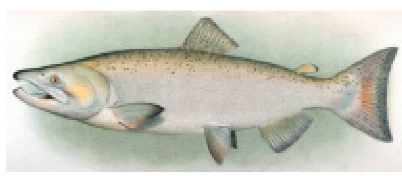
4th Annual Salmon Ocean Ecology Meeting

15-16 January, 2002

Abstracts & Participants List



National Marine Fisheries Service

Santa Cruz Laboratory

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4th Annual Salmon Ocean Ecology Meeting
National Marine Fisheries Service
Santa Cruz, Laboratory
15-16 January, 2002

Agenda

Tuesday, 15 January

0830 Introduction

Welcome to Santa Cruz	Churchill Grimes, SWFSC, Santa Cruz
Meeting Background and Objectives	Bill Peterson, NWFSC, Newport

Distribution Papers

0845 *Interannual to Decadal Environmental Variability at the Southern Extent of Salmonid Ranges*
Frank Schwing, NOAA/NMFS-Pacific Fisheries Environmental Laboratory

0910 *Differences In Impacts of Decadal Scale Physical Variability on California Current Chinook and Coho Salmon*
Louis W. Botsford, Department of Wildlife, Fish, and Conservation Biology, University of California, Davis

0935 *Influences of the 1997-1999 El Niño-La Niña on Juvenile Chinook Salmon Off Central California*
Bruce MacFarlane, NOAA/NMFS/SWFSC-Santa Cruz Laboratory

1000 *Tracking Environmental Bottlenecks in the Coastal Zone: What Are the Mechanisms Linking Climate Variability to Oregon Coho (Oncorhynchus kisutch) Marine Survival?*
Elizabeth A. Logerwell, NOAA-Alaska Fisheries Science Center

1025 Break

1050 *Closing the Loop: Links Between Marine and Freshwater Environmental Variability Affecting Oregon Coastal Natural Coho Salmon*
Peter Lawson, NMFS/NWFSC

1115 *Evidence For A Climate Regime Shift in the Northern California Current -- Changes in Nutrients, Chlorophyll and Zooplankton At Two Stations Along the Newport Hydrographic Line*
Bill Peterson, NOAA/NMFS-Hatfield Marine Science Center

1140 *Small-scale Physical Variability in the Columbia River Plume*
David A. Jay, OGI School of Science and Engineering, Oregon Health & Science University

1205 Lunch

1330 *Climate-induced Variation in Keogh River Salmonid Carrying Capacity and Survival in the Ocean*
Bruce Ward, B.C. Fisheries Research and Development

1355 *Shift Happened: Evolution of North-South Gradients in Coho Body Size & Plankton Community Structure on the Continental Shelf During 1998-1999*
Jeannette E. Zamon, Fisheries and Oceans Canada, Pacific Biological Station

Agenda (continued)

Growth Papers

1420 *Evaluating the Performance of Juvenile Chinook and Coho Salmon in Marine Waters of SE Alaska*
Laurie Weitkamp, NOAA/NMFS-NWFSC

1445 *Estimating the Effects of Ocean Condition on the Jacking Rate of Coho Salmon: A New Analysis of the Data Provided by Shapovalov and Taft*
George Watters, NOAA/NMFS-Pacific Fisheries Environmental Laboratory

1510 Break

1540 *Retrospective Growth Analyses: Lessons From The Post-Smolt Growth Zone*
Kevin Friedland, NOAA-CMER, University of Massachusettss

1605 *Long-term Trends in Annual Bristol Bay Sockeye Salmon Scale Growth in Relation to Sockeye Abundance and Environmental Trends, 1955-2000*
Greg Ruggerone, NRC

1630 Discussion

1730 Social Event, Barbecue Dinner, Posters

Wednesday, 16 January

Migration and Stock ID Papers

0830 *Chinook Salmon Data Storage Tag Studies in Southeast Alaska, 2001*
James Murphy, NOAA/NMFS/Alaska Fisheries Science Center-Auke Bay Lab

0855 *Testing Electronic Archival Tags In Coho Salmon In Alaska*
Jennifer L. Nielsen, USGS-BRD-Alaska Biological Science Center

0920 *Increased Power for Life History ID in Chinook: What are the Burning Questions?*
Michael Banks, Coastal Oregon Marine Experiment Station, HMSC, OSU

0945 *Linking Juvenile Production Sources to the Adult Chinook Salmon Fishery Along the Central California Coast Using Otolith Microstructure and Microchemistry: Identifying Hatchery and Wild Sources*
Rachel C. Johnson, University of California-Santa Cruz, Long Marine Laboratory

1010 *Genetic Mixed Stock Analysis of Juvenile Coho Salmon Off Oregon and Washington*
David Teel, NOAA/National Marine Fisheries Service

1035 Break

1100 *An Update on Juvenile Salmon Studies in Barkley Sound, Canada*
Ron Tanasichuk, Fisheries and Oceans Canada, Pacific Biological Station

Agenda (continued)

Trophic Considerations

1125 *The Role of Baitfish in Salmon Ocean Survival*
Robert Emmett, NOAA/National Marine Fisheries Service

1150 *Distribution, Growth, Origin, Trophic and Species Associations of Juvenile Salmonids in the Northern California Current Ecosystem*
Richard Brodeur, NOAA/NMFS-NWFSC

1215 Lunch

1330 *Regional Features Affecting Juvenile Salmon Distribution and Performance Off Oregon and Washington*
Ed Casillas, NMFS-Northwest Fisheries Science Center

1355 *Do Fish Feed At Fronts? Hydrography, Zooplankton, and Feeding Ecology of Juvenile Salmon in Frontal Regions of the Columbia River Plume*
Cheryl A. Morgan, CIMRS, OSU, Hatfield Marine Science Ctr.
Alex De Robertis, NMFS-Northwest Fisheries Science Center, Newport

1425 *Consumption of Red King Crab (Paralithodes camtschaticus) Zoea by Juvenile Bristol Bay Sockeye Salmon (Oncorhynchus nerka) in the Eastern Bering Sea*
Ed Farley, NOAA/NMFS/Alaska Fisheries Science Center-Auke Bay Lab

1450 Break

1510 *IGF-I and Post-Smolt Growth of Coho Salmon*
Brian Beckman, NOAA/NMFS-NWFSC

1535 *Salmon Bioenergetic Models Under Scrutiny: A Plea For Basic Research*
Marc Trudel, Fisheries and Oceans Canada, Pacific Biological Station

