the University of Alaska Fairbanks in Juneau, where he teaches quantitative fisheries classes, supervises a number of graduate students, and continues research on the effects of environmental variability on the distribution, growth, and survival of fishes in subarctic and arctic waters.*

Marine Research: Evolving Yukon River Juvenile Chinook Salmon Research in the Northern Bering Sea - Addressing Information Needs and Improving Uncertainty

James Murphy, Alaska Fisheries Science Center, Auke Bay Laboratories, NOAA, Juneau
Katherine Howard, Alaska Department of Fish & Game, Division of Commercial Fisheries, Anchorage

Abstract:

Surface trawl surveys conducted by NOAA Fisheries since 2002 have provided information on juvenile salmon distribution, abundance, stock structure, size, and survival in the northern Bering Sea. These data are used to evaluate how juvenile and adult populations are linked in Yukon River Chinook salmon. Results indicate that juvenile abundance provides a key linkage to the adult population (approximately 70% of the variation in recent returns is explained by juvenile abundance alone). This is consistent with other juvenile salmon research in Alaska and emphasizes the importance of ecological processes during the early life-history stages (freshwater and estuarine stages) of Chinook salmon to recent production declines. Overwinter survival of juveniles in the Bering Sea is also an important linkage between juvenile and adult populations and juvenile size and migration are believed to contribute to overwinter survival of juveniles. The future of this research program attempts to be responsive to the changing needs, costs and challenges associated with large-scale field programs. The program objectives are to (1) conduct long-term monitoring of abundance to develop management tools, and (2) to pursue focused short-term studies of mechanisms related to survival, growth and condition of juvenile Chinook salmon. Efforts are underway to transition these large pelagic surveys to a smaller and more economical vessel platform, and to modify the sampling plan to more specifically target salmon questions. Efforts are also underway to pursue a short-term research project that will provide new insights into Yukon Chinook salmon smolt biology, distribution, outmigration timing, habitat use and nutritional status.

Jim Murphy *has been involved in salmon ocean ecology research since his thesis research on salmon bycatch in the highseas squid driftnet fishery at the University of Alaska, Fairbanks. He continued research on the ocean life-history stage of salmon as a Fisheries Research Biologist at the Auke Bay Laboratory in Juneau, AK through the Southeast Coastal Monitoring Program in the Gulf of Alaska and the*

Bering-Aluetian Salmon International Survey in the Bering Sea. He currently serves on the Yukon River Joint Technical Committee and provides expertise on marine fisheries and research relevant to Canadian-origin salmon stocks. His recent research focus has been on juvenile Chinook salmon ecology in the northern Bering Sea and the application of marine surveys to pre-season forecasts of Canadian-origin Chinook salmon returns.

Katherine Howard *is Alaska Department of Fish & Game Commercial Fisheries Division's Regional Research Biologist for the Arctic-Yukon-Kuskokwim Region, and formerly served as the Yukon Area Research Biologist. Her work has focused on assessment and productivity modeling of Yukon River Chinook salmon, as well as collaborative research with NOAA partners on northern Bering Sea juvenile marine salmon research. Ongoing studies include efforts to maintain long-term monitoring of northern Bering Sea juvenile Chinook salmon and short-term studies to provide insight into potential mechanisms structuring early marine survival of Chinook salmon, such as the Yukon Delta smolt project funded by AYK SSI.*

Freshwater Research: Landscape Ecology and Watershed Processes - Long-Term Studies to Understand the Freshwater Drivers Affecting Anadromous Salmonids

Gordon Reeves, US Forest Service, Pacific Northwest Research Station, Corvallis

Abstract:

