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Paralytic Shellfish Toxin Resistance Mechanisms in Bivalves

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At least two paralytic shellfish toxin resistance strategies exist in bivalves, incorporating two very different groups of proteins; the voltage gated sodium channel and soluble saxitoxin binding proteins. These proteins have the ability to bind saxitoxin and its derivatives with high affinity. In the soft-shelled clam, Mya arenaria it was recently reported that a single amino acid substitution in the sodium channel conferred nerve resistance to saxitoxin. We have since examined the amino acid sequence of sodium channels from a variety of other bivalve species including Saxidomus giganteus, Siliqua patula, Arctica islandica, Mercenaria mercenaria, Venerupis philippinarum and others collected from the US Pacific and Atlantic coasts. A similar resistance strategy appears to be involved in shellfish resistance and we observed identical amino substitutions of the STX binding domains of the sodium channel. Soluble STX binding proteins activity was also investigated in these species and in the case of S. giganteus, was determined to be highly localized in the siphon and demonstrating nanomolar binding affinities with STX, dcSTX and NeoSTX. In addition, ubiquitous low level STX binding activity was observed across all isolated tissue types in S. giganteus and Macoma secta indicating that circulation of the protein through the hemolymph was likely.

Assessing the feeding ecology of beluga whales in Cook Inlet, Alaska using chemical tracers

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Cook Inlet beluga (white) whales have been declining in number since 1994 when the National Marine Fisheries Service (NMFS) began conducting annual aerial surveys of the population. In response, Cook Inlet beluga whales were listed as a protected species under the Endangered Species Act in October 2008. Initial efforts to understand the decline in the Cook Inlet beluga population focused on subsistence harvest effects; however, this is no longer thought to be the predominant factor influencing the belugas' decline. Another possible contribution to the decline of these whales may be a lack of adequate prey. Regrettably, the specific diet of these whales is largely unknown so it is difficult to evaluate the impact of declining fish runs on the Cook Inlet beluga population. It is known however that returning adult salmon are an important prey species of these whales, particularly during late spring through early autumn. Unfortunately, since 1990, commercial fisheries for sockeye salmon, as well as sport fisheries for Chinook and coho salmon, have reported declines in a number of fish runs in the Inlet. The focus of this project was to use chemical tracer data to help infer the predominant prey of this population of white whales. Specifically, between 2001 and 2008 blubber and skin samples from a combination of catch and release, stranded, and subsistence harvest Cook Inlet beluga whales were collected along with representative samples of their most likely whole-body fish prey (including non-salmonid species) and all of these samples were analyzed for their fatty acid compositions and their $^{15}N/^{14}N$ and $^{13}C/^{12}C$ stable isotope ratios. From these data, a semi-quantitative model based on a combination of these fatty acid and stable isotope results was developed to assess what combination of specific prey most likely represents the predominant prey of Cook Inlet beluga whales. The preliminary conclusion obtained as a result of this study continues to point to salmonids, in particular chum salmon, as the most important contributors to the diets of these whales during spring and summer.

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Tools useful for both qualitative forecasting of adult salmon returns and for understanding the underlying climate and oceanographic mechanisms which may control rates of return

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This poster describes how physical and biological oceanographic conditions affect the growth and survival of juvenile salmon in the coastal waters of the northern California Current off Oregon and Washington. As an aid to understanding relationships between oceanographic conditions and juvenile salmon, we present in the poster a number of indices based on physical, biological and ecosystem metrics that are (a) useful for forecasting the survival of salmon up to one to two years in advance, and (b) that define the term "ocean conditions" in a more precise manner. Most of the information shown in this poster is based on our own observations of the physical and biological characteristics of coastal waters made during frequent oceanographic cruises to the coastal upwelling ecosystem off the Pacific Northwest since 1996. This information is presented on the Center's webpage (see "Ocean Index Tools") and is updated twice each year, in late spring after spring run fish have entered the ocean and in November/December after we have finished analyzing data collected during that calendar year.