1600 *An Assessment of the Contribution Rates of CWT-Tagged Groups of Juvenile Salmonids from California's Central Valley to the Adult Population*
Randy Bailey, Bailey Environmental

1625 Open discussion
Coordinating coastwide salmon research
Next meeting location

1700 Adjourn

POSTERS

Juvenile Salmonids in the Northern California Current: Differences in Parasites Obtained Through Trophic Interactions
Rebecca Baldwin, Oregon State University, Hatfield Marine Science Center

Diel Feeding Chronology, Prey Selectivity, and Daily Ration of Juvenile Chinook (Oncorhynchus tshawytscha) and Coho (O. kisutch) Salmon in the Columbia River Plume
Richard Brodeur, NOAA/NMFS-NWFSC

POSTERS (continued)

Pacific Fisheries Environmental Laboratory Provides Easy Access to Salmon-Relevant Environmental Data
Lynn deWitt and Roy Mendelssohn, NMFS/SWFSC-Pacific Fisheries Environmental Laboratory

Searching for a Life History Approach to Salmon Escapement Management
E. Eric Knudsen, USGS, Alaska Science Center

Feeding Habits of Outmigrating Juvenile Chinook Salmon (Oncorhynchus tshawytscha) in the San Francisco Estuary and the Gulf of the Farallones
Elizabeth Norton, National Marine Fisheries Service-Santa Cruz Laboratory

Ontogenetic Changes in the Taxonomic Composition and Size of Prey in Juvenile Chinook Salmon (Oncorhynchus tshawytscha) Diet From Coastal Waters Off Central California
Elizabeth Norton, National Marine Fisheries Service-Santa Cruz Laboratory

Growth, Condition, and Pathogens of Juvenile Salmon Caught Off the Oregon and Washington Coasts
Todd Sandell, Oregon State University, Hatfield Marine Science Center

Post El Niño Changes in Altimeter SSH and Transport in the NE Pacific
Ted Strub, COAS, OSU

Abstracts

An Assessment of the Contribution Rates of CWT-Tagged Groups of Juvenile Salmonids from California's Central Valley to the Adult Population

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Jud Monroe, Environmental Planning, Documentation and Coordination

This study examines the relationship between four inland release variables and adult contribution rate for 834 groups of chinook salmon reared at 8 facilities, released from 1972 to 1995, at approximately 70 locations in California's Central Valley or San Francisco Estuary. This analysis included groups from all four races of chinook salmon including: 73 winter-run (Coleman National Fish Hatchery), 18 spring-run (Feather River Fish Hatchery), 42 late fall-run (Coleman National Fish Hatchery), and 701 fall-run. The release variables include: 1) year of release, which addresses potential for long-term trends in salmon survival hypothesized to be affected by increasing water exports, pollution, and reduced Delta outflow; 2) number of fish in each release group, was chosen to examine density dependent factors such as predation/predator avoidance; 3) calculated length at release, evaluated the assumption that larger fish should result in higher contribution rates; and 4) release site, measured in terms of distance released from the Golden Gate Bridge, as a surrogate for the effects of many potentially adverse conditions occurring along longer emigration routes. Adult contribution rate was calculated using coded wire tag returns from three sources: 1) ocean fishery sampling (collected with regularity and a relatively consistent methodology), 2) inland harvest census and salmon carcass counts (not been conducted in as systematic a manner), and 3) hatchery spawners.

No significant relationships between the inland release variables and adult contribution rate were identified for winter-run chinook salmon (n = 73 groups). These results may be an artifact of the small number of fish per release group. Adult contribution rates for these fish were low (0.0 to 1.5 percent), with no recorded returns for 43 of the 73 tagged groups.

No relationships with the four inland release variables were identified for spring-run Chinook salmon (n = 18 groups) , possibly because of the low number of groups and high variability in release strategy. Adult contribution rates ranged from 0.0 percent to above 5 percent.

No meaningful relationships between inland release variables and adult contribution rates of late-fall-run Chinook salmon (n = 42 groups) were identified. Adult contribution rates varied from 0.1 percent to over 3.0 percent and data show high within-year variability in adult contribution rates.

Complete data and adult tag returns were available for 701 groups of fall-run Chinook. Adult contribution rates varied significantly by rearing facility and "within" a rearing facility. Much of this variation was attributable to experimental releases of fry-sized fish, which were consistently associated with low rates (nearly always < 1.0 %); and releases of yearlings (rates 0 to 15%), with only about 30 percent of these releases exceeding 2%. For smolt-sized fish, rates varied from 0.0 to about 10% (mean approximately 2%). Statistically significant relationships were identified between the inland release variables and adult contribution rate: 1) calculated length at release (r^2 values for various facilities range from 0.05 to 0.28) and 2) statistically weak relationships were found with number of fish per release group, year of release, and distance released from the Golden Gate Bridge. Comparisons of adult contribution rate among general release area and within-Delta releases from specific hatcheries showed no significant differences except for significantly lower rates for Feather River Fish Hatchery releases made within the Delta.

Management recommendations were designed to improve the overall coded wire tagging program. Caution is urged when using the Pacific States Marine Fisheries Commission's database, finding ways to incorporate inland tag recoveries, and finding ways to adjust tag recoveries given ocean distribution population shifts related to El Nino/La Nina conditions and spatial and temporal changes in fishing effort distribution along the Pacific Coast.

Juvenile Salmonids in the Northern California Current: Differences in Parasites Obtained Through Trophic Interactions

Rebecca E. Baldwin, Cooperative Institute for Marine Resource Studies, Oregon State University, Hatfield Marine Science Center, Newport, Oregon
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Kym C. Jacobson, NMFS, Hatfield Marine Science Center, Newport, Oregon

Ocean salmon abundance is largely determined by juvenile survival in near-shore regions, and is affected by interannual and interdecadal changes in the physical ocean characteristics and by changes in ecosystem food web dynamics.

Parasite analysis is one method used to better understand pelagic trophic structure by clarifying food web linkages between predator and prey, identifying possible endemic regions of infection, and providing information on how anadromous fish use ocean habitat. Juvenile Chinook and Coho salmon were collected offshore in the northern California Current between June and September, 2000 from six transects between Newport and Crescent City, California (funded by GLOBEC). An additional 6 transects were located between La Push, Washington and Newport, Oregon (funded by BPA). A total of 14 species of macroparasites were recovered. Three trematodes, *Genolinea* sp., *Podocotyle* sp., *Hemiurus* sp., and one nematode, *Anasakis simplex*, were the most common. Although all four parasites occurred throughout the northern California Current, patterns of infection suggest that the southern Oregon fish have been infected by more parasites than northern fish. Spatial and temporal comparisons between these two studies will be discussed.

