17th Annual Salmon Ocean Ecology Meeting

29-31 March 2016
Juneau, Alaska

17th Annual Salmon Ocean Ecology Meeting

Baranof Hotel and Conference Center
Juneau, Alaska - 29-31 March 2016

Host Sponsor: Alaska Fisheries Science Center
Ted Stevens Marine Research Institute
Juneau, Alaska

Regional Coordinators:

California:	Megan Sabal	Brian Wells
Oregon:	Ric Brodeur	Jessica Miller
Washington:	Brian Beckman	Brian Burke
British Columbia:	Eric Hertz	Marc Trudel
Alaska:	Andrew Gray	Joe Orsi

Contributors: Alaska Seafood Marketing Institute
Fishheads Technical Services
Douglas Island Pink and Chum, Inc.

Artwork: Ray Troll

17th Annual Salmon Ocean Ecology Meeting

Juneau, Alaska, 29-31 March 2016

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17th Annual Salmon Ocean Ecology Meeting, Juneau, Alaska, 29-31 March 2016

Tuesday, March 29th: Workshop Session: Treadwell Ballroom

0730-0830: Registration, light breakfast, coffee

0830-0845: Welcome and Introductions: Alaska hosts

0845-0900: ***Part I: Oceanography and Ecosystem Status***

Introduction: Brian Burke and Brian Beckman

- General format
- Activities and Expected outcomes/products

0900-0930: **Tom's movie of ocean conditions, w/annotation:** (Tom Wainwright) & (Brian Beckman)

Regional background: effects of the blob and El Niño on regional ecosystems

0930-1000: **Alaska**: Ellen Yasumiishi and Stephani Zador

1000-1030: Coffee Break

1030-1100: **British Columbia**: Sue Grant and Marc Trudel

1100-1130: **Oregon/Washington:** Laurie Weitkamp and Bill Peterson

1130-1200: **California**: Brian Wells

1200-1230: **Discussion**: Brief questions for any of the regional presenters (group panel up front)

1230-1400: **LUNCH BREAK** (catered on site)

1400-1530: ***Part 2: The salmon response***

The blob versus specific stocks – what's the score? A chance for individuals to provide a slide or two, showing how the anomalous conditions may have affected salmon stocks or forecasting models. We will ask a handful of people to show slides, but welcome additional slides by *anyone*!

1530-1600: Coffee Break

1600-1630: **Exercise:** Mapping the blob onto the salmonscape – spatial and temporal patterns of effects on adult size and abundance – may lead to multi-author manuscript

1630-1700: **Next steps** – Basecamp, opportunities for collaborations across regions and surveys, and future meetings

17th Annual Salmon Ocean Ecology Meeting, Juneau, Alaska, 29-31 March 2016

Wednesday, 30 March: Salmon Ocean Ecology: Treadwell Ballroom

*Presenting author

0730-0830: Registration, light breakfast, coffee

0830-0840: **Introduction:** Joe Orsi

0840-0850: **Poster titles** (1-min summaries by authors) and viewing opportunities

0850-0920: **Keynote Speaker: *Skip McKinnell*.** The Ocean: An Evolutionary Force in Sockeye Salmon Migration

SESSION 1: Trophic relationships of salmon. Leader: Brian Beckman

0920-1000: **Oral presentations** (2)

Contrasting Trends in Salmon Size-at-Age in Southeast Alaska: What Does the Recent Warm Period Tell Us About the Underlying Cause?
Leon D. Shaul and Harold J. Geiger*

Predation Impact by Juvenile Salmon on Early Life Stages of Rockfish Prey in the Eastern North Pacific *Richard D. Brodeur*, Elizabeth A. Daly, Jamal Moss, and Emily A. Fergusson*

1000-1030: Coffee Break

1030-1200: **Oral presentations** (4)

Seasonal Variation in the Biochemical Ecology of Lower Trophic Levels in the Northern California Current *Jessica A. Miller*, William T. Peterson, Louise Copeman, Xiuning Du, Cheryl A. Morgan, and Marisa N. C. Litz*

Caught in the Middle: Bottom-up Drivers of Top-down Impacts on Chinook Salmon
Brian K. Wells, Jarrod Santora, Mark Henderson, John Field, Russell Bradley, Peter Warzybok, David Huff, and David Ainley*

Trophically Transmitted Parasites Reflect Differences between Natural-Origin and Hatchery-Produced Juvenile Salmonids in Freshwater, Estuarine and Marine Habitats
K. C. Jacobson, A. K. Aceves, L. A. Weitkamp, J. Losee, Don Van Doornik, C. A. Morgan*

Effects of the Warm Ocean 'Blob' on May and June 2015 Juvenile Salmon in the Northern California Current Ecosystem
Elizabeth A. Daly and Richard D. Brodeur*

1200-1330: **LUNCH BREAK** (on your own)

SESSION 2: Ocean migration and distribution. Leader: Ric Broduer

1330-1500: **Oral presentations** (4)

Oceanic Movement, Behavior and Mortality of Chinook Salmon, Elucidated with Pop-Up Satellite Tags
Andrew C. Seitz, Michael B. Courtney, Mark D. Evans, and Jim Murphy*

Musings on Thermal Stress, Marine Migration and Salmon Survival
*Tom Wainwright**

Salish Sea Chinook Salmon Survival Related to Juvenile Size and Distribution
Iris Kemp, Dave Priekshot, Chrys Neville, and Marc Trudel*

Investigating Fine Scale Spatiotemporal Patterns in Distribution, Diet, and Growth of Juvenile Chinook Salmon using Microtrolling and Small Vessel Oceanography
W. Duguid, T. Iwanicki, and F. Juanes*

1500-1530: Coffee Break

SESSION 3: Salmon attributes in response to ocean conditions. Leader: Andy Gray

1530-1700: **Oral Presentations** (4)

The Effect of Growth on Age at Maturity of Western Alaskan Chinook Salmon (*Oncorhynchus tshawytscha*): A Contrast with Southern Populations
Jared Siegel, Milo Adkison, and Megan McPhee*

What's Up Jack? A Workshop-Style Approach to Assessing Varying Jack Rates in Columbia River Spring Chinook Salmon
*Brian Beckman**

The Odd Squad: Testing Beamish's Hypothesis of Metabolic Divergence between Brood-Year Lines of Pink Salmon *Oncorhynchus gorbuscha*
Megan V. McPhee and Brian R. Beckman*

Have Gender-Specific Growth and Maturation at Sea Influenced the Decline of Western Alaska Chinook Salmon?
Greg Ruggerone, Brendan Connors, Bev Agler, and Lorna Wilson*

1700-1800: **Poster session**, AJ Room (across the hall from the Treadwell Ballroom)

1800-2100: **Banquet (Sponsor: ASMI, Michael Kohan presentation)**

~1900: **Banquet speaker: *Michael Schmidt.*** Climate change, collaboration and improving salmon management with ocean ecology

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Thursday, 31 March: Salmon Ocean Ecology: Treadwell Ballroom

*Presenting author

0730-0830: Light breakfast, coffee

0830-0845: Announcements

0845-0915: **(Bob Emmett meeting dedication: *Kurt Fresh*)**

SESSION 4: Forecasting approaches and evaluations. Leader: Laurie Weitkamp

0915-1000: **Oral Presentations** (2)

Pre-season Forecast Models for Pink Salmon in Southeast Alaska: What Have We learned?
Joseph Orsi, Emily Fergusson, Alex Wertheimer, and Ellen Yasumiishi*

Forecast Error of Bristol Bay Sockeye Salmon in Relation to Pink Salmon Abundance
Greg Ruggerone, Bev Agler, Brendan Connors, Ed Farley, Jim Irvine, Lorna Wilson, and Ellen Yasumiishi*

1000-1030: Coffee Break

1030-1200: **Oral Presentations** (4)

Pacific Salmon Commission Chinook Model: A Tool for Managing Coast-wide Chinook Salmon Fisheries
John K. Carlile, Randy L. Peterson, and Dani F. Evenson*

Evaluating the Performance of Salmon Abundance Forecast Models: a Sacramento River Fall Chinook Case Study
Michael R. O'Farrell, Arliss J. Winship, William H. Satterthwaite, Brian K. Wells, and Michael S. Mohr*

Models Migrating Toward Data: Probabilistic Salmon Population Forecasting Using Integrated Analysis
Eric R. Buhle, Mark D. Scheuerell, and James T. Thorson*

Juvenile Chinook Salmon Abundance in the Northern Bering Sea: Implications for Future Returns and Fisheries in the Yukon River
James M. Murphy, Kathrine G. Howard, Jeanette C. Gann, Kristin Cieciel, William D. Templin, and Charles M. Guthrie III*

1200-1330: **LUNCH BREAK** (on your own)

SESSION 5: Early marine diet, growth, and interactions. Leader: Brian Wells

1330-1500: **Oral Presentations** (4)

Regional and Inter-Annual Patterns of Juvenile Coho Salmon Growth in the Strait of Georgia
Meredith L. Journey, Marc Trudel, Chrys Neville, and Brian Beckman*