Latitudinal gradients in zooplankton community along the west coast of North America: Auke Bay AK (57°N) to Crescent City CA 41°N.

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Zooplankton were ampled in shelf waters off the coast of North America by research teams at the NMFS lab in Auke Bay (Sturdevant), by scientists at the Institute for Ocean Studies in British Columbia (Mackas), and by the Peterson Zooplankton group in Newport. This poster combines data from each of these studies and illustrates that there is an alongshore gradient in copepod species composition with the number of species increasing from north to south. Community structure changes gradually as well. A surprise result was that coastal waters off northern California harbor a community that is more similar to the coastal Gulf of Alaska (off Auke) then communities immediately to the north. We think this might be due to the much stronger upwelling off N. California as elsewhere which brings subarctic water (and copepods) up to the surface there.

Effect of mesoscale physical oceanographic variability on zooplankton community structure in shelf and slope waters from central Oregon to northern California

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Upwelling is more-or-less a linear process in waters north of Heceta Bank Oregon. However immediately south of Heceta Bank (44°N), the California Current starts to break up into eddies and filaments, caused by a meansdering upwelling jet over southern Heceta Bank, and by variations in intensification of the field of the winds at and south of Cape Blanco which leads to stronger upwelling there and instabilities in the upper layer flows. This poster shows the influence that these mesoscale features have on copepod distributions and copepod community structure. Coastal communities can be found far offshore due to transport in large filaments that develop off Cape Blanco. Nearshore communities are similar up and down the coast however mid and outer shelf communities can be found well offshore due to their entrainment in offshore advection of mesoscale eddies and filaments. Thus these physical features can transport a high biomass of copepods seaward thus fueling an enriched food chain far offshore in waters that are not very productive. This also has implications on the vertical flux of copepod carbon to the deep-sea.

Euphausiid population dynamics in the coastal upwelling zone off the Oregon Coast

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We sampled hydrography, chlorophyll, copepods and euphausiids during biweekly cruises at several hydrographic stations off Newport Oregon (44º40'N) and during bimonthly cruises over large scale spatial grids (5-12 transect lines between 41º50'N and 44º40'N). The result is a unique data set showing temporal and spatial variations in the distribution and abundance of the euphausiids, *Euphausia pacifica* and *Thysanoessa spinifera*, in the northern California Current (NCC). Our zooplankton data set (2001-2007) encompasses warm and cold years and variable upwelling conditions. *Euphausia pacifica* biomass was usually 10-50 mg C m^{-3}. *Thysanoessa spinifera* biomass was generally <5 mg C m^{-3}. Average summer *E. pacifica* biomass showed a marked increase from inshore to offshore while *T. spinifera* biomass was from 1-5 mg C m^{-3} at all stations. Euphausiid growth rates were not affected by differences upwelling. Euphausiid egg production was strongly affected as the timing of spawning seems to be tied to upwelling, therefore changes in upwelling are likely to result in changes in euphausiid spawning behavior.

Molting and growth of *Euphausia pacifica* and *Thysanoessa spinifera* in the coastal northeast Pacific

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We sampled hydrography, chlorophyll, copepods and euphausiids during biweekly cruises at several hydrographic stations off Newport Oregon (44º40'N) and during bimonthly cruises over large scale spatial grids (5-12 transect lines between 41º50'N and 44º40'N). The result is a unique data set showing temporal and spatial variations in the distribution and abundance of the euphausiids, *Euphausia pacifica* and *Thysanoessa spinifera*, in the northern California Current (NCC). While at sea, we incubated adult and juvenile euphausiids for measurement of vital rates (egg production and molting rates). *Euphausia pacifica* and *Thysanoessa spinifera* are the dominant euphausiids in coastal Northeast Pacific - a dynamic environment, with seasonally strong upwelling. Instantaneous growth rate (IGR) experiments were conducted throughout 2001-2006, encompassing distinctly different oceanographic conditions with 2001, 2002 and 2006 were cold and productive; 2003-2005 were warmer and less productive. IGR experiments allow us to calculate growth in length in mm per day. Positive growth ranged from 0 to 0.9 mm per day. Negative growth occurred during all seasons, usually in larger animals of both species. Individual growth decreased as animals got larger but was highly variable.