IGF-I and Post-Smolt Growth of Coho Salmon

B.R. Beckman, Integrative Fish Biology Program, Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA
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Pacific Salmon typically spend 1-3 years foraging and growing in the ocean prior to returning to freshwater spawning sites. Inter-annual differences in ocean temperatures and productivity may have profound effects on the growth of these animals. Growth variation may influence age of maturation, size at maturation, and overall year-class survival. Thus, understanding variation in oceanic growth rates is important to understanding variation in the fitness of Pacific salmon.

Growth is mediated by the endocrine system; consequently, endocrine correlates of growth may provide valuable tools for assessing relative growth rate and related fitness values, based on a single blood sample. A simple experiment was conducted to validate the use of insulin-like growth factor-I (IGF-I) as an indicator of growth. There was a good relation between growth (in length) of PIT-tagged Coho salmon and plasma IGF-I value over two week periods (r^2 range from 0.4 – 0.6, 5 trials).

Subsequently, blood samples were obtained from coho salmon in the Pacific Ocean (Oregon to British Columbia). IGF-I data obtained from these samples shows both geographic and interannual variability. These preliminary data show that IGF-I levels may be used to assess growth rates of salmon in the ocean. Moreover, they suggest differences in oceanic conditions do result in differences in salmon growth.

Differences in Impacts of Decadal Scale Physical Variability on California Current Chinook and Coho Salmon

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Examination of Chinook and Coho salmon catch records and physical data from the California Current indicate that these species both covary with the dominant EOF of the upwelling index, ocean temperature and sea level, in a way that reflects El Nino conditions. However, their responses to the shift in physical conditions in the mid-1970s differed in that Coho salmon collapsed to low abundance synchronously along the coast, whereas Chinook salmon did not, but rather continued to vary asynchronously with an apparent spatial pattern. Proposed explanations of these differences involve reference to greater variability in Chinook salmon life history. A test of one such difference, variation in spawning age distribution, indicates that it does not explain the observed differences. Assessment of potential differences in straying and metapopulation structure also provide no clear explanation. We conclude that the differences in response could be caused by differences in physical/biological interactions in the marine phase, and that such differences should be considered by those engaged in field studies of these interactions.

Distribution, Growth, Origin, Trophic and Species Associations of Juvenile Salmonids in the Northern California Current Ecosystem

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Information is summarized on juvenile salmonid distribution, size, growth, stock origin, and trophic and environmental associations from the June and August 2000 GLOBEC cruises with particular emphasis on differences related to the regions north and south of Cape Blanco off Southern Oregon. Juvenile salmon were more abundant during the July-August cruise as compared to the June cruise and were distributed northward from Cape Blanco. There were distinct differences in distribution patterns between salmon species with Chinook found close inshore in cooler water all along the coast. Coho salmon were rarely found south of Cape Blanco. The nekton assemblages differed significantly between cruises. June samples were dominated by juvenile rockfishes, rex sole, and sablefish, which were almost completely absent in August. The forage fish community during June was comprised of herring and whitebait smelt north of Cape Blanco and surf smelt south of Cape Blanco. The fish community in August was dominated by Pacific sardines and jack mackerel. Significant differences in growth and condition of juvenile salmon indicate different oceanographic environments north and south of Cape Blanco. The condition index was higher in juvenile yearling Chinook salmon to the south of Cape Blanco whereas condition was higher in juvenile Coho to the north. Genetic mixed stock analysis indicated that during June most of the Chinook salmon in our sample originated from rivers along the central coast of Oregon. In August, Chinook salmon sampled south of Cape Blanco were largely from southern Oregon and northern California while north of Cape Blanco, most Chinook salmon were from the Central Valley in California. Distance offshore and temperature were the dominant explanatory variables related to Coho and Chinook salmon distribution. These species consumed mainly juvenile fishes, euphausiids, decapod larvae, and hyperiid amphipods. Diet overlap by weight between juvenile Coho and Chinook salmon was high (> 80%) but was substantially lower between these salmon and other non-salmonid nekton.

Diel Feeding Chronology, Prey Selectivity, and Daily Ration of Juvenile Chinook (*Oncorhynchus tshawytscha*) and Coho (*O. kisutch*) Salmon in the Columbia River Plume

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Juvenile Chinook and Coho salmon were caught by trawling throughout a diel period on three consecutive days (21-23 June 2000) at stations located 8 and 20 nautical miles offshore from the mouth of the Columbia River. After each trawl, the available prey field was sampled with four different types of nets (meter net, bongo net, neuston net, Isaacs-Kidd midwater trawl). The meter net caught the largest variety of prey items; however the abundance estimates for more evasive and migrating prey items like adult euphausiids were higher in the nighttime bongo net samples. Stomach contents, by percent body weight, peaked during morning hours and reached their minimum at night, suggesting a predominantly diurnal feeding pattern. At the far offshore station, the diet was dominated by the hyperiid amphipod *Vibilia australis*. Other important food items were fish larvae and juveniles, various crab megalopae, euphausiids, and other hyperiid amphipods. With increasing body size, juvenile Chinook salmon consumed a larger proportion of fish. In general both Chinook and Coho salmon were highly selective predators, preying mostly on large and heavily pigmented prey items. Small copepods and euphausiids in the early developmental stages dominated the prey field, but were almost absent in the salmon diet. Estimates for daily rations ranged from 1.7 to 3.0% wet body weight for juvenile Chinook to 3.6% for juvenile Coho salmon.

Regional Features Affecting Juvenile Salmon Performance and Distribution in Coastal Habitats of the Pacific Northwest

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The appropriate spatial scale to evaluate and define linkages between distribution and performance of juvenile salmon (a highly mobile fish) and habitat features in the nearshore coastal environment is of concern. Recent studies characterizing the role of the Columbia River plume and coastal features off Oregon and northern California (GLOBEC) to survival and growth of juvenile Chinook and Coho salmon reveal relationships between physical habitat features and salmon can be effectively identified. Examples include 1) relationships between upwelling events, stable isotope signatures, and growth of salmon, 2) non-random distribution of juvenile salmon in frontal regions associated with mixing of the Columbia River plume and the California Current, and 3) differences in growth of juvenile salmon in the coastal regions of Oregon and Washington which transcend changing ocean conditions. An approach to utilize empirically defined salmon-habitat linkages to characterize impact of changing ocean conditions to habitat opportunity through the use of physical habitat metrics important to salmon will be presented.