Density Density Dependent Effects During Juvenile Sockeye Salmon Early Marine Residency
Cameron Freshwater, Marc Trudel, Terry Beacham, Stewart Johnson, Chrys Neville, and Francis Juanes*

Size-Selective Mortality of Hatchery and Wild Chinook Salmon (*Oncorhynchus tshawytscha*) in Puget Sound
Madilyn M. Gamble, Kristin Connelly, Jennifer Gardner, David Beauchamp, and Joshua Chamberlin*

Characterizing the Condition of Outmigrating Chinook and Steelhead in the Columbia River Estuary *Laurie Weitkamp, Kurt Fresh*, Don Van Doornik, and Kym Jacobson*

1500-1530: Coffee Break

1530-1630: **Oral Presentations** (3)

Fine-Scale Spatial and Stock Variations among Juvenile Chinook Salmon and Steelhead in the Columbia River Plume: May 2015
Cheryl A. Morgan, Brian R. Beckman, Brian J. Burke, Laurie A. Weitkamp, Jessica A. Miller, Kym C. Jacobson, and Donald M. Van Doornik*

Effects of Fry Stocking on Freshwater Growth of Juvenile Sockeye Salmon (*Oncorhynchus nerka*) in an Alaskan Lake: A Retrospective Analysis
Jodi Neil, Bev Agler, Greg Ruggerone, Milo Adkison, and Megan McPhee*

Developing quantitative measures of risk using spatial/temporal overlap – an ecological example with seabirds & salmon
Jeannette E. Zamon, Brian J. Burke, Mary E. Hunsicker, David J. Teel, and Elizabeth M. Phillips*

1630-1700: **Invited wrap up speaker: *Peter Hagen.*** Summary Remarks

1700-1715: **Concluding remarks** (Next SOEM host region/coordinators)

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ORAL PRESENTATIONS

TROPHIC RELATIONSHIPS OF SALMON

Contrasting Trends in Salmon Size-at-Age in Southeast Alaska: What Does the Recent Warm Period Tell Us About the Underlying Cause?

Leon D. Shaul[1] and Harold J. Geiger[2]

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[2]St. Hubert Research Group, 222 Seward Street, Suite 205, Juneau, AK 99801 (Email: shrg@ak.net, Tel: 907-723-3234)

Oral presentation

Abstract: Average size-at-age of adult salmon in Southeast Alaska has converged since the early-1980s, increasing in small flexible planktivores (pink and 2-ocean sockeye salmon) while decreasing in larger nektivores (coho and Chinook salmon). One hypothesis for these contrasting trends is that they reflect a decrease in average trophic level of salmon forage caused by increasing numbers of maturing pink salmon, an intraguild predator that preys upon squid and competes with them for zooplankton prey. Another hypothesis holds that these contrasting trends can be explained by species-specific trophic level and growth responses to post-1998 cooling. In a recent analysis, we found that much (65%) of the variation in average weight of coho salmon over a 45-year period is equally explained by variables representing climatic and top-down control of their primary offshore prey (squid). However, the relative roles of climatic variation and salmon foraging in increasing size of flexible planktivores are less clear. Here we examine changes in adult size during recent warming to test competing hypotheses, and find the response within trophic groups to be generally consistent with species-specific estimates of thermal tolerance. In 2015, mature pink salmon were 7% heavier than average, continuing a trend toward larger size, despite recent warming and the second largest Gulf of Alaska harvest in history, while average length of 2-ocean sockeye salmon decreased to near the 1982–1998 average. Average 4-ocean Chinook length was the second smallest on record, consistent with a protracted size decline, while coho salmon weighed 8% more than our model prediction but 11% below average. Although the apparent growth response during recent warming was species- and age-specific, the overall response pattern remained consistent with the hypothesis that pink salmon have influenced the trophic structure of offshore salmon forage to their benefit and to the detriment of higher trophic level consumers.

Predation Impact by Juvenile Salmon on Early Life Stages of Rockfish Prey in the Eastern North Pacific

Richard D. Brodeur[1], Elizabeth A. Daly[2], Jamal Moss[3], and Emily A. Fergusson[3]*

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Oral presentation

Abstract: Although predation is thought to be the major limiting factor in fish recruitment, there have been few studies examining the effects of predators on prey populations. Juvenile Chinook and coho salmon are highly piscivorous (60-90% of their diets by weight is fish) in their first summer at sea and are likely to be one of the most important fish predators on larval and juvenile fishes in coastal waters. The aim of this study is to examine predation pressure on juvenile rockfish (*Sebastes* spp.) prey by juvenile Chinook and coho salmon in coastal regions of the Northern California Current (NCC) and off Southeast Alaska (SEA) to examine: 1) proportions of the rockfish prey in the diets of each predator by season and year and compare these to available prey fishes from contemporary trawl sampling, 2) sizes of fish prey consumed compared to available sizes, and 3) overall prey consumption using bioenergetics modeling and estimates of salmon present in coastal waters. Juvenile rockfishes were the dominant prey in early summer and, to a lesser extent, in the fall over 8 years of sampling (2004-2011) in the NCC. Prey fish sizes range from <10 mm to >100 mm which represents a challenge to getting estimates of prey availability and may require multiple gears types (plankton to small-mesh trawls) to get quantitative measures of prey selection. Total consumption by both predators was estimated to vary from 27% to 15% of total juvenile rockfish available for summer and fall, respectively. For SEA, rockfish were also an important prey species for both salmon species although there was substantial variability over the 4 years (2010-2013) sampled. Rockfish consumption estimates off SEA for both predators combined averaged around 7% of available prey for the summer period.

Seasonal Variation in the Biochemical Ecology of Lower Trophic Levels in the Northern California Current

Jessica A. Miller[1], William T. Peterson[2], Louise Copeman[3], Xiuning Du[4], Cheryl A. Morgan[4], and Marisa N. C. Litz[1]

[1]Oregon State University (OSU), Fisheries & Wildlife
[2]NOAA Fisheries, Northwest Fisheries Science Center
[3]OSU, College of Earth, Ocean, and Atmospheric Sciences
[4]OSU, Cooperative Institute of Marine Resources Studies

Oral presentation

Abstract: Strong correlative evidence indicates that variation in the spatial distribution, growth, and survival of juvenile salmon is related to the copepod community composition within the Northern California Current (NCC). A hypothesized mechanism for this observation is that copepod communities dominated by lipid-rich, boreal species support enhanced growth and survival of early stages of forage fishes that directly feed on copepods, which has cascading effects on higher trophic levels (the “lipid quantity" hypothesis). An alternative hypothesis (the “lipid quality” hypothesis) is that variation in abundance of certain essential fatty acids, such as DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid), is responsible for variation in growth and condition of primary and secondary consumers. However, seasonal and interannual variation in the quantity and quality of copepod lipids is not well documented and the relative importance of species composition versus diet in determining the quantity and composition of the copepod lipids is not yet well understood. Therefore, we characterized variation in the lipid classes and fatty acids present in phytoplankton and copepods collected at an oceanographic station off Oregon (NH05) from June 2012 to December 2013. We completed community analyses on the phytoplankton and copepod species and fatty acid composition and identified seasonal transitions based on each of those communities. We observed a very high level of covariation between species and biochemistry across trophic levels, and there were distinct seasonal differences. However, seasonal differences in the quantity of lipids were only evident for the copepod community when delineated by their fatty acid, not their species, composition. Furthermore, copepod species community shifts were consistently offset from shifts in their fatty acid composition, which more directly reflected shifts in the species and biochemistry of primary producers and highlights the importance that seasonal variation in primary production plays in regulating the lipid composition of primary consumers.

Caught in the Middle: Bottom-up Drivers of Top-down Impacts on Chinook Salmon

Brian K. Wells[1], Jarrod Santora[2], Mark Henderson[3], John Field[1], Russell Bradley[4], Peter Warzybok[4], David Huff[5], and David Ainley[6]

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[6]H.T. Harvey & Associates, 983 University Avenue Building D, Los Gatos, CA 95032

Oral presentation

Abstract: It is accepted that predation by seabirds on juvenile salmon in the ocean may be substantial, however statistical evidence is rare. As suggested by our colleagues, including Pearcy and Emmett, the impact of predation may be greater when alternative prey items are lacking and/or the environmental conditions lead to an increased geographic overlap between seabirds and juvenile salmon. Building on these concepts, in this study we show evidence that Common Murre in central California become more aggregated on the shelf in Spring during years of low productivity and limited prey (e.g., juvenile rockfish). While on the shelf, Common Murre switch to an anchovy-dominated diet. However, the overlap in distributions leads to an increase in predation on juvenile salmon as well – as much as 10% -- which appears great enough to impart significant mortality on the salmon populations. We demonstrate these impacts with GAMS to parse the interactive effects of winter preconditioning, juvenile salmon size, prey abundance, and Common Murre abundance on salmon survival in central California.