Seasonal and inter-annual fluctuations in adult and juvenile *Euphausia pacifica* and *Thysanoessa spinifera* abundance for the years 1998 through 2006 in the California Current

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Understanding the annual and seasonal variability in abundances as well as the distribution of *Euphausia pacifica* and *Thysanoessa spinifera* and how these species respond to climatic changes may prove useful for fisheries management decisions, once an ecosystem approach to management is adopted, because these species are the primary food items for a broad variety of fish, bird and mammal species. We have combined data from multiple scientific sampling projects and cruises to produce coast-wide charts showing the distribution and biomass of euphausiids in plankton net samples collected at night from 1998 through 2006, along transects ranging from northern California to northern Washington. Several hot-spots were identified and will be shown on our poster.

The timing and location of spawning for the Euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off the Oregon coast, USA.

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Our 10-year time series (1996-2005) of biweekly sampling of *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, Oregon shows peaks in euphausiids eggs occurring from late February through early November with a great deal of interannual and cross-shelf variability. Euphausiid egg density is poorly correlated with chlorophyll concentrations and surface temperature. We gain greater insight into the phenology of euphausiid spawning through the study of adult euphausiid densities and continuous datasets (temperature and currents from a mooring on our transect line, wind data and the Bakun upwelling index) from the area.

Migration timing, growth, and estimated parr-to-smolt survival rates of wild Snake River spring-summer Chinook salmon from the Salmon River basin, Idaho, to the lower Snake River

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Abstract.--Survival, growth, and juvenile migration timing are key life history traits for at-risk salmon populations. To estimate these traits in threatened wild Snake River spring-summer Chinook salmon *Oncorhynchus tshawytscha*, we tagged these fish as parr in 3 to 17 natal streams from 1988 to 2008. We injected passive integrated transponder (PIT) tags into parr collected from streams within the Salmon River basin in Idaho. Each spring, after the previous summer's tagging, fish were detected as smolts in the juvenile fish bypass systems of lower Snake River dams. Estimated parr-to-smolt survival to Lower Granite Dam (excluding migration years 1989-1992) ranged from 3 to 48% for individual populations and from 8 to 25% (yearly average 16%) for all streams combined. From 1998 to 2004, estimated parr-to-smolt survival declined from 25 to 8%, then from 2005 to 2008 survival increased from 8 to 21%, due, in part, to parr density-dependent effects. Overall annual average growth rates from tagging to detection at Little Goose Dam ranged from 35.1 to 44.5 mm from 2001 to 2008, with significant differences in growth among sites and years. Growth of individuals was positively related to elapsed time between tagging and recapture and negatively related to length at tagging. Annual migration timing distributions for fish populations from the different streams varied highly within and between years. From 1989 to 2008, timing of the 10th to 90th percentile passing Lower Granite Dam ranged from 22 to 55 d for the combined wild populations (average 39 d). Median passage date was negatively related to autumn temperature, spring temperature, and March river flow, and was positively related to elevation of the tagging site. Baseline data generated by this project provide a foundation for understanding the bio-complexity of these populations, an understanding critical to effective recovery efforts for these threatened wild fish stocks.