Pacific Fisheries Environmental Laboratory Provides Easy Access to Salmon-Relevant Environmental Data

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PFEL's data holdings and related data products provide a suite of fisheries and marine mammal relevant data that cover the entire spectrum of the ocean environment - from surface or near-surface wind and pressure data that can affect the ocean, to surface and subsurface measurements of important oceanographic parameters that are updated near real-time. These include a variety of FNMOC fields, gridded fields calculated from GTS and GTSPP observations, and database systems that provide rapid access to the raw COADS and WOD98 datasets.

We will be demonstrating PFEL's implementation of the Live Access Server developed at PMEL, which provides the ability to subset, visualize, and download over the internet most of our gridded datasets. We will also be demonstrating our CD-ROM implementation of the COADS dataset and the CODE software for performing extraction and summarization from a desktop computer for COADS Release 1a,b,c (1790-1997).

The Role of Baitfish in Salmon Ocean Survival

Robert Emmett[1], Paul Bentley[1] and Gregory Krutzikowski[2]
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Historical datasets indicate that Northwest baitfish (e.g., Pacific herring, northern anchovy, Pacific sardine, and smelt) abundance has fluctuated widely over the last 50 years. Salmon ocean survival has also fluctuated widely since records began. Since 1999 we have noted a marked increase in the number of baitfish off Washington and Oregon. This increase appears to be related to decreasing ocean temperatures, changing zooplankton species and abundance, and decreased predator abundance. We hypothesize that baitfish abundance directly affects salmon ocean survival by acting as "alternative prey" for predators and thus decreasing predation rates.

Consumption of Red King Crab (*Paralithodes camtschaticus*) Zoea by Juvenile Bristol Bay Sockeye Salmon (*Oncorhynchus nerka*) in the Eastern Bering Sea.

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The Wisconsin bioenergetics model was used to quantify juvenile (freshwater age 1 and 2) sockeye salmon (*Oncorhynchus nerka*) consumption rates on red king crab (*Paralithodes camtschaticus*) zoea in the eastern Bering Sea during summer (July to September) 1999. The consumption estimates along with estimates of sockeye salmon smolt and red king crab zoea abundance (1984 to 1992) were then used to determine the fraction of red king crab consumed by juvenile sockeye salmon in the eastern Bering Sea from 1984 to 1992. The model results indicate that the estimated fraction of red king crab zoea stage II consumed by juvenile Bristol Bay sockeye salmon can be substantial, approaching more than 45% during some years (1986 and 1991). These results suggest that red king crab zoea consumption by juvenile sockeye salmon during years of high juvenile sockeye salmon abundance may have contributed to the sustained low recruitment of red king crab during the 1980s and 1990s.

Retrospective Growth Analyses: Lessons From The Post-Smolt Growth Zone

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There is a lot to be said for analyzing the data we have on hand, especially when it holds the promise of solving many of the most vexing problems science faces in regard to the marine ecology of salmonids. The data on hand are archives of scale samples from specific stocks of salmon, and considering that we have already paid for the collection and preservation of these material, the further analysis of circuli spacing seems the logical next step to take. Growth patterns found in the circuli spacing of Atlantic salmon scales have already provided valuable insights on the survival, maturation mechanisms, nursery habitat, and recruitment synchrony of both North American and European stocks, this accomplished with less than 5% of the available scale archives analyzed to date. These techniques and approaches will be considered in light of how they might be applied with Pacific salmonids.

Small-Scale Physical Variability in the Columbia River Plume

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Juvenile Coho and Chinook salmon are often found in association with Columbia River plume fronts and other small-scale features of the coastal ocean, e.g., upwelling fronts and eddies. These features may be important, both for their influence on biological productivity and for their specific support role for salmonids. Velocity variability in the plume area occurs most strongly at periods between a few hours and a few days, with the shortest periods characteristic of periods when low-salinity water is present. The characteristic length scale for a unit change in salinity is 10 to 100X smaller when plume water was present than otherwise. Another important property of the plume fronts is the strong convergence in the cross-frontal direction, coupled with strong shear in the along-frontal direction. Tidal variability is also 3-10X larger in the plume area than is typical for the Oregon-Washington shelf. This enhanced variability is caused by internal tides that are concentrated in the plume area, and are much more variable than surface tides. Internal tides likely represent one of the mechanisms by which nutrients are supplied to the plume. The interaction between plume fronts and internal tides increases velocities and shears in frontal zones, possibly acting to disperse juvenile salmonids. Plume turbidity is also important to salmonids, and preliminary results suggest that fluctuations in turbidity occur on even smaller scales than is the case for salinity. The importance of small-scale variability in the plume area may constrain biological sampling in this part of the coastal ocean.

Linking Juvenile Production Sources to the Adult Chinook Salmon Fishery Along the Central California Coast Using Otolith Microstructure and Micro-chemistry: Identifying Hatchery and Wild Sources

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Identifying the relative contribution of larval and juvenile sources to adult stocks is a central problem in fisheries management. Juvenile sources provide a critical link to the long-term persistence of harvested adult populations. Determining the differential contribution of juvenile Chinook salmon from the California Central Valley rivers and hatcheries to the fishery would identify important production sources critical to the maintenance of the stock. Current tagging methods, which tag a small proportion of hatchery fish, provide limited information on recruitment of hatchery fish into the fishery and no information on wild fish. Potential impacts of hatcheries on wild populations, or changes in the fishery composition, have been difficult to monitor and quantify, due to limited tools for identifying hatchery and natural individuals in mixed populations. This study examines the use of daily growth increments, and transition phases from embryonic through early juvenile stages reflected in sagittal otoliths, as natural tags to distinguish hatchery and wild juveniles in the Central Valley. We developed a discriminant function using differences in average increment width, standard error, otolith circularity, distance to hatch and exogenous feeding. Using this predictive equation we were able to correctly classify 100 % of hatchery 95 % of wild individuals using a jackknife procedure. This classification technique will be used to link the production of adults along the Central California Coast to river and hatchery origin. In addition, future research using otolith isotopic composition to determine smaller scale river and hatchery origin within the Central Valley will be discussed.