Trophically Transmitted Parasites Reflect Differences between Natural-Origin and Hatchery-Produced Juvenile Salmonids in Freshwater, Estuarine and Marine Habitats

K. C. Jacobson[*1], *A. K. Aceves*[2], *L. A. Weitkamp*[1], *J. Losee*[4], *Don Van Doornik*[3], *and C. A Morgan*[5]

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Oral presentation

Abstract: Trophically transmitted parasites provide an extended diet history in fish beyond what is obtained by documenting consumed prey. They have reflected the effects of ocean conditions and diversity of diet on growth and condition of juvenile salmon in the ocean. In those studies, we noted differences in parasite communities between marked and unmarked juvenile salmon. Differences in the behavior and ecology between natural-origin and hatchery salmon indicate to what extent hatchery salmon serve as a surrogate for natural-origin fish. Subsequently, we documented differences in juvenile coho salmon (*Oncorhynchus kisutch*) obtained directly, and above, a hatchery to confirm differences prior to release of hatchery fish. The percent of wild coho salmon infected with one or more taxa ranged from 30% - 90% compared to 10% of the hatchery fish. The number of parasites recovered from infected hatchery coho was also significantly less than those from infected wild fish. These results confirmed that hatchery fish eat few natural prey in the hatchery and freshwater parasites reflect diet history during migration through freshwater. A subsequent comparison between hatchery and natural origin Mid/Upper Columbia River Chinook salmon (*Oncorhynchus tshawytscha*) from the lower Columbia River estuary (2007-2011) indicated a trend for natural origin fish to harbor more freshwater (50% vs 14%) and marine (50% vs. 35%) parasites than hatchery fish, suggesting that juvenile hatchery Chinook salmon may not be consuming prey at the same rate, or diversity, as natural origin fish during river and estuarine emigration. In May 2015 we focused on collecting enough juvenile Chinook salmon to compare natural origin to hatchery produced juveniles after they just entered the ocean. Despite small sample sizes of unmarked MUCR and Snake River Chinook salmon, the difference in intestinal parasites between marked and unmarked fish was unequivocal with a mean abundance of freshwater parasites in unmarked salmon of 39.9 compared to only 3.8 from marked fish. Other differences and the utility of parasites as biological markers will be discussed.

Effects of the Warm Ocean 'Blob' on May and June 2015 Juvenile Salmon in the Northern California Current Ecosystem

Elizabeth A. Daly[1] and Richard D. Brodeur[2]

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Oral presentation

Abstract: Anomalously warm ocean conditions persisted throughout winter, spring, and summer of 2015 (+2°C above normal). Warm winter conditions occurred when the prey resources of juvenile salmon developed and in the spring and summer as the salmon entered the ocean. The biomass of ichthyoplankton in January-March is inversely related to October-December PDO conditions the prior year and positively to adult salmon returns several years later. PDO conditions in late 2014 were almost double (warmer) than those of any year in our 18 year time series, and would have predicted a biomass 95% less than the amount that was actually sampled in January-March of 2015. The increased biomass was primarily due to abnormally high biomasses of Northern anchovy and rockfish larvae. May diets of juvenile Chinook salmon collected in coastal waters of the Northern California Current reflected higher proportions of juvenile rockfish being eaten, but no evidence of Northern anchovies being consumed. The May Chinook salmon diet composition most closely resembled those of other warm years of our study period. June diets also reflected a warm prey community being consumed with higher amounts of juvenile rockfish, crab megalopae and juvenile Northern anchovies being eaten, somewhat resembling the diets from the 1998 El Niño period. Both May and June Chinook salmon had one of the highest percentages of empty stomachs but overall stomach fullness was average for May but very low in June. Residuals of length-weight relationships showed that most salmon (not just Chinook salmon) were below average weight for their length. For Chinook salmon in 2015, they weighed 17.6% less that the same size fish in a cold ocean year (2008). Higher condition or fatness of Chinook salmon relates to increased adult returns two years later which suggests that the prospects for the 2015 ocean-entry smolts are not that favorable.

OCEAN MIGRATION AND DISTRIBUTION

Oceanic Movement, Behavior and Mortality of Chinook Salmon, Elucidated with Pop-Up Satellite Tags

Andrew C. Seitz[1], Michael B. Courtney[2], Mark D. Evans[3], and Jim Murphy[4]

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[3] University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, PO Box 757220, Fairbanks, AK 99775-7220 (Email: mdevans@alaska.edu, Tel: 907-474-7202)
[4] Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, NOAA Fisheries, 17109 Point Lena Loop Road, Juneau, AK 99801 (Email: jim.murphy@noaa.gov, Tel: 907-789-6651)

Oral presentation

Abstract: To examine the oceanic ecology of Chinook salmon, about which little is known, we are conducting a proof-of-concept study in which large, immature Chinook salmon are tagged with pop-up satellite archival transmitting tags in the Bering Sea. While externally attached to the fish, the tags measure and record ambient light (for daily geoposition estimates), depth and temperature data. On a pre-programmed date, the tags release from the fish, float to the surface of the ocean and transmit the recorded data to overhead satellites which are then retrieved by project investigators. Most tagged Chinook salmon have remained in the Bering Sea while occupying depths to 200 m and water temperatures from 4 to 13°C during summer and autumn. Based on temperature records, predation of Chinook salmon by salmon sharks occurs in the Bering Sea. One additional tagged Chinook salmon left the Bering Sea and transited across the Gulf of Alaska while occupying depths to 500 m and water temperatures between 3 and 9°C during winter. These data provide valuable information about regional oceanic ecology of Chinook salmon, which may be used in a variety of ways, such as for improving bioenergetics models, avoiding bycatch, and informing evaluation of high-seas salmon survey data.

Musings on Thermal Stress, Marine Migration and Salmon Survival

Tom Wainwright

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Oral presentation

Abstract: Much has been written about ocean temperature and salmon survival, but most studies suffer from three limitations:

· Most studies look at either broad regional patterns (e.g., PDO) or single point (pier or mooring) observations of temperature, while migrating fish experience a sequence of local temperature patterns at shifting locations along their migration corridor.

· Most examine monthly or seasonal averages, while fish respond to temperature at physiological and behavioral time scales.

· Most focus on seasonal temperature anomalies, while fish respond (non-linearly) to absolute temperatures.

With modern high-resolution integrated surface temperature (SST) data sets, we should be able to do better; I present some ideas on how we might.

To anthropomorphize unapologetically, I begin with the assertion that fish don't care about monthly anomalies, they, like the three bears, care about whether today's porridge (seawater) is too cold, comfortably cool, or stressfully (even lethally) warm. On this basis, I propose that the direct effects of temperature on early marine growth and survival may be related to cumulative thermal stress (CTS), i.e., an integration of stressful temperatures experienced over the course of their migration. As a first approximation to this, I present an analysis of SST patterns in the migration corridor of Oregon coho salmon. First, based on thermal-tolerance literature, I translate observed temperature to potential thermal stress as a function of degrees above a critical temperature. Next, I define a hypothetical migration pattern for coho salmon in their first 6 months at sea (May – Oct). By overlaying this pattern on daily high resolution (daily, 0.25 degree) SST maps for 1982-2015, I obtain a stock-specific annual CTS index that can be related to recruitment time series. So far, the approach shows some promise, but there is much room for refinement.

Salish Sea Chinook Salmon Survival Related to Juvenile Size and Distribution

Iris Kemp[1], Dave Priekshot[2], Chrys Neville[2], and Marc Trudel[2]

[1]Long Live the Kings, Seattle, WA
[2]Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada

Oral presentation

Abstract: Marine survival of many Salish Sea salmon stocks has declined since the 1980s and remains low. Determining factors that drive survival is essential to understanding declines and to developing management and recovery actions. Marine survival trends for Salish Sea stocks differ from trends of stocks in adjacent regions, suggesting that conditions within the Salish Sea contribute to low survival. In Puget Sound and the Strait of Georgia, juvenile salmon generally outmigrate from rivers in spring and summer, reside in nearshore and offshore habitats within the Salish Sea for a period of time, and then eventually move out of the Salish Sea to the Pacific Ocean. Early marine growth and survival may vary spatially, since the Salish Sea is composed of several oceanographically-distinct regions. We synthesized coded-wire-tag (CWT) data from the Regional Mark Information System database with 17 years of trawl surveys in Puget Sound and the Strait of Georgia to examine relationships among release region, release timing, release size, capture size, and overall smolt-to-adult survival of CWT Chinook salmon. Early marine distribution patterns of juvenile CWT Chinook within the Salish Sea will also be discussed.

Investigating Fine Scale Spatiotemporal Patterns in Distribution, Diet and Growth of Juvenile Chinook Salmon using Microtrolling and Small Vessel Oceanography

W. Duguid[1], T. Iwanicki[2], and F. Juanes[3]

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Oral presentation

Abstract: While many juvenile Pacific Salmon migrate rapidly onto the continental shelf, some stocks remain in nearshore waters such as the Salish Sea through their first summer at sea. Epipelagic habitats in such areas can be highly structured. The interaction of wind and tidal currents with complex topography results in spatial variability in water column stratification and generates hydrological features such as tidal jets and island wakes. This variability may result in regions where conditions conducive to rapid growth result in predictable concentrations of juvenile salmon; potentially modulating interactions between these salmon and higher and lower trophic levels. We employed 'microtrolling' (modified recreational fishing gear deployed from a small vessel) to investigate distribution, diet and growth of juvenile Chinook salmon in the Southern Gulf Islands from July to October 2015. Sampling occurred across tidal cycles at five sites characterized by differing physical oceanography. We investigated diets using gastric lavage and assessed recent growth using scale circulus spacing and RNA:DNA ratios from non-lethal muscle biopsies. We related Chinook salmon distribution, diet and growth to water column stratification and zooplankton abundance data collected concurrently with fish sampling. Understanding how resident stocks of juvenile salmon use nearshore epipelagic habitats may help explain trends in their productivity while also providing general insights into how behaviour interacts with fine scale oceanography to influence the ecology of juvenile salmon at sea.