Spatial Ecosystem Modelling of the Upper Gulf of California using Atlantis

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A spatially explicit biogeochemical food-web model of the upper Gulf of California (Sea of Cortez) is developed using the Atlantis modelling framework. The purpose of the study is to simulate and test various ecosystem-based management (EBM) strategies for the upper Gulf to determine likely impacts on artisanal fisheries and conservation of marine resources, including rare and endemic species. Parameterization of the model in this data-poor region has relied on numerous field studies directed to provide original data for the Atlantis model. Efforts include trawl sampling, reef diving transects, stomach content analysis, community interviews, port-level sampling and log book analysis, and reconstruction of biomass trends from local ecological knowledge interpreted using a fuzzy logic approach. A new spatial biomass allocation algorithm based on substrate, habitat affinities and other factors increases the applicability of biomass data. A novel maximum-likelihood method is used to interpret stomach content data for the diet matrix. Modifications have been made to Atlantis to improve representation of the area's ecology and take advantage of specialized data. Recommendations from this project will influence regional EBM plans and species-specific management plans to be adopted by Mexican fishery authorities in the 2010-2012 time frame.

NMFS and Ecoinformatics: Using technology and databases to help restore endangered and threatened salmon populations.

Andrew Albaugh

The evolution of computer science and database technology has impacted fisheries science in countless ways. The discipline of ecoinformatics, or the management of biological and environmental information with a focus on both human and computer elements, is quickly becoming an essential tool within the NMFS organization, and it too continues to evolve. At the Northwest Fisheries Science Center we have developed several such tools to aid Technical Recovery Teams (TRT) in the management and production of data critical to salmon ESA listing decisions. The Salmon Population Summary (SPS) database and the Salmon Population Analyzer (SPAZ) statistical program were created to aid in the production of regular Status Review Reports. SPS is a database system that stores salmon abundance, wild fraction, harvest numbers, and age structure data summarized at the ESU and Population level across the Northwest Region. SPAZ is a statistical package that utilizes the data generated in SPS to produce population trend data that then feeds directly into the listing and de-listing decisions under the ESA. In the recent past each TRT chair had different methods and practices when dealing with their own salmon data. This resulted in a very tedious and laboring endeavor when it came to generating the needed salmon population summaries and trends for a Status Review. Moving forward, it is our intent, with both SPS and SPAZ, to allow those tasked with the job of restoring endangered and threatened salmon species the ease and flexibility to manage their own data on a central system. SPS and SPAZ will demonstrate how a large agency in charge of managing data over a very large spatial scale can benefit from the tools created within ecoinformatics.

Community and Genetic Analyses of Macroparasites from Pacific sardine (*Sardinops sagax*) caught in the California Current System

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Tagging studies of Pacific sardine (*Sardinops sagax*) during the peak of their fishery in the 1930s and 1940s suggested that larger individuals migrated north to feedings grounds off the Columbia River and into Canadian waters after spawning off of southern California in April. These large sardines remained in the Pacific Northwest until the onset of winter storms before they migrated back to southern California to overwinter. To assess the current behavior and potential population structure of Pacific sardine within the California Current System (CCS) we are examining the community structure of macroparasites, which are acquired through trophic interactions. Approximately 2200 sardines were collected from 2005 through 2007 between 50° to 32° North latitude, and 120° to 125° West longitude. From approximately 1000 sardines examined to date we have identified five parasite species as potential biological tags. The trematodes *Lecithaster gibbosus* and *Pseudopentagramma petrovi* were common only off of Vancouver Island, while the nematode *Anisakis* spp. was common from Vancouver Island to northern California. The trematodes *Parahemiurus merus* and *Myosaccium ecaude* were found throughout the study area but were most prevalent off of southern California. Recently, as a complementary approach to the macroparasite community analysis, a population genetic analysis of the mitochondrial gene *COX2* in *Anisakis* spp. was initiated to assess if the genetic structure of *Anisakis* spp. can provide insight into the population structure of sardines. Fifty-five unique haplotypes were observed in 66 individual nematodes. Overall nucleotide diversity was 4.7%. Identical nematode haplotypes were observed off of the Columbia River (n=4), the Columbia River and Willapa Bay, Washington (n=2), Newport, Oregon (n=2), and off of California at Point Delgada and San Nicolas Island (n=2). More individual nematodes will be examined from off of Vancouver Island and southern California. With four different macroparasite communities currently identified, our data suggest that Pacific sardine are not migrating throughout the entire study region. Thus the historical paradigm of one sardine population migrating between southern California to southern British Columbia may no longer be accurate.