Many studies on the ecology of Chinook salmon focus on the relations between abundance and features of habitat units and other small spatial scale features. My research has considered larger scales, the watershed and basis, to explore and understand processes that help explain patterns of habitat use at smaller scales. Work on the upper Copper River, AK found that the spawning and rearing areas for Chinook Salmon (stream-type) occurred portions of the basin with specific geomorphic (gradient, stream size) and environmental (percent of watershed occupied by glaciers) conditions. These areas comprised about 6% of the total watershed area. The distribution of ocean-type Chinook salmon in Elk River, OR was also restricted to a relatively small portion of the watershed. In both cases, not all suitable patches were occupied at the same time. The timing of high flows and adult abundance influence annual occupancy in Elk River. Similar patterns were observed for Coho Salmon in streams in the Oregon Coast. Populations used specific parts of watersheds and the rates of occupancy were directly related to the size of the population. These studies suggest the production of salmon may occur in relative small portions of a watershed that have particular geomorphic features. Monitoring programs can be designed to direct effort more strategically and effectively at such areas to better track and understand trends in abundance. Other work with Chinook salmon monitored smolt production for 18 years in Elk River, a small watershed on the southern Oregon coast. Annual production from the basin was relatively constant over the course of the study but production from different parts of it varied widely. Most monitoring programs only attempt to capture smolts during the peak migration period and do not consider migration at other times. We operated smolt traps for 9-11 months of the year in Elk River. This allowed us to not only get a better estimate of total smolt numbers but to discern life-history variation within the population. NOAA Fisheries studied use of the estuary on the Columbia River and saw that different life-histories used the estuary at different times over the year. Otoliths from returning adults can be an additional source of life-history information, particularly about which specific life-history or histories were most successful at a given time. Such work is generally not

considered in monitoring programs but its inclusion could provide new and valuable insights into changes in population numbers and associated environmental factors.

Gordon Reeves *is a Research Fish Biologist in the PNW Research Station. His expertise is in the freshwater ecology of anadromous salmon and trout, conservation biology of those fish, and aquatic aspects of landscape ecology. He has studied the ecology of anadromous salmon and trout in the Pacific Northwest, northern California, Idaho, and Alaska and fish ecology in New Zealand and New York. He has published over 75 papers on the freshwater ecology of Pacific salmon and trout, effects of land management activities on the freshwater habitats of these fish, conservation plans, and dynamics of aquatic ecosystems in the PNW and Alaska. He led committees that developed and evaluated options for managing federal lands in the PNW and Alaska and served as the Team Leader of the Aquatic and Land Interaction Program at the PNW Station in Corvallis from 1995 – 2012. He was co-leader of the Coastal Landscape Analysis and Modeling Study, a long-term, large, interdisciplinary project to model and evaluate forest policy effects at multiple scales. He was also a member of the NOAA Fisheries Technical Recovery Team for ESA listed coho salmon in coastal Oregon. His current research focuses on the potential impacts of climate change on salmon and aquatic ecosystems in the PNW and Alaska, landscape analysis and restoration, and management of riparian ecosystems.*

Landscape Approaches: From Reach to Region - Activities to Advance our Understanding of Climate Change Impacts on Western Alaska's Freshwater Systems

Joel Reynolds, USFWS Western Alaska Landscape Conservation Cooperative, Anchorage

Abstract:

The Western Alaska Landscape Conservation Cooperative (LCC) is a partnership focused on improving conservation of western Alaska's natural and cultural resources through providing improved tools and knowledge related to climate changes and impacts. The LCC's geography spans from the Kotzebue Lowlands to Unimak Island and the Kodiak Archipelago. The LCC has identified a wide range of shared science needs, but among the highest priority needs are those associated with sustaining healthy freshwater systems and the robust aquatic populations, ecosystem services, and human communities that depend upon those systems. For fiscal year 2014 & 2015 the LCC is focusing on Freshwater Systems and the topic of "Changes in freshwater temperatures and its impacts". I'll briefly overview the LCC's recent, current and planned activities associated with this topic and highlight opportunities for engagement and participation. Specific efforts include: advancing establishment of a voluntary, statewide water temperature monitoring network; supporting projects that will improve our understanding of impacts of water temperature changes on key system processes and species; informing resource decision makers in western Alaska of the importance of recent and projected temperature changes in the region's freshwater systems; and helping establish a statewide framework for improving Alaska's hydrographic data through making updating more affordable and updates more accessible.