Searching for a Life History Approach to Salmon Escapement Management

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The interactions between Pacific salmon harvest and nutrient supply to the freshwater portion of the salmon ecosystem have played an as yet unquantified role in the notable decline and loss of some populations and in the sustainability of all populations. We also assert that previous spawner-recruit methods for assessing the effects of harvest on long-term population health have in many cases been inadequate. We therefore developed a heuristic, life-history based, spreadsheet survival model to analyze the effects of various harvest scenarios on population sustainability. The model also incorporates salmon carcass-driven nutrient feedback from the marine to the freshwater ecosystems. We simulated the life history survival steps for a hypothetical Coho salmon population. The model employs survival rates from the literature and individual, stochastically varied, terms for spawner to egg, egg to fry, fry to smolt, and smolt to adult survival. The effects of climate variation and nutrient feedback on survival were simulated, as were density-dependent effects of the numbers of spawners and fry on freshwater survival of eggs and juveniles. We subjected the unexploited equilibrium population to 100 years of 20, 40, and 60% harvest and found each of these harvest rates gradually reduced the population to a steady state of respective reduction, regardless of generous compensatory survival at low population sizes. We encourage salmon researchers to continue exploring this approach and recommend that managers consider this or similar modeling for helping to establish escapement goals and evaluating escapement decisions. Until this and other management techniques are refined, managers should strive for generous escapements to support nutrient rebuilding as well as egg deposition, both necessary for strong future salmon production.

Closing the Loop: Links between Marine and Freshwater Environmental Variability Affecting Oregon Coastal Natural Coho Salmon

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Oregon Coastal Natural (OCN) Coho salmon, spawning and rearing in the river basins of the coast range of Oregon, have shown marked fluctuations in abundance over the past 30 to 50 years and are currently at critically low numbers. We investigated climate effects on OCN Coho in freshwater using smolts and smolts per spawner as indices of productivity and survival respectively. Stream flow indices were developed for four time periods deemed important to successive stages of Coho salmon development (first winter; eggs, first summer; parr, second winter; smolts, and second spring; out migration). In addition we created an index of the fall transition based on the date when winter storms first caused a rise in stream flows. Annual mean air temperature was used as a proxy for water temperature. Air temperature, fall transition, second winter flows and second spring flows were all significant predictors of smolt production. Fall transition and second winter flows predicted smolts per spawner, but correlations were weaker. Logerwell et al. (in review) have identified four environmental factors correlated with smolt to adult survival in the Oregon Production Index area. These factors are winter sea surface temperature (SST) in the smolt year, spring transition date, spring upwelling, and winter SST in the adult year. These four marine factors correlate with annual mean air temperature such that all five variables tend to be negative or positive for Coho production in synchrony. In addition, spring transition and spring upwelling correlate with second winter and second spring flows so that good (poor) freshwater conditions are associated with poor (good) ocean conditions. Thus, environmental factors influence both freshwater and marine stages of the OCN Coho salmon life cycle. These factors may interact to amplify variability in adult recruitment of naturally produced fish.

Tracking Environmental Bottlenecks in the Coastal Zone: What are the Mechanisms Linking Climate Variability to Oregon Coho (*Oncorhynchus kisutch*) Marine Survival?

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To better understand the mechanisms driving variability in Oregon Coho (*Oncorhynchus kisutch*) marine survival, we developed a conceptual model of four environmental bottlenecks through which Coho must pass during early marine life: 1) winter climate prior to smolt migration from freshwater to ocean, 2) the date of the spring transition from winter downwelling to spring/summer upwelling, 3) the spring upwelling season and 4) winter ocean conditions near the end of the maturing Coho's first year at sea. We then parameterized a General Additive Model (GAM) with Oregon Production Index (OPI) Coho smolt-to-adult survival estimates from 1969 to 1998 and environmental data representing each bottleneck (pre-smolt winter SST, spring transition date, spring upwelling wind indices, and post-smolt winter SST). The model explained a high and significant proportion of the variation in Coho survival during the period of record (R^2=0.73). To examine linkages with climate variability, we evaluate the relationships between our local environmental indices and indices tracking hemispheric scale climate patterns, specifically indices for the Aleutian Low, the El Nino-Southern Oscillation, and the Pacific Decadal Oscillation. This approach allows for an assessment of the potential predictability of ocean conditions for OPI Coho.

Influences of the 1997-1999 El Niño-La Niña on Juvenile Chinook Salmon off Central California

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The 1997-1998 El Niño and ensuing 1999 La Niña was one of the largest amplitude ENSO cycles in history. Such large-scale climatological events have been shown to cause profound changes to oceanic ecosystems. Altered temperature structure and circulation patterns can produce changes in lower trophic-level biological productivity and amplified consequences to metabolic processes and growth in fishes. Many stocks of Pacific salmon from the continental United States have been depleted for several decades; the impact of a large El Niño - La Niña could be particularly detrimental to year-classes produced during the event. We describe size-at-age and growth rates of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in the coastal waters of central California during the 1997 1998 El Niño and the 1999 La Niña and their relationships to lipid metabolism, prey abundance, feeding, and physical oceanographic factors.

Do Fish Feed at Fronts? Hydrography, Zooplankton, and Feeding Ecology of Juvenile Salmon in Frontal Regions of the Columbia River Plume

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River discharge results in predictable physical and biological features in the coastal ocean. A well-defined front develops at the seaward edge of riverine plumes where suspended materials and planktonic organisms can become concentrated in a relatively restricted area. Riverine fronts are hypothesized to be favorable habitats for planktivorous fish because of the potential for localized prey aggregations. Here, we examine the zooplankton prey field in tidal fronts, the Columbia River plume, and adjacent ocean waters. In addition, we examine the spatial distribution and food habits of juvenile chum (*Oncorhynchus keta*) and Coho (*O. kisutch*) salmon to determine if these juvenile salmonids ingest more prey at riverine fronts.

The front at the leading edge of the brackish plume was an ephemeral but recurrent feature characterized by sharp color discontinuities that intensified on a tidal cycle. Fish and zooplankton were sampled at the surface expression of the front, and also at stations ~1 km away in both the low-salinity plume and the more saline coastal marine water. Chum salmon were rare in the plume, but were abundant in both the frontal regions and in marine waters. Coho salmon were more abundant at the front compared to plume or ocean stations. Initial analysis of the prey field and of stomach contents does not support the hypothesis that more prey is either available or was ingested in the vicinity of the front. Thus, although juvenile salmonids were more abundant at frontal regions, our results are not consistent with the paradigm that fish congregate to feed at fronts.