Plasma IGF-I Level as an Index of Growth: Inter-Annual and Geographic Variation in the Growth of Salmon Smolts at Sea

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Insulin-like growth factor-I (IGF-I) is one of the primary endocrine mediators of cell division and growth. Several experiments have been conducted to validate this premise in juvenile coho salmon and a relatively robust relation between plasma IGF-I and individual growth rate has been found ($r^2 = 0.45 – 0.70$). Subsequently, blood samples have been obtained from juvenile salmon captured in a large-scale oceanographic survey of salmon distribution and abundance off the Northwest Coast of the US (Oregon and Washington) in the Pacific Ocean (2000 – 2007). Significant inter-annual differences in mean plasma IGF-I level of coho salmon captured in June have been found. Moreover, these differences in plasma IGF-I level relate directly and significantly to year-class survival in these fish. Thus, plasma IGF-I levels predict oceanic survival rates of coho salmon. In 2007 a more extensive survey was conducted and plasma IGF-I levels were measured in coho salmon captured from the Oregon Coast (latitude 45°N) to Southeast Alaska (latitude 56°N). Significant regional differences in IGF-I level were found, with higher levels found in more northerly waters. These data support the paradigm that juvenile salmon migrate north to take advantage of better growth conditions at northern latitudes, such as more abundant or higher quality food resources. Overall, plasma IGF-I levels appear to provide an accurate index of growth rate of salmon juveniles at sea and these growth estimates allow one to make useful ecological inferences.

Spatial and Temporal Variations in Albacore Habitat in the Northeast Pacific Using Remotely-sensed Environmental Data

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Albacore tuna (*Thunnus alalunga*) occurs through much of the temperate waters of the North Pacific and undergoes zonal feeding migrations across the entire basin. Oceanic habitat preferences and timing of immigration and emigration into the Eastern North Pacific have not been studied in detail. A hypothesis of interest is related to the role of the North Pacific Transition Zone frontal structure as an oceanographic mechanism determining the route and rate of albacore trans-Pacific migration. We used albacore logbook CPUE data for 1999 through 2004 stratified by month, latitude, and longitude (33,652 records) along with satellite-derived environmental variables (Reynolds SST, SeaWIFS SSChl, AVISO SSH, and ERS- or QSCAT-derived wind stress curl). CPUE was mapped for the main fishing season (May through October), overlaid on environmental maps, and pixel-by-pixel environmental records were extracted for each catch location where fishing occurred using both positive and zero sets. The optimum range (mean and variance) of each variable was estimated based on catch and CPUE was related to all environmental variables using GAM modeling by month and year or for the whole dataset combined and also east and west of 130°W. Finally, we plotted binary prediction map of distributional range of this species based on optimal habitat for each month and year. Catch varied significantly between years and all four environmental factors were related to the distribution of albacore in this region.

New Tools for Evaluating Restoration in the Pacific Northwest

David Hamm

There have been enormous efforts to recover endangered salmonid populations throughout the Pacific Northwest. But despite decades of effort, the long-term survival of many populations remains in doubt. This has lead to new initiatives to assess and monitor salmon restoration efforts and fostered the creation of national and regional databases of salmon restoration work. These databases make accessible an unprecedented quantity of data regarding the implementation of restoration projects.

Initial analysis of the PNSHPT database suggest that greater scrutiny is needed to understand the motivations for restoration project choice. We ask the simple question; is there a good correspondence between habitat need and choice of restoration action? Here we present information tools needed to answer the fundamental question, if a habitat assessment is done, are projects chosen that would repair the problems identified in the assessment?

Development of a multiplex assay to generate a comprehensive mRNA profile to identify potential growth rate indicators in salmon.