SALMON ATTRIBUTES IN RESPONSE TO OCEAN CONDITIONS

The Effect of Growth on Age at Maturity of Western Alaskan Chinook Salmon (*Oncorhynchus tshawytscha*): A Contrast with Southern Populations

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Oral presentation

Abstract: Age at maturity of Pacific salmon species represents a balance between increased reproductive success with size versus greater risk of mortality before maturity with longer marine residencies. Past research has demonstrated that higher growth rates often lead to an earlier age at maturity. The majority of research relating growth to age of maturity in Chinook salmon (*Oncorhynchus tshawytscha*) has described a strong influence of early life history growth, including freshwater and/or first year marine growth. These investigations have largely been performed on populations in the contiguous United States, representing the southern portion of the species' range. Southern populations of Chinook salmon tend to have higher freshwater growth rates and mature at an earlier average age in comparison to more northern populations in Canada and Alaska. In this study we investigate the relationship between growth and age at maturity in two western Alaskan populations through logistic probability modeling of retrospective scale analysis growth data. Due to the later average age at maturity of our study populations, we hypothesized that later growth would have a larger effect on the timing of maturity. Results suggest that while augmented growth throughout the life-history of individuals increases the probability of maturing early, some periods of growth have greater influence than others. In particular, second year saltwater growth has the largest influence on the age at maturity in the two study populations. These results contrast with prior investigations of southern populations, demonstrating a substantially larger influence of marine growth in comparison to freshwater growth in determining age at maturity of western Alaskan Chinook salmon.

What's Up Jack? A Workshop-Style Approach to Assessing Varying Jack Rates in Columbia River Spring Chinook Salmon

Brian Beckman

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Oral presentation

Abstract: It is well known that Chinook salmon have variable life histories, within Columbia River populations, spring Chinook salmon males may mature at age 1, 2, 3, 4, or 5. Males maturing at age 3, after one year of marine rearing, are termed jacks. For a given brood year, jacks generally occur at proportions of 5 – 10%, among all adults. Recently, jack proportions have reached 20 – 30% in some years. Overall, there is both correlated inter-annual variation in jack rates among spring Chinook salmon populations and intra-annual variation between these same populations. In this talk overall patterns in inter-annual jack rate will be compared to varying patterns of marine productivity. This analysis will be conducted in a comparative manner, assessing whether different populations, that may have differing marine distributions, have similar or different inter-annual patterns in jack rate. Overall, this analysis may help encourage spatially and temporally specific analysis of ocean conditions in relation to salmon responses.

The Odd Squad: Testing Beamish's Hypothesis of Metabolic Divergence between Brood-Year Lines of Pink Salmon *Oncorhynchus gorbuscha*

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Oral presentation

Abstract: Due to their fixed two-year life cycle, even and odd brood years of pink salmon are genetically isolated and therefore subject to divergent evolutionary trajectories. Laboratory observations of greater incubation success of the even-year brood line at colder temperatures, coupled with opposing latitudinal patterns in population abundances between the two lines, have led to the hypothesis that postglacial recolonization progressed from a northern refugium for the even line and a southern refugium for the odd line. More recently, observations of changing marine survival of the two brood-year lines in the Strait of Georgia led Dick Beamish to hypothesize that the two lines may also differ in growth and energetics early in their marine life. Specifically, he proposed that the even line used more energy acquired in the first marine summer for energy storage while the odd line invested more energy into growth in length. We tested this hypothesis with ten years of survey data from the Northeast Bering Sea. In support of the hypothesis, we found that juvenile pink salmon from even line maintained higher mass per length and energy density over the month of September than did those from the odd line. In contrast, we did not detect statistically significant differences in length between the two lines, although four years of IGF-1 level data were suggestive of higher somatic growth rates in the odd line.

Have Gender-Specific Growth and Maturation at Sea Influenced the Decline of Western Alaska Chinook Salmon?

Greg Ruggerone[1], Brendan Connors[2], Bev Agler[3], and Lorna Wilson[3]

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Oral presentation

Abstract: Both spawner abundances and harvests of Chinook salmon in western Alaska have declined in recent decades, and a recent study indicated a widespread decline in the length-at-age and age-at-maturation of Chinook across many regions of Alaska. Using scales collected from Yukon, Kuskokwim, and Nushagak Chinook salmon, we created indices of annual growth in fresh water and each year at sea over the past several decades, and tested the following hypotheses: 1) female Chinook salmon grow faster than male Chinook salmon, 2) early maturing Chinook salmon (age 1.3) grow faster than later maturing salmon (age 1.4), and 3) differential growth of female versus male salmon and younger versus older salmon begins during early life and continues through each year at sea. Analysis of the indices of growth indicates that female and early maturing salmon grow faster than male and older maturing salmon, yet female salmon delay maturation (mostly age 1.4) relative to male Chinook salmon (mostly age 1.3), indicating the growth/maturation schedule differs between female and male Chinook salmon. Although rapid growth is important to all salmon species, we suggest that this finding highlights the importance of rapid growth and large size to female Chinook salmon as a means to enhance their reproductive potential (i.e., fecundity and large egg size). However, this apparent strategy of female Chinook salmon to grow fast and delay maturation appears to be traded off with increased mortality since maturing female salmon appear to be less abundant than male salmon. These findings raise the question: to what extent does reduced growth and earlier maturation reflect increased mortality during late marine life and has this contributed to the decline in the abundance of western Alaska Chinook salmon?

FORECASTING APPROACHES AND EVALUATIONS

Pre-season Forecast Models for Pink Salmon in Southeast Alaska: What Have We learned?

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Oral presentation

Abstract: Since 1997, the Alaska Fisheries Science Center's Southeast Alaska Coastal Monitoring (SECM) project has accomplished ocean surveys each year to collect monthly biophysical data associated with seaward migrating juvenile salmon and ecologically associated species in Southeast Alaska (SEAK). These regional ecosystem metrics, which are collected in spring and summer, have been used along with larger basin-scale and global indexes to develop pre-season forecast models to predict adult pink salmon returns to SEAK the ensuing year. Because pink salmon only spend one winter at sea, they lack leading indicator information from sibling models available for most other salmon species. Consequently, previous forecasting methods developed to assess pink salmon returns have often failed thus leaving managers and stakeholders with more questions than answers. For over a decade, the annual SECM pre-season pink salmon harvest models have provided "mostly accurate" forecasts to resource stakeholders, thereby maximizing economic efficiency within the fish processing community. The pink salmon fishery in SEAK is based mostly on wild stocks (97%) that originate from >2,000 streams: the fishery peaked in 2013 with a harvest of 95 M fish, valued at >$130 M USD. For each of the past 12 years, SECM researchers have given oral presentations and handouts of these pre-season pink salmon forecasts at regional stakeholder meetings and posted this information for public access on a pink salmon forecast website. A goal of this presentation is to provide a conceptual model of key factors that influence pink salmon production in SEAK. Finally, an overview of the "track record" of the SECM quantitative forecast models will be shared, as well as an introduction to a newer forecast model approach that incorporates a broader range of significant ecosystem indicators in more of a qualitative fashion.

Forecast Error of Bristol Bay Sockeye Salmon in Relation to Pink Salmon Abundance

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Oral presentation

Abstract: Total sockeye abundance in Alaska tends to be positively correlated with North Pacific pink salmon abundance, leading to questions about the importance of competition at sea between these two species. We examined annual scale growth of Bristol Bay sockeye salmon at sea and forecast error of Bristol Bay sockeye stocks during the past 40 years to further test the hypothesis that competition with pink salmon reduces the growth and survival of sockeye salmon. Sockeye growth during the second and third years at sea exhibited a strong alternating-year pattern and was negatively correlated with pink salmon abundance from eastern Kamchatka. In addition, forecast error of sockeye stocks from southeastern Bristol Bay (Kvichak, Naknek, Egegik, and Ugashik) exhibited an alternating-year pattern suggesting competition with pink salmon also affected survival. After standardizing forecast error relative to adjacent years, forecasts in even-years were too high and forecasts in odd-years were too low, likely reflecting competition with pink salmon during the year prior to the return year. Forecast error was greatest for sockeye spending two rather than three winters at sea. Sockeye salmon from northwestern Bristol Bay (Wood River) exhibited weaker growth and forecast error relationships with pink salmon, a finding consistent with their more easterly distribution at sea. As expected, sockeye scale growth during the first year at sea was not related to pink salmon abundance, and greater growth during this early marine period prior to interaction with abundant pink salmon likely contributed to greater abundance of Bristol Bay sockeye salmon in recent decades. These findings highlight sockeye growth and survival dynamics that cannot be explained by physical oceanographic patterns, and they support the hypothesis that competition with pink salmon adversely affects the growth, survival, and forecast error of Bristol Bay sockeye salmon.