Joel Reynolds *has spent the last fifteen years working to better align science activities with decision-maker information needs (though he wasn't always aware of that goal). For the last 3 ½ yrs he has been working as the Science Coordinator for the Western Alaska Landscape Conservation Cooperative, helping guide and develop the Cooperative's long-term strategy to improve understanding of the expected impacts of landscape-scale drivers of change, especially climate change, and develop adaptation* *strategies for sustaining the region's natural and cultural systems. He came to that position after eight years as the US Fish & Wildlife Service's Regional Refuge Biometrician for Alaska, helping the four-score biologists on the sixteen national wildlife refuges in the state with all-things-biometric. He has also been Statewide Genetics Biometrician for ADF&G's Gene Conservation Laboratory and faculty in the University of Washington's Department of Statistics. His greatest achievement has been keeping up with Carol Ann Woody.*

Freshwater Research: Risks and Benefits of Long-Term Research across Multiple Life Stages - UW's Alaska Salmon Research Program

Daniel Schindler, University of Washington School of Aquatic & Fishery Sciences, Seattle

Abstract:

The University of Washington's Fishery Research Institute (FRI) began working in western Alaska in 1946 in response to fishing industry concerns about the lack of scientific oversight of salmon fisheries in the region. At this time, Alaska fisheries were 'managed' from Washington DC as Alaska was not yet a state. Early FRI goals were to understand the production capacity for salmon, particularly sockeye salmon, of western Alaska watersheds as a way to develop a scientific basis for setting sustainable harvest rates. Early work on Bristol Bay systems and in the Chignik watershed on the Alaska Peninsula focused on developing the techniques for enumerating adult and juvenile salmon as they migrated through marine fisheries, up rivers to their spawning grounds, and then back to the ocean as smolts. A concerted effort was also directed towards understanding the environmental factors that regulated growth and survival of juvenile salmon during their freshwater life stages. By the 1950s, FRI had developed an extensive 'ecosystem approach' to studying salmon throughout their life-cycle, and many of the original monitoring and assessment activities have been maintained through to our present monitoring program.

FRI scientists now have the luxury of being able to evaluate how environmental change (i.e. climate conditions and fishery exploitation) has affected western Alaska salmon stocks over a period of time during which there have been substantial changes in climate conditions, ocean productivity, and escapement goals. Between the late 1950s and the present, climate has warmed substantially in response to changes in the Pacific decadal oscillation and to global warming. Escapements have also changed in response to new management targets that have attempted to optimize salmon production from these systems.

Retrospective analyses of our extensive datasets on salmon ecology, and limnological and environmental variables highlight the utility of some aspects of our monitoring programs while cast doubt about the broad-scale value of others. Enumeration of escapements and the age composition of fish to individual tributary populations has been particularly valuable as it has led to the recognition of considerable response diversity in recruitment of salmon stocks, among the populations that inhabit the same watershed. Limnological surveys provide some explanations for why some systems produce more fish than others, and have also highlighted the sensitivity of ecological conditions in lakes and streams to ongoing climate change. Western Alaska streams and lakes are distinctly more productive now, following decades of climate warming, than they were in the 1950s. Extensive work studying the ecology of juvenile salmon has highlighted the

interactions between changing climate and escapement levels (i.e. density-dependence) in regulating the growth and life-history responses during salmon freshwater residency. However, the degree to which these relationships provide explanatory power for understanding the causes of recruitment variation, in both retrospective analyses and in forecasting, is distinctly weak.

We should expect that salmon ecosystems will continue to change as they respond to ongoing and new environmental changes. Our ability to understand and forecast how salmon respond to environmental conditions will always be highly uncertain, particularly as new stressors such as ocean acidification develop. Effective management should maintain the flexibility necessary to respond to changes in stock productivity, and prioritize maintenance of the basic monitoring needed to manage the resources (i.e. how many fish are out there?).

Daniel Schindler *is the Harriet Bullitt Endowed Chair of Conservation in the School of Aquatic and Fishery Sciences at the University of Washington. Most of his research focuses on a variety of issues regarding the functioning of watersheds that support Pacific salmon in western Alaska, and the socio-economic dynamics of fisheries that operate in these ecosystems. He is a principal investigator of the UW-Alaska Salmon Program that has studied salmon ecosystems in Alaska since the 1940s, and he spends several months of the year in the field in the Bristol Bay region. Schindler has been a recipient of the Distinguished Research Award from the UW College of Ocean and Fishery Sciences, and of the Carl R. Sullivan Fishery Conservation Award that was awarded to the UW-Alaska Salmon Program from the American Fisheries Society in 2012. He has provided service to a variety of governmental and non-governmental organizations, and serves on the editorial board of the journals Ecology, Ecological Monographs, and Ecosystems. He earned a B.Sc. with Honours from the University of British Columbia (1990), and a M.S. (1992) and Ph. D. (1995) from the University of Wisconsin-Madison. He was hired onto the faculty at the University of Washington in 1997 and teaches undergraduate and graduate students in Limnology, Aquatic Sciences, and Ecology.*