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The growth rate of Coho post-smolts is strongly correlated to the returning adults the following year (i.e., survivorship). The goal of this project is to develop indicators of growth rate as a tool to predict the health and abundance of returning salmon. Previous studies have relied on measuring circulating hormone levels in the blood. This practice has several limitations; most notable are the volume of plasma and the size of the individual needed to accurately measure the proteins in the blood. Previous work has shown a strong correlation of circulating insulin-like growth factor I (IGF-I) protein to IGF-I messenger RNA (mRNA) levels in the liver. The focus of this study is to explore a more comprehensive panel of fish growth-related transcripts using Quanti-gene multiplex technology from Panomics Inc. This technology permits the simultaneous quantification of multiple targeted mRNAs within a single tissue homogenate using sequence specific probes and requires no reverse transcription or amplification like with PCR. Initial results have confirmed the relationship between IGF-I mRNA and circulating IGF-I protein and revealed other growth-related factors as potential molecular indicators of grow status in salmon. The amount of tissue required to generate these data requires drastically less material and can be used on alevin and parr to elucidate changes in transcriptional profiles in response to a variety of stimuli including growth, pollution exposure, and reproductive status in a variety of tissues.

Developing a decision support system to systematically assess the broad diversity of threats to Lower Columbia Chinook, a test case for the 5-year status review

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In this paper we look at the wide variety and complexity of threats facing threatened and endangered species, develop a method for conducting a systematic risk/threats analysis for the 5 year status review, and apply those methods to Pacific Salmon. To evaluate what is keeping salmonid populations and ESUs from attaining recovery, we first identified current limiting factors and threats to the Lower Columbia Chinook ESU (LCR). Due to the large number of populations in the LCR Chinook ESU (32) we chose to concentrate our efforts on three populations, one from each run timing, and at least one from each state, as well as populations with varying limiting factors (Sandy Late Fall, Upper Cowlitz Spring, and Big Creek Fall). Combining and synthesizing many disparate data, in this case 46 metrics per population, in a valid and meaningful way presents a practical problem. One way to overcome this problem is to utilize a decision support system approach. A decision support system (DSS) is a computer-based tool that can be used to evaluate information and aid managers in decision making. Our fuzzy logic DSS evaluates whether there are major factors limiting the recovery of a population. Resulting values for our three test populations are as follow: Big Creek fall Chinook = 0.75, Sandy River late fall Chinook = 0.66, Upper Cowlitz spring Chinook = 0.80. Interpreting these results, we can say we are moderately certain that the Upper Cowlitz spring Chinook population faces major risk factors limiting recovery. We are somewhat less certain that the Big Creek fall Chinook population faces major risk factors. With a final score of 0.66, we are fairly uncertain regarding major risk factors for the Sandy River late fall Chinook population, however, because the value is still far from 0.0, it may be safe to assume the population faces minor to moderate risks.

Potential Role of Non-Retinal, Non-Pineal Opsins in Modulating Effects of Light on Pituitary Hormone Secretion in Pacific Salmon (*Oncorhynchus spp.*)