Pacific Salmon Commission Chinook Model: A Tool for Managing Coast-wide Chinook Salmon Fisheries

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Oral presentation

Abstract: The Pacific Salmon Treaty requires annual reporting of catches, escapements, abundance indices, estimates of incidental mortality and exploitation rates for Chinook salmon fisheries and stocks harvested within the Treaty area from Cape Suckling in Alaska to Cape Caution in Oregon. The Pacific Salmon Commission Chinook Model is a multi-stock, multi-fishery forward cohort analysis model that fulfills portions of this obligation by generating yearly estimates of key statistics relevant to the Treaty's management system. The structure and purpose of the Model have evolved over time since its initial construction in 1983. Currently, the primary function of the Model is to produce abundance indices which in turn determine the total allowable catches for three major mixed-stock fisheries in the Treaty area (Southeast Alaska, Northern British Columbia, and West Coast Vancouver Island). A secondary function is to provide preseason estimates of exploitation rate indices to inform management of fisheries that are managed on an individual stock basis. The Model is recalibrated each year, incorporating the latest catches, exploitation rates estimated from coded-wire tags, terminal runs, escapements, and forecasts. The Model is sensitive to a number of inputs including stock and age-specific maturation rates and terminal run/escapement forecasts. The number of stocks and fisheries represented in the Model is currently being expanded and future improvements have been identified. Although the Model incorporates environmental variability, its ability to reflect changing ocean conditions and fish population dynamics has degraded in recent years.

Evaluating the Performance of Salmon Abundance Forecast Models: a Sacramento River Fall Chinook Case Study

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Oral presentation

Abstract: In response to a string of years with poor forecast performance, we constructed and evaluated a series of new abundance forecast approaches for the Sacramento Index (SI: the adult abundance index for Sacramento River fall Chinook salmon). A range of models were considered, including those that incorporated effects of density dependence, local environmental conditions, the abundance of the previous cohort, and trends or autocorrelation in the jack-to-SI relationship. We assessed model performance using quantitative approaches, such as cross-validation and the propensity for forecast errors to be of sufficient magnitude to lead to management errors. Forecast performance was also assessed qualitatively by examining the ability of forecasts to track trends in the SI. Several models achieved higher accuracy than the status quo model, but no single model performed best across all performance criteria and substantial forecast error remained across all approaches considered. Models including environmental covariates generally performed better than the status quo approach, but there were differences in the relative importance of individual environmental variables over time and among model formulations. Simpler models often had similar or better performance than the more complex environmental models. In particular, the model incorporating temporally autocorrelated errors demonstrated potential for modest forecast improvement with relatively low model complexity.

Models Migrating Toward Data: Probabilistic Salmon Population Forecasting Using Integrated Analysis

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Oral presentation

Abstract: Predictive models of population dynamics that can forecast the risk of decline or extinction are an essential tool in the management of imperiled species. Estimates of uncertainty are a critical component of such forecasts, since they allow decision-makers to weight the costs and benefits of various scenarios by their probability of occurrence. For Pacific salmon and steelhead, estimates of quasi-extinction risk have often relied on relatively simple stock-recruit models fitted to run reconstruction data or life cycle models whose parameters are estimated in a piecemeal, stepwise fashion from multiple data types (e.g. stage-specific abundance, mark-recapture). These approaches to parameter estimation do not make the most efficient use of shared information across data sets, they conflate process and observation error, and as a result they can lead to biased estimates of population dynamics and risk. We present an alternative approach using integrated analysis, in which state-space models describing the age-structured adult-to-adult dynamics and the noisy observations are fitted to time series of spawner abundance, age composition, hatchery influence, and harvest. We illustrate the approach with data for Snake River spring/summer Chinook salmon, comparing single-population forecasts with a version of the model that shares information hierarchically across multiple populations. We also show how environmental covariates such as indicators of ocean conditions can be incorporated into the analysis to help improve forecast precision.

Juvenile Chinook Salmon Abundance in the Northern Bering Sea: Implications for Future Returns and Fisheries in the Yukon River

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Oral presentation

Abstract: The abundance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) is estimated in the northern Bering Sea and guidance is provided for future returns and fisheries for Chinook salmon in the Yukon River. Significant international concern of the state of Yukon River Chinook salmon has developed due to their declining productivity and subsequent closures of commercial, sport, and personal use fisheries and severe restrictions on subsistence fisheries. Juvenile abundance is estimated for the Canadian-origin stock group of Chinook salmon from the Yukon River based on surface trawl catch data, mixed layer depth adjustments, and genetic stock composition of Chinook salmon in the northern Bering Sea near the end of their first summer in the ocean (September). Abundance estimates ranged from a low of 0.62 million in 2012 to a high of 2.57 million in 2013 with an overall average of 1.5 million from 2003 to 2015. Estimates of juvenile survival were relatively low (average of 5.2%), but were significantly correlated ($r = 0.88$, $p < 0.001$) with adult returns, indicating that much of the variability in survival occurs during earlier life stages (freshwater and initial marine). Early life-history productivity (juveniles-per-spawner) has increased since 2013, resulting in higher estimates of juvenile abundance in the northern Bering Sea. This increase in juvenile abundance is projected to result in larger runs and increased subsistence fishing opportunities for Chinook salmon in the Yukon River as early as 2016.

EARLY MARINE DIET, GROWTH, AND INTERACTIONS

Regional and Inter-Annual Patterns of Juvenile Coho Salmon Growth in the Strait of Georgia

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Oral presentation

Abstract: Early marine growth in juvenile salmon is positively correlated with overall survival to reproductive age. In this study, regional patterns of juvenile coho (*Oncorhynchus kisutch*) salmon early marine growth were analyzed over a three-year period (2012-2014) to provide insight into possible mechanisms regulating regional and inter-annual variation in survival. Insulin-like growth factor-1 (IGF1), a hormone used to assess instantaneous growth in fishes, was measured in late June and early July in the Strait of Georgia, Johnstone Strait, and Queen Charlotte Strait. A consistent pattern of significantly lower IGF1 concentration was observed in Queen Charlotte Strait, Johnstone Strait, Malaspina Strait, and the Gulf Islands across all years when compared to the main basin of the Strait of Georgia. Additionally, IGF1 concentration in 2012 and 2014 was significantly higher in the Discovery Islands, Desolation Sound, and Northern Strait of Georgia. Coho salmon in 2013 showed less variation in IGF1 concentration from north to south within the main basin. Diet composition in 2012 and 2014 showed significant overlap within the Strait of Georgia. There was not a significant overlap in diet composition between 2013 and 2012 nor 2013 and 2014. Additionally there was a significant correlation between IGF1 concentration and the percent of herring in diets among years. There were no correlations between sea-surface temperate, thermocline presence, or water column stability between years of high growth and years of low growth in the Strait of Georgia. These data suggest that early marine growth of juvenile coho salmon varies between oceanographically different though proximally close regions within the Strait of Georgia. Additionally the variation in IGF1 concentration between years correlates to variation in coho salmon diet composition.

Density Dependent Effects During Juvenile Sockeye Salmon Early Marine Residency

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Oral presentation

Abstract: Spawner length-at-age data and growth reconstructions from scales have been used to identify density dependent processes during ocean rearing in salmonids; yet, the strength and timing of these effects remains uncertain. Since previous analyses have relied upon data from returning adults, density dependent effects during early marine residency may be particularly underrepresented. Here we use otolith microstructure techniques to examine potential density dependent effects during early marine residence in twelve populations of juvenile sockeye salmon (*Oncorhynchus nerka*). We tested whether smolt size, migratory phenology, and marine growth differed between years of extremely low (2011) and extremely high juvenile abundance (2012) in the Strait of Georgia. After accounting for stock-specific variation, juvenile salmon that migrated in 2012 were smaller at ocean entry, but out-migration phenology and marine growth rates did not differ between years. The stable growth rates that we observed indicate early marine residency may provide an opportunity for compensatory growth after density dependent impacts in freshwater, even in years of high juvenile salmon abundance.

Size-Selective Mortality of Hatchery and Wild Chinook Salmon (*Oncorhynchus tshawytscha*) in Puget Sound

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Oral presentation

Abstract*:* Since 1980, marine survival rates of Chinook salmon in the Salish Sea have declined precipitously while those of stocks from adjacent regions have remained steadier. This pattern has motivated research into factors operating within the Salish Sea that could affect marine survival. Previous research indicates a strong relationship between smolt size in July and marine survival, suggesting that size-selective mortality may limit marine survival. However, it is unclear where and when this size-selective mortality takes place. Our study used a fine-scale sampling scheme in four Puget Sound watersheds to identify whether, where, and when size-selective mortality occurs in Puget Sound during the first marine growth season. We followed seven hatchery release groups and two wild populations of sub-yearling Chinook smolts through their outmigration and first summer of growth in Puget Sound. By taking scale samples from each cohort repeatedly in freshwater, estuarine, nearshore marine, and offshore epi-pelagic habitats, we identified changes in the average growth history of each cohort among sequential habitats and across time periods within habitats. Our results suggest evidence of habitat-specific size-selective mortality associated with the transition between nearshore and offshore feeding, as well as unique patterns of time-specific size-selective mortality and size-dependent outmigration within habitats for each cohort. Understanding when and where size-selective mortality occurs will allow for a more accurate interpretation of time- and habitat-specific growth rates for stocks across Puget Sound, which in turn will help direct future conservation and restoration efforts.