Marine Research: Risks and Benefits of Research on the Estuarine and Marine Ecology and Survival of Juvenile Salmonids in the California Current

Laurie Weitkamp, NOAA, NW Fisheries Science Center, Newport

Abstract:

The Northwest Fisheries Science Center has been investigating juvenile salmon marine ecology in the northern California Current since 1998. The goal of this program is to understand key linkages between physical processes and growth and survival of juvenile salmon. This information is then used to provide managers with timely abundance predictions for Columbia River populations. Major components of the program are: 1) spring (May, June) and fall (September) surveys of juvenile salmon in marine waters (including physical parameters, Chlorophyll A, and zooplankton measurements); 2) bi-monthly sampling throughout the year along the Newport line (physical water properties, Chlorophyll A, and zooplankton); 3) sampling of juvenile salmon immediately before ocean entry in the Columbia River estuary; and 4) a diverse modeling component. Laboratory analyses for salmon collected in the ocean and estuary include genetic stock identification, food habits, pathogens and macro-parasites, and growth estimates.

This research effort has greatly increased our understanding of the northern California Current

ecosystem overall and how it affects juvenile salmon, although there are many aspects we still don't fully understand. For example, we have a good sense of the extremes of ocean conditions for salmon ("good" or "bad"), but don't have a good understanding of the importance of specific factors during intermediate years. Our research has also shown that, beginning with ocean entry timing, juvenile salmon have stock-specific migratory patterns that subject them to unique suites of ocean conditions, which in turn results in differential growth and probably survival. This talk will provide additional examples of what we have learned about juvenile salmon and what we still don't know, and how lessons learned in the California Current might be applicable to studies of Yukon River Chinook salmon.

Laurie Weitkamp *has been a Research Fisheries Biologist at NOAA Fisheries' Northwest Fisheries Science Center (NWFSC) since 1992. Laurie's primary research interests concern estuarine and marine ecology of Pacific salmon, and the factors that affect their survival. She leads a study of juvenile salmon in the Columbia River estuary, which is a part of a broader study examining the marine ecology of salmon in the northern California Current. Previous research documented the marine ecology of juvenile coho and Chinook salmon in southeast Alaska, and marine distributions of adult salmon. Other research interests include salmon life history diversity and lamprey estuarine and marine ecology. Laurie's responsibilities include Endangered Species Act listings of Pacific salmon, starting with the West Coast coho salmon status review and continuing with Oregon Coast coho salmon recovery planning. Laurie received her BS, MS, and PhD degrees at the University of Washington.*

Marine Research: Review and Synthesis of Southeast Alaska Marine Juvenile Chinook Salmon Research Programs and Findings

Alex Wertheimer (Ret.), Alaska Fisheries Science Center, Auke Bay Laboratories, NOAA, Juneau

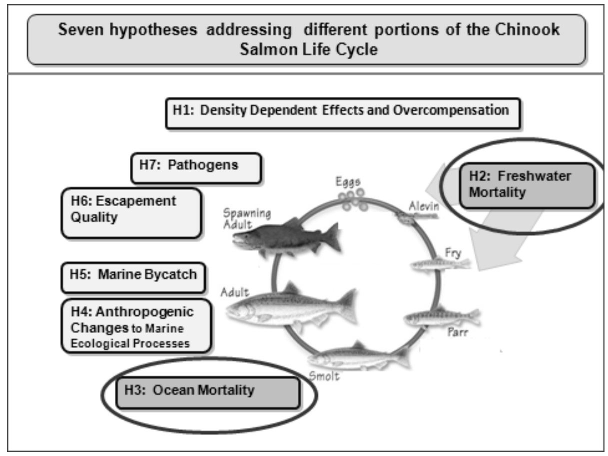
Abstract:

This presentation focuses on three information sets relevant to the survival and marine ecology of juvenile Chinook salmon in southeast Alaska (SEAK): 1) coded-wire tag (CWT) studies providing estimates of marine survival of SEAK wild and hatchery Chinook salmon stocks; 2) long-term marine survival data for Chinook salmon released at the Little Port Walter (LPW) Marine Station; and 3) the Southeast Alaska Coastal Monitoring (SECM) program. The CWT data are used to compare trends in marine survival for hatchery and wild stocks of SEAK Chinook salmon; for cross-correlation analysis to evaluate local and regional coherence in the survival rates between release sites, and to examine the association of survival rates with regional-scale environmental factors. The LPW survival data are reviewed to examine effects of juvenile size at entry to the marine environment on survival, and to contrast survival of a hatchery stock with the survival of the donor wild stock. The LPW data are also used to examine the effects of local, regional, and basin-scale environmental conditions during the first months of juvenile marine residency on annual variability in marine survival. Finally, results from the SECM program and its precursors are reviewed to provide insights into the abundance, distribution, seasonal migration, and feeding ecology of juvenile Chinook salmon in SEAK.

Alex Wertheimer *has worked for over 40 years as a research biologist studying the enhancement, early marine ecology, and management of Pacific salmon in Alaska. He retired from NOAA Fisheries/National Marine Fisheries Service in 2009, and currently works (part-time only!) as a research consultant. Research topics have included salmon enhancement technology; hatchery/wild salmon interactions; juvenile* *salmon marine ecology; effects of oil contamination on early life-history stages of salmon; incidental fishing mortality; and forecasting salmon abundance. He has served on the Alaska Genetics Policy Development Team; Chinook Salmon Plan Team for Southeast Alaska; NPFMC Salmon Plan Team; NMFS Biological Review Team for Chinook Salmon; the Chinook Technical Committee of the Pacific Salmon Commission (PSC). He is currently a US member of the Committee for Scientific Cooperation for the PSC.*

EXCERPTS FROM: ARCTIC-YUKON-KUSKOKWIM CHINOOK SALMON RESEARCH ACTION PLAN: EVIDENCE OF DECLINE OF CHINOOK SALMON POPULATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Section 5 of the CHINOOK SALMON RESEARCH ACTION PLAN describes seven hypotheses identified by the expert panel that provide plausible explanations for the recent changes in AYK Chinook salmon abundance addressing different portions of the salmon life phases (see figure). The section provides for each hypothesis a description, discussion of the biological plausibility, a summary of the evidence available, and a set of research themes and questions to guide future research.



Excerpted here are descriptions of two of the seven hypotheses from pp. 44-50 of the ACTION PLAN which are the focus of our Juvenile Chinook Salmon Workshop: Hypothesis 2- Freshwater Mortality and Hypothesis 3- Marine Mortality listed on (circled in figure above). The full CHINOOK SALMON RESEARCH ACTION PLAN can be accessed at: http://www.aykssi.org/aykssi-chinook-salmon-research-action-plan-2013/

5.2 Hypothesis 2 – Freshwater Mortality

Hypothesis: *Change in the suitability or productivity of freshwater habitats used for spawning, rearing and migration has contributed to declines in AYK Chinook salmon stocks.*

5.2.1 Description of the Hypothesis

This hypothesis examines the way in which productivity and population dynamics of Chinook salmon populations are linked to environmental conditions that control growth and survival during the freshwater component of their life cycle. Adult, embryonic, and juvenile stages are all vulnerable to changes in freshwater environmental conditions. In adults, mortality associated with temperature and oxygen constraints during migration are likely variables that could be important. Incubating embryos could be affected by several variables including winter temperatures, oxygen regimes, flow-related gravel scouring, and entombment by fine sediment. In juvenile stages, food resources that affect growth rates and associated survival during smoltification, and mortality losses to freshwater predators are variables that could affect overall population dynamics.

Additional research is needed to improve our understanding of the role of environmental variables on salmon population dynamics. The freshwater portion of the life cycle of Chinook salmon provides greater management opportunities because freshwater processes are more likely to be responsive to management actions than those processes relevant to the marine life stage. Thus, our ability to distinguish between freshwater and marine stressors on Chinook salmon population dynamics is important for management decisions.