Chinook Salmon Data Storage Tag Studies in Southeast Alaska, 2001

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Chinook salmon were tagged in April and May 2001 with temperature and pressure data storage tags during two surveys in coastal Southeast Alaska by scientists from the National Marine Fisheries Service, Auke Bay Laboratory. Six tags have been recovered to date from the 48 Chinook salmon tagged. The duration between tagging and recovery ranged between 4 and 86 days and the minimum distance traveled by each fish ranged between 0 and 585 nm. Depth data from the data storage tags indicate that Chinook salmon, unlike other species of salmon, migrate to their deepest daily depths during the night.

Testing Electronic Archival Tags in Coho Salmon in Alaska

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We tested the implementation of a new technology – electronic archival smolt tags – in Alaskan Coho salmon. Our study population was the Fort Richardson Hatchery Coho salmon from Ship Creek – a tributary to Cook Inlet running through Anchorage. We selected a hatchery stock due to accessibility, ability to supplement early growth, and weir recovery site in the release river. The Alaska Department of Fish and Game operates this hatchery for production of Coho, Chinook, rainbow trout and Arctic char for release to sport fisheries. Outdoor raceways and indoor tanks are heated by diversion of discharge water from an electric power plant. We were able to put Coho pre-smolts on an accelerated diet in winter to reach large size-at-age (157-250 mm FL; mean weight = 92g). In May 2001 we surgically implanted 60 Coho with LOTEK Marine Technologies' beta dummy-prototype archival tags. Tag weight equaled 2-7% body weight in our test fish. During our development of surgical procedures modifications were integrated into the engineering of the external light stalks for beta tags. We observed fish behavior post surgery for 2-6 weeks and had a 95% survival rate. All 57 tagged Coho smolts were volitionally released with the hatchery Coho in the spring into Ship Creek. No tagged Coho jacks were observed at the weir in the fall of 2001. We plan an additional release of 200 tagged Coho this spring (2002). These fish will be fitted with tags that have active temperature and pressure sensors and pit-tagged to aid in recovery.

Ontogenetic Changes in the Taxonomic Composition and Size of Prey in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) Diet from Coastal Waters off Central California

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Populations of Chinook salmon (*Oncorhynchus tshawytscha)* which migrate through the San Francisco Estuary into the coastal waters of California are in decline. These populations are not only subjected to the impacts of a highly urbanized, industrialized and agricultural freshwater and estuarine system, but may also have decreased survival rates during early marine residence. Juvenile Chinook salmon have been shown to grow rapidly, increasing in size and metabolic requirements during their first year in the ocean. The ability to consume larger prey items with increased predator size may improve their energy efficiency. The relationship between prey and predator size has been well documented, but there is no information on feeding habits of juvenile chinook salmon in the coastal waters off central California. Juvenile salmon were collected from May through October 1995-1999 during their first year of residence in the ocean to assess changes in dietary composition and the relationship between prey size and predator length. Analysis of stomach contents revealed a shift in dominant prey items with increasing predator size. In the smaller size classes, there was a greater diversity of prey items where copepods, euphausiids, decapods, and amphipods formed the major portion of their diet. The shift in diet to include more fish, primarily northern anchovy, was evident in larger salmon.

Feeding Habits of Outmigrating Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the San Francisco Estuary and the Gulf of the Farallones

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Limited research exists on the feeding habits of juvenile Chinook salmon (*Oncorhynchus tshawytscha)* while transiting the San Francisco Estuary and during their first year in the marine environment off central California. Knowledge of juvenile salmon trophodynamics will improve the ability to assess habitats and resources crucial to their survival. Juvenile salmon were collected in May and June, 1995 to 1999 from four locations in the San Francisco Estuary and from the coastal ocean in the Gulf of the Farallones. Samples were obtained starting at the confluence of the Sacramento and San Joaquin Rivers proceeding downstream to the ocean. Analysis of stomach contents revealed interannual differences in dominant prey items at specific sampling locations. Significant changes in diet were also found as juveniles transited through the system. In the upper bays, there was a greater diversity of feeding where insects, amphipods, mysids, and cladocerans formed a major portion of the diet. In Cental San Francisco Bay, diets consisted of mainly amphipods, but fish larvae and insects also made up significant portions. Fish larvae, decapods and euphausiids were the main prey items in the Gulf of the Farallones.

Evidence For A Climate Regime Shift in the Northern California Current- Changes in Nutrients, Chlorophyll and Zooplankton Along the Newport Hydrographic Line

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Hydrographic data and nutrient, chlorophyll and zooplankton samples have been collected biweekly at several hydrographic stations off Newport Oregon (latitude 44° 40'N) for 12 years, from 1969-1973, 1983 and May 1996 through present. All data were collected at stations 1, 3, 5, and 10 miles from shore. The data set represents two time periods in the climate cycle: the cool phase of the PDO (1969-1973; 1999-2001) and warm phase of the PDO (1983, 1996-1998). Notable changes that have occurred recently is that the PDO changed signed to negative, beginning in July 1998 and has remained negative since. The PDO has not been negative for this long a period since 1976. In the plankton, we have noted a doubling of copepod biomass, and a shift in copepod species composition to high biomass of "boreal neritic species" and a reduction in biomasss of "transitional zone and subtropical neritic species". Zooplankton now resemble closely the assemblage seen in the 1970's. These observations indicate that a fundamental change has occurred in the California Current over the past three years. Survival of Coho salmon has also increased dramatically over the past few years, in concert with changes in productivity of the northern California Current.

Long-term Trends in Annual Bristol Bay Sockeye Salmon Scale Growth in Relation to Sockeye Abundance and Environmental Trends, 1955-2000

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Pacific salmon populations in Alaska, along with some prey species, increased substantially after the marine climate shift during the mid-1970s. However, average length of adult salmon has declined in recent decades leading to concerns about the carry capacity of the ocean to support Pacific salmon. We measured annual marine scale growth of Bristol Bay and western Alaska sockeye salmon, 1955 to 2000, in order to test whether long-term growth trends were consistent during each of the three years that sockeye salmon inhabit the ocean. The time series of sockeye scale patterns indicates sockeye salmon growth during the first two years at sea increased after the mid-1970s, whereas growth during the third year tended to be below average. A density-dependent growth model shows that adult size at age of sockeye salmon was density-dependent, but adult size was greater after the mid-1970s when abundance is incorporated into the model. Effects of the 1997 El Nino even on sockeye growth will be discussed.