Characterizing the Condition of Outmigrating Chinook and Steelhead in the Columbia River Estuary

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Oral presentation

Abstract: The Columbia River estuary is the site of one of the largest habitat restoration programs in the Nation, as tidal inundation is restored to 1000s of acres of former wetland habitat. Numerous benefits of this restoration have been demonstrated for juvenile fall Chinook salmon, which reside in restored habitats. In contrast, very little is known about the benefits of restored habitats for interior stocks of spring Chinook salmon and steelhead, which receive protection under the U.S. Endangered Species Act. These interior salmon typically take less than a week to migrate the 235 km from Bonneville Dam to the mouth of the Columbia, making it unlikely they reside for any length of time in restored habitats. With funding from the U.S. Army Corps of Engineers (USACE), we will try to determine if these fast-migrating salmon benefit from habitat restoration, under the hypothesis that restored habitats should increase the availability of invertebrate prey and therefore increase growth of juvenile salmon as they move downstream. We will accomplish this by sampling salmon at multiple locations spanning the 235 km-long estuary, using genetics and internal tags to determine stock of origin, and a variety of metrics to characterize fish condition, including physiological metrics that rapidly respond to changes in growth rate. The USACE is also funding sister studies to measure the production and export of prey from restored habitat types. We are coordinating with studies characterizing juvenile salmon condition farther upstream (NWFSC, University of Washington) and downstream (NWFSC and AFSC ocean studies) so that we can follow a cohort of fish as they move from the headwaters, through the hydrosystem and estuary, and out into the ocean. This type of coordinated study across such geographically and ecologically diverse habitat types has not been attempted before, but is expected to yield truly fascinating results.

Fine-Scale Spatial and Stock Variations among Juvenile Chinook Salmon and Steelhead in the Columbia River Plume: May 2015

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Oral presentation

Abstract: In 2015, NOAA fisheries re-invented its May juvenile salmon survey with a focus on assessing juveniles from Interior Columbia River stocks soon after they emigrated from the Columbia River Estuary and while they were still within the plume. From May 24th – 27th, 2015 approximately 400 yearling Chinook salmon and almost 300 juvenile steelhead were collected within 20 nautical miles of the Columbia River mouth. A high diversity of genetic stocks were captured; including Chinook salmon from Snake River spring, mid-/upper Columbia River spring (both ESA listed) and Upper Columbia River summer-fall stocks. An unexpected and interesting result was the high catches of juvenile steelhead from Salmon River, Clearwater River, Mid & upper Columbia River/Lower Snake, and Lower Columbia River stocks (all ESA listed). Significant differences were found among both Chinook salmon and steelhead stocks in length and growth, as indicated by Insulin-like growth factor 1 (IGF1) levels, and condition factor. Most of the Chinook salmon examined did not have elevated Sr:Ca within their otoliths, which indicates that they recently (<3 days) entered marine waters. Chinook salmon that had elevated otolith Sr:Ca were longer, growing faster (IGF1), and in better condition than those that did not have elevated otolith Sr:Ca, perhaps lending insight into the role of initial marine residence (estuarine and early ocean) on performance of juvenile Chinook salmon in the Columbia River Plume.

Effects of Fry Stocking on Freshwater Growth of Juvenile Sockeye Salmon (*Oncorhynchus nerka*) in an Alaskan Lake: A Retrospective Analysis

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Oral presentation

Abstract: Variation in marine survival of Pacific salmon (*Oncorhynchus* spp.) is influenced by size-selective mortality. Management actions, such as stocking of salmon fry into rearing lakes, may reduce individual smolt size through competition, with negative consequences for marine survival. In populations with multiple freshwater ages, however, density dependent growth can result in delayed smoltification and a greater number of fish emigrating at a larger size after an additional year in fresh water. We evaluated the effects of fry stocking of sockeye salmon (*O. nerka*) on freshwater growth and age composition in an Alaskan nursery lake, and subsequent size-selective mortality at sea. Chilkat Lake in northern Southeast Alaska supports a sockeye salmon population important to local fisheries. Declining production in the 1980s resulted in stocking of more than 19 million sockeye salmon fry from 1989 to 2004. We measured scales collected from adult sockeye salmon returning to Chilkat Lake over 35 years (1978-2012) to test the following hypotheses: 1) total fry density (wild and stocked) had a negative impact on freshwater growth of age 1.3 and 2.3 fish in the year of stocking and on the following year class co-existing in the lake; and 2) increased fry density led to older age-at-smoltification. In years for which we also had smolt data (1994-2005), we compared age-1 and age-2 smolt lengths to back-calculated smolt lengths from surviving adults and examined size-selective mortality at sea. Our findings suggested that the second year of freshwater growth of age 2.3 fish was negatively affected by fry density. We also found that increased fry density did not increase age-at-smoltification. The results of size-selectivity mortality at sea were inconclusive, possibly due to the short duration of the data set or sampling bias.

Measuring Fish Exposure to Avian Predation Risk with Models of Spatial & Temporal Overlap

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Oral presentation

Abstract: There has been consistent interest in quantifying relationships in spatial and temporal patterns among species in marine environments to address important questions about predator-prey interactions, climate change, fisheries impacts, and marine spatial planning. For more than 20 years, researchers hypothesized that early marine survival of anadromous fishes like Pacific salmon is strongly driven by predation on juveniles, yet there are surprisingly few direct empirical studies of ocean predator overlap with salmon. To investigate the degree to which ocean avian predation impacts Chinook salmon from the Columbia River, USA, we applied spatially-explicit models to measure overlap between seabirds and salmon and to assess environmental covariates (e.g. distance from shore, salinity, chlorophyll-*a*, distance to seabird colony) for association with spatial structure. Data from synoptic seabird and salmon surveys in May and June of 2003-2012 revealed that two species of seabirds (common murres *Uria aalge* and sooty shearwaters *Puffinus griseus*) accounted for ≥80% of birds counted between Newport, OR and the US-Canadian border. Density matrices in May and June revealed a "predator hot zone" that brackets the Columbia River mouth from Cape Meares, OR to Grays Harbor, WA. Predator-prey overlap varied in both time and space, in part due to population-specific differences in the marine migration and resulting spatial distribution of salmon. Model results provide a new index of predation risk that provides insight into mortality factors affecting early marine survival of salmon.

POSTERS

Opposing Trends in Upstream and Downstream Migration Synchrony between Dolly Varden and Pacific Salmon

Donovan Bell[1,2], Ryan Kovach[3], John Joyce[2], Scott Vulstek[2], and David Tallmon[1]

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Poster presentation

Abstract: Climate-induced shifts in migration timing may create a mismatch between predators and their prey (*e.g.*, Dolly Varden and early life history Pacific salmon). Migration timing shifts have been reported for numerous salmonid species, including Pacific salmon (*Oncorhynchus spp*.) and Dolly Varden (*Salvelinus malma*). Anadromous populations of Dolly Varden feed heavily on Pacific salmon eggs after their migration from the ocean to freshwater (upstream migration) and on juvenile Pacific salmon during and after their migration from freshwater to the ocean (downstream migration). Thus, a mismatch with Pacific salmon could negatively impact Dolly Varden, but it remains unknown whether Dolly Varden and Pacific salmon will remain matched in the future. We used long-term fish count data from the NOAA Auke Creek Weir to quantify annual migration synchrony between Dolly Varden and Pacific salmon during both upstream and downstream migrations. We then tested for trends in migration synchrony both over time and with environmental variables. We found opposing trends in migration synchrony between upstream and downstream migrations. Upstream migration synchrony was stable and may increase with future warming conditions. In contrast, downstream migration synchrony appears to be declining and may continue to decrease as regional temperatures rise. Downstream mismatch appears to be particularly likely for Dolly Varden and pink salmon (*O. gorbuscha*). Our study highlights the contrasting effects climate change can have on predator-prey synchrony at different life history stages.

Salmon Prey Assemblages and Oceanographic Conditions along the California Current Shelf Ecosystem

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Poster presentation

Abstract: Early ocean entry is a critical life history period for juvenile Chinook salmon out-migrants whose survival is known to be affected by the availability of suitable prey on the shelf at the time and location of ocean entry, and whose condition at this stage has been correlated to adult salmon return. In turn, the spatial distribution and composition of forage assemblages is influenced by biogeographic and oceanographic conditions such as latitudinal gradients and upwelling. In this study we describe the distribution of marine nekton assemblages relative to biogeographic and oceanographic conditions in the California Current shelf ecosystem between 2011 and 2015. Nekton samples were collected during annual mid-water trawls conducted by the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (J. Field, PI) and the NWFSC Pre-recruit Groundfish Survey (R. Brodeur, PI). Analyzed samples were limited to those collected at sites where bottom depth was < 200m from 36'N to 47'N. Oceanographic data (sea surface temperature, salinity, stratification, and upwelling) at the time and location of each trawl, as well in monthly time steps up to five months prior to trawls, were derived from the Data Assimilative Regional Ocean Modeling System (ROMS). We use nonmetric multidimensional scaling to identify clusters of taxa, and generalized additive models to identify the covariates that best describe the observed clustering pattern. This study extends prior research to relate oceanographic and biogeographic variables relative to juvenile Chinook salmon forage assemblages along a wider swath of the California Current ecosystem.