5.2.2 Plausibility of the Biological Mechanism(s)

For most salmon populations the freshwater stages sustain about half of the total egg-to-adult mortality (Bradford 1995). However, for stream-type Chinook salmon egg-to-smolt survival can be higher than other species, but marine survival can be lower due to their longer residence time in saltwater. Mortality can occur during the incubation stage as a result of environmental variables (e.g., spawning gravel, streamflow, ice, freezing), and during the rearing phase by environmental (e.g., streamflow, temperature, dissolved oxygen) or biological (e.g., food production, predation, competition, disease) variables. Fisheries interception of the marine-derived nutrients (MDN) transported from marine to freshwater ecosystems by migrating salmon has been widely proposed to reduce the capacity of freshwater habitats to support growth of juvenile salmon. Freshwater habitats are also vulnerable to anthropogenic and climate-related change. Mortality during the seaward migration in rivers could also be an important potential driver for population trends, especially for populations that have long riverine migratory routes (Quinn 2005). The central question underlying this hypothesis asks whether any specific variable in the freshwater environment, or some combination, could have contributed to the observed trends in AYK Chinook salmon.

5.2.3 Summary of the Evidence for the Hypothesis

Little evidence exists to support the hypothesis that large-scale environmental forcing produces coherence in abundance or survival only during the freshwater phase of salmon populations. Bradford (1999) found that coherence in the production of coho salmon smolts was limited to streams less than 30 km from each other, and even for adjacent streams the correlation in annual smolt abundance estimates was low ($r < 0.3$). A similar conclusion was reached by Rogers and Schindler (2008) for sockeye salmon in Bristol Bay. Bradford (1999) suggested that the effects of environmental variables would be “translated” to effects on stream biota by the nature of the catchment, and with the possible exception of extreme events, the effects of a single environmental forcing agent could be watershed-specific (e.g., as revealed by Crozier and Zabel 2006 for Snake River Chinook stocks). Furthermore, limited evidence suggests that the freshwater life history of AYK Chinook salmon is plastic, with juveniles undergoing a variety of migration and rearing strategies in their first year (Bradford et al. 2008) in response to environmental variation. This diversity in life history reduces the likelihood that a single environmental or biological forcing agent will be able to generate coherent trends in freshwater survival across a broad spatial scale.

While a lack of evidence of large-scale coherence produced by drivers acting solely within the freshwater phase of salmon populations exists, evidence for coherence among escapement indices occurs at broad watershed scales in the AYK region. For the upper Yukon River stocks, the available escapement indices suggest that the trends in abundance fluctuate coherently across the basin (Fleischman 2012, Figure 2). A similar conclusion is reached in comparing the trend in recruits-per-spawner for Kuskokwim River and upper Yukon River stocks (Catalano 2012). For a mortality factor to be a driver of trends in abundance or productivity and produce coherence among returning adults among geographically distant stocks, that variable must operate at large spatial scales, or on a habitat that populations use in common such as in the ocean or major fresh water migratory routes (as adults between the ocean and freshwater spawning habitat or as juveniles between freshwater and the ocean).

Nonetheless, recent analyses of Neuswanger et al. (2012) indicated that some variation in adult returns rates was correlated with environmental variables affecting the productivity in freshwater habitats. However, this study took place in a single tributary system in the middle portion of the Yukon River, and whether its conclusions could apply throughout the AYK region is unknown. Anthropogenic effects on freshwater habitats in most portions of AYK region are relatively minor and are largely restricted to placer gold mining in a few basins (with the notable exceptions of many Nome subdistrict watersheds and the Tuluksak River watershed, a tributary to the Kuskokwim River). Placer mining has impacted a number of non-natal juvenile rearing streams in the Canadian portion of the basin. These effects would not provide coherent trends across a broad spatial scale but could be important at local scales. Last, the impacts of climate change on freshwater habitat conditions in the AYK region are expected to be substantial and a combination of retrospective analysis and focused field research may provide insights into the linkage between future climate change and freshwater habitats. These effects could provide broad spatial-scale coherence in the future.

5.2.4 Priority Research Themes and Example Questions

<u>Role of Environmental Variables on Ecology of Chinook Salmon in Streams</u>

1. **Do environmental forcing variables such as flow extremes explain trends in Chinook salmon productivity in the AYK region? This analysis will extend and generalize the preliminary results for the Chena River (Neuswanger et al. 2012). Other drivers could be considered, including temperature and abundance of other species. Additional life stages should also be included, such as embryo incubation,**

juvenile overwintering habitat, and juvenile downstream migration. This analysis could guide further work on effects of climate change on freshwater habitats. [1]

2. **Are marine and freshwater habitat conditions linked by large-scale climate variation? Does co-variation exist across these habitats due to climate variation that could confound the analyses of one or the other? As an extension of #1, inter-annual and decadal variation in freshwater and marine environmental signals should be compared to determine if co-variation exists across environments that could confound analyses.**

Role of Downstream Smolt Survival to the Ocean

3. Does variation in smolt abundance and delivery to the ocean significantly explain later adult returns to rivers? Can inference about trends in freshwater and marine mortality be improved by an adult escapement/smolt assessment program? Partitioning mortality between freshwater and marine life stages is required as a step toward identifying the life stages that are influential in determining population trends. However, estimating smolt abundance in large-river systems is difficult and expensive. Possibly, other sources of information can be gathered to index smolt abundance such as nearshore marine sampling.