Growth, Condition and Pathogens of Juvenile Salmon Caught Off the Oregon and Washington Coasts

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Changes in upwelling regimes and ocean productivity have been linked to fluctuations in the productivity of salmon species in the Northeast Pacific. Two projects are currently underway (Global Ocean Ecosystems Dynamics (GLOBEC), southern Oregon coast; Bonneville Power Administration (BPA), Washington and northern Oregon coasts) to examine factors affecting near-shore juvenile salmon distribution and survival. A major focus of this project is to investigate the growth and bioenergetic health of juvenile salmon in relation to the Columbia River plume, including determination of the prevalence and distribution of three pathogens (*Renibacterium salmoninarum, Nanophyetus salmincola* and Erythrocytic Inclusion Body Syndrome (EIBS) virus) which influence salmonid growth and survival. In 2000, ocean trawls were conducted aboard contracted fishing vessels using an 88-meter trawl net. Surface trawls were made along predetermined transects along the Oregon and Washington coasts. The results of this study illustrate temporal and spatial differences in the prevalence and severity for two of the three parasitic species of juvenile salmonids examined from different regions of the northwest U.S. coast. The prevalence of both *R. salmoninarum* and *N. salmincola* decreased in fish caught in the BPA study as the summer progressed, but even more striking was the decrease in the prevalence of *R. salmoninarum* in salmonids caught above and below the Newport, Oregon transect line. The prevalence of EIBS virus was very low in juvenile salmon from both areas. This work demonstrates that these infections may directly influence the health of juvenile salmonids during the critical ocean transition phase.

Interannual to Decadal Environmental Variability at the Southern Extent of Salmonid Ranges

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The physical environment of the Northeast Pacific Ocean is known to vary on a multitude of time scales, with El Niño events and decadal-scale regime shifts being particularly prominent. Recent studies have suggested that a major regime shift in North Pacific climate occurred following the 1997-98 El Niño event, and that significant changes in marine biota followed. Here we present an overview of recent changes (1998-present) in the physical environment of the Northeast Pacific, and put these observations in the context of observed interannual to decadal variability over the past 50 years. In particular, we describe fluctuations in upper-ocean water properties and circulation within the California Current System, and in the larger-scale atmospheric forcing. Recent changes in the growth and survival of salmonids in the southern extent of their ranges (Oregon-California) are likely associated with these changing environmental conditions.

Post El Niño Changes in Altimeter SSH and Transport in the NE Pacific

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Eight years (October 1992 – September 2000) of altimeter data are used to examine changes in the sea surface height (SSH) and geostrophic transport fields following the 1997-1998 El Niño. Data from before the El Niño (October 1992–October 1996) can be compared with the period following the El Nino (October 1998 – October 2000). The shorter period following the El Niño results in greater noise in those fields, complicating the comparison. The motivation is to explain why zooplankton population communities have switched from warmer water species to cooler water species. This could be due to advection of the cooler water and populations from the north or to growth of those populations in response to strong upwelling. Initial results show that sea level in the 100 km next to the coast is lower than before the El Niño, consistent with a colder water mass. However, height gradients associated with geostrophic currents do not show greater advection from the north (if anything, coastal flow is poleward). In the large-scale NE Pacific, the Alaska Gyre appears to have strengthened and the eastward flow in the North Pacific Current also strengthened along 45ºN, but turns equatorward far from the coast. Within 1000 km of the coast, the change in SSH and circulation is more confused.

An Update on Juvenile Salmon Studies in Barkley Sound, Canada

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The work to examine the early marine phase of juvenile Chinook, Coho, sockeye and chum salmon in Barkley Sound continued in 2001. Timing of movement of fish through the Alberni Inlet/Barkley Sound study area was similar to that in 2000, as was the distribution of wild and hatchery fish. The forecast of marine survival for Coho, which is based on euphausiid biomass during June-August of the first marine year, was accurate for the Robertson Creek hatchery and Carnation Creek wild Coho populations. Sampling extended outside of Barkley Sound on to the continental shelf and purse-seining was tested as a method for sampling juvenile salmonids. Chinook wild and hatchery smolts were found exclusively nearshore (<0.5 n. m.) in water less than 25 m deep. Chum and sockeye smolts were found near the surface within 5 n.m. of shore. Coho smolt catch compositions changed with distance from shore; the proportion of hatchery fish and fish size increased with distance. Steelhead trout smolts were the furthest distance from shore and were collected in waters from 140 – 160 m deep. Analyses to be presented will have compared the size and species compositions of purse-seine catches with surface mid-water trawl samples taken two days before. In addition, diet analysis for sockeye indicated that they ate smaller euphausiids (*T. spinifera*, 3-5 mm) than Coho did. A preliminary relationship, which appears capable of explaining a substantial proportion of the variation in Barkley Sound sockeye marine survival rate as a function of *T. spinifera* biomass, will also be presented.

Genetic Mixed Stock Analysis of Juvenile Coho Salmon off Oregon and Washington

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Little is known about the population origins of juvenile Coho salmon in the northern California Current. In this study we apply genetic mixed-stock methods to samples of juvenile Coho salmon caught in coastal waters from central Oregon to northern Washington during the summers of 1998-2000. We compare early and late summer samples to detect seasonal shifts in stock compositions along the coast. Recent efforts at Pacific Northwest hatcheries to mark the majority of their releases of Coho salmon with a fin clip provide new opportunities to identify hatchery fish in ocean samples. We therefore examine the population origins of hatchery-marked and unmarked samples and use this information to estimate the percentage of wild Coho salmon along the coast. We also use data from earlier tag-recovery studies to search for decadal shifts in the marine distributions of particular stocks and to examine changes in the relative proportions of wild and hatchery fish in the region's coastal Coho salmon population.

Salmon Bioenergetic Models Under Scrutiny : A Plea for Basic Research

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Bioenergetic models offer a useful framework for for understanding salmon ecology and have been used to study a large number of processes; salmon growth and migration, predator-prey and food web interactions, habitat selection, and as a basis for establishing stocking policies. Like most models, bioenergetic models require the estimation of numerous parameters. Despite their importance, surprisingly little is known about the energetics of most salmon species. As a consequence, bioenergetic models of salmon have often relied on parameters borrowed from other "closely" related species or values extrapolated from one life-stage or size-class to another. In this paper, we review the current state of knowledge on Pacific salmon and steelhead trout energetics. Using published data on standard metabolic rates and swimming costs of Pacific salmon and steelhead trout, we show how much bias can be introduced into bioenergetic models even when parameters are borrowed from closely related species of the same genus or extrapolated between life-stages.