Genetic Stock Composition Analysis of Chinook Salmon Bycatch Samples from the 2014 Gulf of Alaska Trawl Fisheries

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Poster presentation

Abstract: A genetic analysis of samples from the Chinook salmon (*Oncorhynchus tshawytscha*) bycatch of the 2014 Gulf of Alaska (GOA) trawl fisheries for walleye pollock (*Gadus chalcogrammus*), rockfish (Sebastes spp.), and arrowtooth flounder (*Atheresthes stomias*) was undertaken to determine the stock composition of the sample sets. Samples were genotyped for 43 single nucleotide polymorphism (SNP) DNA markers and results were estimated using the Alaska Department of Fish and Game (ADF&G) SNP baseline. In 2014, genetic samples were collected from Chinook salmon taken in the bycatch of the Gulf of Alaska (GOA) pollock trawl fisheries using a simple random sample protocol with trip being the primary unit. This is the first year for this sampling protocol and resulted in the largest available genetic sample set to date with 10.7% of the salmon bycatch successfully genotyped. Based on the analysis of 1,163 Chinook salmon bycatch samples, British Columbia (43%), West Coast U.S. (35%), Coastal Southeast Alaska (16%), and Northwest Gulf of Alaska stocks (5%) comprised the largest stock groups. Weighting the available sample sets to the total bycatch by season and statistical area did not appreciably change the overall stock composition. In 2014, genetic samples from the bycatch of the rockfish catcher vessel (CV) fishery in the central GOA were collected by the fishing industry using a census sampling protocol where every Chinook salmon encountered was sampled. Based on the genotyping of 398 Chinook salmon bycatch samples collected from the 2014 GOA rockfish CV trawl fishery in NMFS Statistical Areas 620 and 630, West Coast U.S. stocks (WA/OR/CA) represented the largest stock grouping (72%) with smaller contributions from British Columbia (17%), Coastal Southeast Alaska (7%), and Northwest GOA (3%) stocks. Based on the genotyping of 404 Chinook salmon bycatch samples collected throughout the 2014 GOA arrowtooth flounder trawl fishery from the catcher-processors (CP) FV Vaerdal and FV US Intrepid; West Coast U.S. stocks (WA/OR/CA) represented the largest stock grouping (51%) with smaller contributions from British Columbia (36%), Coastal Southeast Alaska (10%), Northeast GOA (2%) and Northwest GOA (2%) stocks.

Exploring the Variability of Juvenile Salmon Catch and Their Associated Prey Assemblage during the 2015 NOAA Ocean Salmon Survey

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Poster presentation

Abstract: An objective of the annual NOAA Ocean Salmon Survey is to identify patterns of condition and abundance of juvenile salmon populations along the Pacific coast. While an extended time series allows for some inter-annual inference as to the impacts of ocean condition on salmon survival, many questions remain about the inherent variability of salmon catch as a result of our sampling methods. To further understand variation in juvenile salmon condition, it is necessary to assess the availability of prey during these early marine stages. During the 2015 summer and fall Ocean Salmon Surveys, we explored this variability by conducting repeat rope trawls of salmon catch at specific sampling stations. Additionally, we used a Methot trawl net to capture coincident forage available to juvenile salmon during our fall study period. Analysis of the variability of salmon catch between repeat tows revealed a poisson shape and the range of catch values for a given site could be great. The prey community sampled by the Methot net also revealed high inter-site and spatial variability in the composition and abundance of salmon prey. Ninety two percent of the total prey catch was composed of sanddabs, sole, carinaria, amphipods and larval crabs (mainly zooea). Overall, our results indicate a need to account for the patchy nature of juvenile salmon distribution in future surveys, as well as the inclusion of prey field sampling methods so as to better comprehend and possibly predict the abundance and distribution of juvenile salmon in response to changing oceanic conditions.

Evaluation of Alternative Indices of Recent Growth in Juvenile Chinook Salmon

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Poster presentation

Abstract: The hypothesis that size selective mortality in the first marine year is a major regulator of recruitment in juvenile Pacific Salmon has led to interest in assessing the recent growth of field caught fish. Understanding differences in growth across years, regions, habitats and prey fields may provide insights into how conditions experienced in the first marine year impact survival. Plasma insulin like growth factor (IGF-1), muscle RNA to DNA ratio (RD) and scale circulus spacing have all been used as indices of recent growth in juvenile salmonids. We concurrently assessed these three growth rate indices in a laboratory study of post-smolt, young-of-the-year, ocean-type Chinook salmon. Individually PIT tagged fish were reared at three different feeding levels (0.5, 1.0, and 3.0 % body weight per day) for 30 days to compare the strength of relationships between individual specific growth rates (length and weight) and each of the three growth rate indices. A second group of fish, which had been maintained at a feeding level of 1.0 % body weight per day, was divided into low, high, and control feeding treatments and subsampled at 2, 6, 8 and 14 days to compare the time required for each growth rate index to respond to a change in growth conditions. Plasma IGF-1 concentration was more strongly correlated with growth than RD or circulus spacing; both IGF-1 and RD responded within 4 days to a change in growth conditions. Our results suggest that only IGF-1 has potential to provide information on growth rate of an individual fish; however, circulus spacing and RD may be valuable in certain applications to compare relative growth performance among groups.

Effects of Dietary Fatty Acids on Juvenile Salmon Growth, Biochemistry, and Aerobic Performance: A Laboratory Rearing Experiment

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Poster presentation

Abstract: Juvenile salmon undergo important ecological transitions as they migrate from freshwater to the ocean, a phase characterized by rapid growth and high mortality. Variations in the nutritional quality of marine prey may be as important as prey quantity in determining salmon survival during this critical period. Growth, and hence survival, may be related to both the onset and intensity of piscivory. We tested the hypothesis that prey nutrient composition and predator nutritional history affects growth, biochemistry, and swimming performance in a population of subyearling Chinook salmon (*Oncorhynchus tshawytscha*). Salmon were reared for 12 weeks on three energetically similar experimental diets. Diets were created with ratios of docosahexaenoic acid (DHA) to eicosapentaenoic acid (EPA) of 0.56, 0.94, and 1.47 by altering the amount of krill, anchovy, and two fatty acid supplements. Tagged salmon reared on the high DHA:EPA anchovy diet grew faster (0.33 ± 0.05 mm d^{-1}) than fish reared on the low DHA:EPA krill diet (0.27 ± 0.03 mm d^{-1}) or blended diet (0.29 ± 0.02 mm d^{-1}). Tissue turnover in salmon, measured in half-lives, averaged 24 days for essential fatty acids, and 67 days for bulk isotopes of nitrogen and carbon, indicating that predator tissue fatty acids reflect diet sooner than stable isotopes. After the rearing experiment, salmon were starved for 4 weeks and their critical swimming speeds measured to determine whether nutritional history had an effect on aerobic performance. Although there were no significant differences in swimming performance among diet treatments, there was a significant relationship between swimming speed and an individual's size and storage lipids across diet treatments ($R^2 = 0.88$, $p = 0.04$), indicating that the level of past piscivory may have carryover effects that benefit juveniles through their first ocean winter.

The Southeast Alaska Coastal Monitoring (SECM) Project: Research Milestones from Nearly 20 Years of Ocean Monitoring

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Poster presentation

Abstract: Beginning in May of 1997, researchers from the Alaska Fisheries Science Center began monitoring stations along a principal salmon seaward migration corridor leading through Southeast Alaska (SEAK) and out into the Gulf of Alaska. This monthly monitoring has been maintained for nearly two decades from May until August, and has become known as the Southeast Alaska Coastal Monitoring (SECM) project. This research has contributed to a better understanding of juvenile salmon ocean distribution and ecology and fostered the development of several time series related to salmon production. This effort involves oceanographic sampling and surface trawling to study a multitude of metrics related to salmon by scientists from around the Pacific Rim. The SECM project helps to integrate basin-scale climate observations, regional oceanographic monitoring, and fisheries research to provide a sound scientific basis for understanding marine ecosystems and the impact of climate. This effort also supports Ecosystem-Based Management by providing data to resource managers and stakeholders. For example, one key product from this SECM research has been a pre-season pink salmon harvest forecast delivered annually to stakeholders. This poster highlights some significant milestones from SECM research on biological interactions of salmon, ecologically-associated species, and biophysical oceanography in order to better understand climate effects and mechanisms influencing regional salmon productivity.