Marine-Derived Nutrients

4. Are marine-derived nutrients (MDN) an important contributor to production of juvenile Chinook salmon in freshwaters across the AYK basin? MDN is likely important in areas where high densities of pink, chum, and possibly sockeye salmon occur. Chinook salmon occur at substantially lower spawning abundances than these other species so the contribution of Chinook salmon to MDN in freshwater is probably minor compared to contributions from more abundant species. Interior regions have high densities of carcass predators and juveniles frequently disperse extensively; these variables can reduce the effects of MDN on juvenile production.

Climate Change and Adult Migration.

5. Are mid-summer temperatures in large rivers in western North America increasing as a result of changes in snowmelt, precipitation, land and water use, and air temperature? Warm temperatures can contribute to an increase in the incidence of migration mortality, either as a result of stress, energy depletion, or increased susceptibility to disease. Stress resulting from interactions with fishing gear can also increase due to high temperatures.

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[1] Bold text indicates a research priority selected as a "high priority" within the Chinook Salmon Research Action Plan

5.3 Hypothesis 3 – Ocean Mortality

Hypothesis: *Ocean conditions (physical and biological) have changed in the Bering Sea, causing an increase in mortality of Chinook salmon during their the early marine portion of their life cycle and contributing to declines of AYK Chinook salmon stocks.*

5.3.1 Description of the Hypothesis

Scientists have long recognized the importance of the ocean to salmon population dynamics via survival to maturity and return to the rivers as adults (e.g., Pearcy 1992, Beamish 1993). Indeed, Chinook salmon spend most of their life history and gain more than 95% of their weight while at sea. Changes in the physical environment (e.g., temperature) can affect salmon directly via physiological processes, with ultimate consequences for growth and reproduction. Changes in the physical environment can also affect salmon indirectly through changes in the food web. For example, increased upwelling can lead to better primary and secondary production, leading to increased food availability for juvenile salmon. Changes in the biological environment, such as food-web structure (i.e., prey, competitors, predators), can also affect feeding rates and ultimately survival. Importantly, both natural and human drivers play important roles in structuring the marine environment, though human drivers are addressed under Hypothesis 4. A potential exists for considerable sharing of ocean habitats among stocks, and therefore trends in survival during the early ocean phase of Chinook salmon can produce regionally synchronous changes in salmon abundance.

5.3.2 Plausibility of the Biological Mechanism(s)

Two time periods are believed to be especially important for salmon survival during their time at sea: the spring and summer months immediately after smolt out-migration, and the first winter at sea (Beamish and Mahnken 2001). An expanding body of literature links conditions in the marine environment to salmon survival. Some studies have been based on large-scale descriptors (e.g., Pacific Decadal Oscillation, Mantua et al. 1997) whereas others have relied more on direct measurements of regional physical conditions (e.g., sea surface temperature, Mueter et al. 2002).

Differences in migration timing can lead to matches or mismatches with important prey resources and predators that ultimately translate into varying growth opportunities and differences in survival (e.g., Scheuerell et al. 2009, Holsman et al. 2012). Chinook salmon endure long periods of low forage during winter and must rely on stored energy accumulated during the growing season for survival through the winter.

Changes to the marine environment experienced by AYK Chinook salmon upon entry to the marine environment and during the early period of the marine portion of their life cycle are certainly a plausible explanation for their decline in recent years.