Increased funding and scientific recognition of the need for additional basic research will be necessary to build more accurate bioenergetic models for Pacific salmon, especially when they are applied to the ocean phase of the life cycle.

Climate-Induced Variation in Keogh River Salmonid Carrying Capacity and Survival in the Ocean

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Smolt yield and adult returns of steelhead trout (Oncorhynchus mykiss) and Coho salmon (O. kisutch) at the Keogh River on northeastern Vancouver Island has shown large variation in survival during both the freshwater and ocean phases of the life history. In the early 1990s, both species experienced a large and persistent decline in survival. The estimated carrying capacity for steelhead trout in freshwater declined by more than a factor of 3 (mean 7,000 smolt recruits, 1977 to 1990; <2,000, 1991 to 1997) and was coincident with numerical declines to record low levels in yield of Coho and Dolly Varden Salvelinus malma. Meanwhile, the sea survival of both steelhead and Coho dropped by a factor of 5 (from 15% to 3%) when compared to the previous decade. Recruitment dropped below replacement levels. Variation in smolt-to-adult survival within the decades of the 1980s and 1990s seems to be related to El Nino events of successively increasing intensity and frequency, followed by an equally intense La Nina that is now dissipating. An increase in marine survival for the 1997 and 1998 steelhead and Coho smolts may have been short-lived, based on our results from electronic escapement counts over the past two years (1999 and 2000 smolts). We suggest that it is too early to judge whether a new trend towards higher marine survival is emerging, and caution that our observations may indicate a continuation of poor survivals and reduced productivity. Our findings may be an indication of the magnitude of future climate changes on salmon stocks.

Estimating the Effects of Ocean Condition on the Jacking Rate of Coho Salmon: A New Analysis of the Data Provided by Shapovalov and Taft

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Many workers have documented relationships between ocean conditions and survival rates of juvenile Coho salmon, but, apparently, relatively little effort has been spent relating ocean conditions to jacking rates. This lack of scientific effort is surprising given that jacking rates probably play important roles in Coho population dynamics. For example, jacking rates may influence the degree of inbreeding in small populations. I am studying whether (and to what degree) ocean conditions affect jacking rates by integrating environmental data into a population dynamics model. I fit this model to two sets of observations on Coho salmon: counts of jack and hooknose males collected during the spawning run, and smolt-to-adult survival rates estimated from tagging studies. Simulation testing (although not very rigorous) suggests that the model can do relatively well at predicting the observed counts and survival estimates. Nevertheless, the estimated effects of ocean condition on simulated jacking rates were biased low. Estimates of environmental effects on simulated survival during the first ocean season were also biased, but the direction of that bias depended on the relative amounts of process and observation error used in the simulation and assumed during the estimation. Although I need to test the model more extensively, I will hazard to present the results from a quick and dirty fit to the data provided by Shapovalov and Taft (1954).

Evaluating the Performance of Juvenile Chinook and Coho Salmon in Marine Waters of SE Alaska

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Two core hypotheses in ocean salmon science are that: 1) events in coastal regions during the early stages of ocean residency largely regulate marine survival rates of Pacific salmon, and 2) the condition of fish reflects marine habitat characteristics occupied during this critical period, and consequently serves as a predictor of marine survival. To test these hypotheses, I am examining the "performance"--size (length, weight), growth rate, pathogen and parasite prevalence, diet, stomach fullness, and energy levels--of juvenile Chinook (*Oncorhynchus tshawytscha*) and Coho (*O. kisutch*) salmon inhabiting marine waters of SE Alaska. These fish were collected in 1997-2000 as part of NMFS Southeast Alaska Coastal Monitoring (SECM) Program. The program documents the early ocean ecology of juvenile salmon in SE Alaska, with a focus on pink and chum salmon. I am quantifying the spatial and temporal variation in 1) marine environments, 2) indicators of juvenile Chinook and Coho salmon performance, and 3) overall marine survival of these fish, in order to explore the statistical relationships between these three factors. Juvenile Chinook and Coho salmon in marine waters of SE Alaska provide an exciting contrast to the same species in the California Current System (CCS) because these northern fish inhabit marine environments that are very different from their southern counterparts and exhibit species-specific differences in marine survival rates. This provides a unique opportunity to examine strong interregional and interspecific contrasts in Chinook and coho salmon during their critical first summer in the ocean.

Shift Happened: Evolution of North-South Gradients in Coho Body Size & Plankton Community Structure on the Continental Shelf During 1998-1999

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Regime shifts in climate, zooplankton abundance, and salmon production have been described primarily for offshore environments at decadal time scales. The seasonal and monthly evolution of regime shifts in shelf environments is poorly understood. We present results from a fine-scale look at the evolution of what may be a regime-shift between 1998 and 1999.

Body sizes of juvenile Coho along the British Columbia coast showed a strongly bimodal distribution in October 1998, with mean sizes approximately 200 g in southern BC shelf waters versus 400 g in northern BC and SE Alaskan waters. This changed to a unimodal size distribution in October 1999 (mean size approximately 300 g), with no geographic differences evident. We examined these size differences in the context of the concurrent changes in the zooplankton.

Shelf zooplankton assemblages off British Columbia and southeast Alaska showed significant between-year and north-south differences. Relative abundance changes were dominated by regional shifts in the composition of small-bodied shelf copepods, whereas biomass changes were dominated by increases in the biomass of hydrozoans, a pteropod (*Limacina*), and a shelf euphausiid (*Thysanoessa spinifera*). California-shelf copepods (*Paracalanus, Ctenocalanus, Calocalanus*) were found as far north as Barnaof Island, AK (56.3ºN) in July 1998; however, they were four to ten times more abundant south of Queen Charlotte Sound (52ºN). *Ctenocalanus* and *Clausocalanus* abundance declined steadily from June to October 1998. *Paracalanus* may have had at least one reproductive event in August 1998; however, all California shelf copepods had disappeared from the BC coast by May 1999. Results will be discussed in relation to current hypotheses about how regime shifts affect food web pathways leading to salmon.

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