Historic Dietary Aspects of Juvenile Pacific Salmon, Pacific Herring, and Eulachon in the Strait of Georgia from 1966 to 1968

Geoffrey Osgood[1], Laura Kennedy[1], Jessica Holden[1], Eric Hertz[1], Skip McKinnell, and Francis Juanes[1]

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Poster presentation

Abstract: The ecosystem approach intended by fisheries management frameworks aims to manage fisheries target species as part of a larger ecosystem, incorporating variables such as climate and community interactions into management decisions. The approach, however, requires a larger breadth of information than traditional fisheries management. The Fraser River plume is a prominent feature in the Strait of Georgia associated with increased zooplankton abundance and, subsequently, juvenile salmon residence. Using an unpublished historical data set collected in the Fraser River plume between 1966 and 1968, we have investigated the diets of juvenile salmonids along with a potential competitor, Pacific Herring, to gauge potential species interactions in the spring and early summer. During this time, salmonids are opportunistic generalists with high individual variation and low between species variation in diets, although certain species, such as Chinook and Sockeye Salmon, show clear differentiation and some species of prey appear particularly important. Herring and eulachon diets are unique when compared to salmon during this time. We hope that these historical data can be compared to recent or future studies and aid ecosystem approaches to salmon management by identifying potential differences in feeding habits or species interactions, particularly in relation to changing environmental conditions.

Changing Length of Auke Creek Salmon

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Poster presentation

Abstract: In recent years, a trend of decreasing body length has been observed in some Southeast Alaska salmonid populations. This study was undertaken to determine whether this pattern holds for Auke Creek salmon and, if so, what biotic and abiotic factors are contributing to this phenomenon. We analyzed 31 years of coho salmon (*Oncorhynchus kisutch)* and sockeye salmon (*O. nerka*) length data from Auke Creek Weir in Juneau, Alaska. The adult coho show a statistically significant decrease in mean length over time of 29.32 (± 3.04) mm with the best predictors of change being annual lagged PDO and annual total pink salmon (*O. gorbusch*) harvest (R^2 = 0.27, p = 0.0025, n = 6930). Sockeye salmon analysis is in the final stage and will be completed for presentation. A great deal of fluctuation in length across the time series was also observed.

Spatial, Temporal, and Ontogenetic Shifts in the Diet of Juvenile Yukon River Chinook Salmon

Wesley W. Strasburger[1] and Jim Murphy[1]

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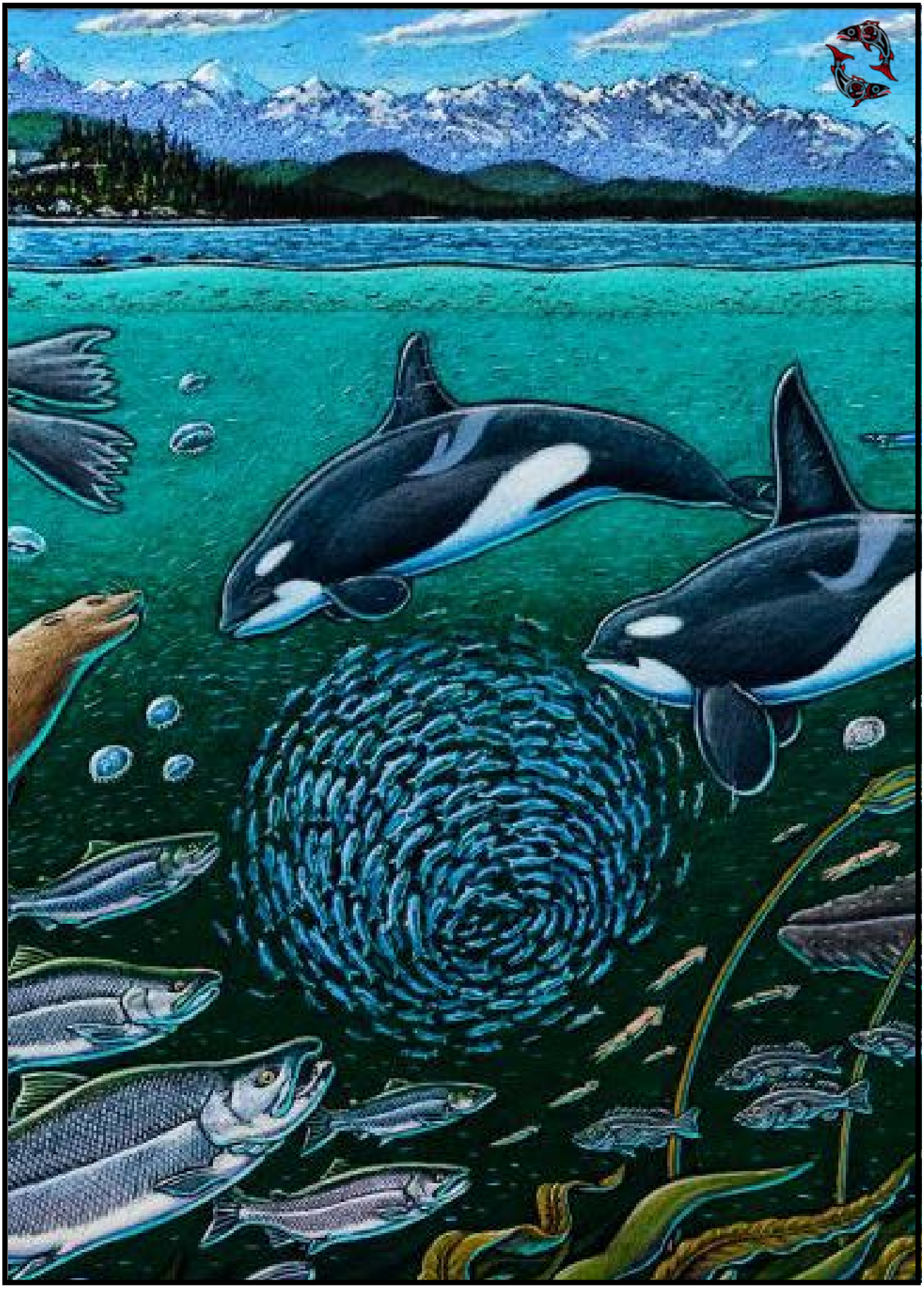
Poster presentation

Abstract: Over the last decade the production of Yukon River Chinook Salmon has declined to levels eliciting the closure of commercial and reduction of subsistence fisheries, respectively. The decline in production is not yet understood. Recently, low numbers of juvenile-per-spawner, and subsequently, returns-per-spawner, seem to confirm the hypothesis of low production due to high early life history mortality. Whether this mortality is more pronounced in the freshwater or marine phase of Chinook salmon early life history is not well understood. The failure of multiple stocks throughout western Alaska seems to suggest a large scale and more likely marine explanation. A better understanding of the transition between freshwater and marine feeding and energetic strategy, and thus early marine survival, will increase our ability to forecast and understand adult returns. Freshwater, estuarine, and marine phase juveniles were collected throughout three different survey efforts from May-September during both 2014 and 2015. Samples were preserved and returned to Auke Bay Laboratories (NOAA) in Juneau, Alaska for dietary and energetic processing. Both dietary composition and energetic content shifted over time, with the dietary composition generally increasing in oceanic influence over time and with increased body length. Additionally, prey items ingested shifted with increasing time from surface oriented prey field to pelagic prey fields. Energetic content continued to increase over time and fish body length, especially with the introduction of highly energetic marine prey content.

Meeting dedication: Robert (Bob) Emmett

Our friend and colleague Robert (Bob) Emmett passed away Monday, April 27th, 2015, after a long battle with the cancer that was attacking his body. Bob spent almost his entire career in the service of NMFS at the NWFSC and was a friend to many throughout our Center as well as at the SWC. Bob was never very far from estuaries and the ocean and his passion for sardines, tuna, and of course salmon was infectious. He was a leader in his field and an inspiration to many young scientists (and older scientists as well). Bob was always there to lend a hand or provide advice and could be counted on to get done whatever he was asked to and, to do it very well. Bob hailed from the East Coast where he got his B. S. from the University of Massachusetts in 1977. He moved west, landing at the Hammond Lab in 1977 where he began work for the NWFSC (it was then the NW&AFSC). He received his Masters from the University of Oregon in 1982 and finally got his PhD at Oregon State University in 2006. After moving to Corvallis from the NOAA lab at Hammond at the mouth of the Columbia River in the late 1990s, Bob commuted to Hatfield for about 7 years until he moved to Toledo in about 2002 with his family. In 2011, Bob moved back to the Hammond Laboratory on the Columbia River to take over as Field Station Chief. He retired from government service last summer to focus on his health. Bob was heavily involved in the local community serving on the Toledo City Council and helping with the local swim teams, especially with their fundraising. Bob was an avid gardener and with his wife Amy were home wine makers for many years; a glass of their Super Tuscan red or Sangiovese was a glass to relish.

A friend who spoke with him near the end said he asked that we carry on in his place, with a particular emphasis that we take time to appreciate and love our jobs and to not let 'the rules' prevent us from 'having fun' or stopping our passion. His friendship, warm smile, and infectious laugh, will be missed by all who knew him. Our thoughts and prayers go out to his wife, Amy, to his kids, Nathan and Alyson, and to the rest of his family.