5.3.3 Summary of the Evidence for the Hypothesis

Scheuerell (2012) presented an analysis of an extended Ricker model used to incorporate the possible effects of environmental covariates on four AYK stocks (i.e., Chena River, Salcha River, Kuskokwim River, and Canadian-origin Yukon River). After accounting for intrinsic productivity and density-dependence within a hierarchical Bayesian framework, Scheuerell found additional evidence that various "ocean indicators" offer additional power in explaining temporal trends in recruits-per-spawner. In particular, those indices associated with sea-level pressure (i.e., Arctic Oscillation Index, North Pacific Index, Bering Sea Pressure Index) and, to a lesser extent, sea temperature (i.e., Pacific Decadal Oscillation) appeared most important. While these associations between survival and large-scale climate indices do not provide a mechanistic explanation for which specific processes are causing variation in survival, they do suggest that broad-scale changes in the environment are translating into a changing suitability of the ocean encountered by juvenile Chinook salmon during their early marine life phase. Perhaps more importantly, each of the four stocks showed different responses to the indicators, suggesting: 1) the different stocks do not use the same places in the ocean as either juveniles or adults, or 2) smolts from the different stocks out-migrate at different times, and thus experience different conditions upon ocean entry.

Murphy (2012) showed preliminary evidence based on a short time-series of data that the juvenile salmon abundance index for Canadian-origin Chinook salmon correlates with overall patterns in recruits-per-spawner, suggesting year-class strength is largely set during the first 2.5 years of life. However, a lack of data on intermediate stream-life stages (e.g., parr, smolts) precludes concluding that the hypothesized effects of a changing ocean environment on marine survival/mortality exclusively caused the connection to the patterns in recruits-per-spawner. That is, although several of the indicators discussed by Scheuerell (2012) (e.g., sea surface temperature) describe conditions within the Bering Sea per se, others (e.g., Pacific Decadal Oscillation) describe larger synoptic climate patterns that also manifest themselves over the continental land mass and may have affected the early life stages in freshwater or estuarine habitats.

Murphy (2012) also showed that the past spatial distribution of juvenile Chinook salmon in the Bering Sea indicated that few fish have been caught in southeastern areas since 2007. It is unclear why Chinook salmon are no longer caught in the southern Bering Sea; however, multiple factors are likely contributing, including changes in the distribution and abundance of Chinook salmon as well as changes to the survey design. Large differences in the distribution of juvenile Chinook salmon in the northeastern Bering Sea occurred between warm and cold years, which likely reflect changes in the migration patterns of juveniles. Large-scale changes in the migratory pattern of juveniles have the potential to alter marine survival, the apparent relationship between the number of juveniles and returns-per-spawner, and marine distribution patterns during their later marine life history stages. Last, Chinook salmon are piscivorous, and despite differences in diet content between warm and cold years, the diet data available suggest that they appear to maintain adequate food intake and energy levels.

5.3.4 Priority Research Themes and Example Questions

Forecasting Adult Salmon Returns to Rivers

1. **When stocks other than those from the Chena River, Salcha River, Kuskokwim River, and Canadian-origin Yukon River are analyzed with a hierarchical Ricker model, do they show the same relationships with ocean indicators? Will adding additional covariates improve the explanatory power of such models? Add additional covariates and other populations/stocks, where possible, to the hierarchical Ricker model to empirically assess the potential effects of changes in the marine climate system on survival rates of AYK Chinook salmon.** [2]

2. **What combination of freshwater and marine environmental variables, measured at different life history stages, and spawning stock size best predicts the next generation of salmon returns? Do these variables co-vary? Examine co-variation between freshwater (e.g., streamflow) and marine variables (e.g., sea surface temperature) at varying time lags (i.e., matching with life history, 0-5 years) to better understanding potential linkages between conditions in freshwater and in the nearshore ocean for determining recruitment success. Develop forecasting tools for returns.**

Early Marine Survival

3. **At what life stage is the strength of recruitment determined? When during the life cycle does most variation in mortality occur? Is mortality greatest during their first year at sea? Obtain abundance estimates of freshwater rearing stages (parr) and migrant/early ocean stages (smolts) to better pinpoint when in the migration timing and where in the life cycle mortality occurs.**

4. **What processes affect the survival of AYK Chinook salmon during their first year at sea? How do food availability, temperature, and other variables appear to affect survival? A better understanding is needed of the processes affecting survival of AYK Chinook salmon during their first year at sea.**

5. Do migration timing and pathways vary by life stage among AYK stocks? Improvement of genetic tools to better identify origin/population of fish caught at sea would allow exploration of this question.

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[2] Bold text indicates a research priority selected as a "high priority" within the Chinook Salmon Research Action Plan