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In vertebrates, seasonal reproduction is regulated by endocrine responses to daylength and in some cases light quality. Most mechanistic studies have focused on light perception by the retina or pineal gland, yet in some nonmammalian species, photoperiodic cycles of gonadal development persist even after removal of the eyes and pineal gland. Photoreceptive proteins, or opsins, are present in deep brain tissue in addition to the retina and pineal gland, and have been localized near gonadotropin-releasing hormone (GnRH) neurons in birds. However little is known about the mechanisms whereby light influences the hypothalamus-pituitary-gonad (H-P-G) axis. To better understand the influence of light on salmon reproduction, we are investigating the physiological link between nonretinal and nonpineal light perception, and the release of reproductive hormones in the H-P-G axis. We hypothesize that light influences pituitary hormone release via opsins present in the hypothalamus and/or pituitary. As a first step to test this hypothesis, we examined the expression of mRNA for the five salmon visual opsins by RT-PCR of total RNA from the eye, whole brain, and pituitary gland of sockeye salmon. In the pituitary, four of the five salmon visual opsins were detected and mRNA for a yellow-green light receptor (rhodopsin-1) and ultraviolet light receptor (short-wave sensitive-1) was present at quantifiable levels. To determine whether the sensitivity of the pituitary to different qualities of light changes during sexual maturation, the abundance of opsins in pituitaries collected between March and October leading up to spawning was assessed by quantitative real-time PCR. While the rhodopsin-1 mRNA abundance remains stable, the level of short-wave sensitive-1 mRNA is elevated just prior to and during spawning. These data are the first report of multiple opsins detected in the pituitary gland at abundances that are regulated differently with a shift in life-history stage. We then tested the direct effects of light on the pituitary gland by exposing isolated coho salmon pituitaries to full spectrum light or complete darkness in medium containing isobutylmethylxanthine to inhibit phosphodiesterase. Levels of the intracellular messenger, cyclic guanosine monophosphate (cGMP) were measured since opsins are G-protein coupled receptors that can couple to phosophodiesterase or guanylyl cyclase. Levels of the gonadotropins secreted into the media were also assessed. Pituitaries exposed to light had significantly higher levels of cGMP than those maintained in darkness. However, no consistent effect of light on gonadotropin release was observed. Future experiments will localize opsins to specific cell types in the pituitary so that assessments of light on secretion of specific pituitary hormones can be examined.

Taking it in stages: a life-cycle analysis of factors influencing the status of endangered spring Chinook

Jon Honea, Jeff Jorgensen, and Michelle McClure

A critical element of recovery planning is rigorously identifying key limiting factors. Efforts to restore habitat for Pacific salmon (*Oncorhynchus* spp.) have been an focus of many plans to improve their status. However, the potential of habitat restoration to drive recovery of Pacific salmon depends on other important factors influencing their survival such as alterations to the hydrosystem used for migration, competition and interbreeding with hatchery salmon, harvest rates, and climate influences on survivorship in the ocean. A life cycle model is a useful framework for assessing the relative importance of each of the various factors influencing salmon survivorship at each life stage from egg to fry to smolt to ocean adult and finally to spawner. We focus on the wild spring-run Chinook salmon population of the Wenatchee River basin to illustrate the utility of life cycle models for comparing the various threats a population may face. Our goal is to assess the potential for habitat actions to improve population status in the context of other important factors limiting their survival. This analysis will show how much habitat restoration can be depended on to restore salmon in the face of other influences including survivorship through the Columbia River hydrosystem, interactions with a large population of hatchery fish, and climate effects on ocean survival. This is a work in progress.

Life History and genetics of chum salmon in the southern portion of their range (California, Oregon, and Columbia River) and possible impacts of climate and habitat changes.

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Spawning populations of chum salmon historically extended as far south as the San Lorenzo River in California and 322 km upstream in the Sacramento River. In 1905-06 chum salmon juveniles were the most abundant salmon species in streams surveyed between the Sacramento and Columbia rivers. Today, these populations have greatly declined, and in the Columbia River are now listed under the ESA as a threatened species. Little life history, genetic, or other biological information has been developed on these fish. This information is important as southern populations may represent remnants of historical populations with characteristics essential to the successful restoration of depleted present day populations. Information developed in conjunction with ODFW, WDFW, and USFWS includes demographic, genetic, and life history data, such as presence or absence of spawning populations, age structure, and timing of migrations. Preliminary microsatellite genetic data indicate population structure among coastal populations and differences from interior and Puget Sound runs. Coastal populations may also contain unique genotypes and adaptations which may be important as increasingly rapid changes in climate, pollution impacts, and development expose salmonids to pressures beyond their ability to adapt, forcing further declines and even extinction.

Species and stock identification of juvenile salmon tissues collected from the stomachs of double-crested cormorants (*Phalacrocorax auritus*)

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A multi-agency study begun in the 1990's has documented the substantial impact of fish-eating birds on the survival of juvenile salmon in the Columbia River Basin. One area of study is East Sand Island near the mouth of the Columbia River, which is inhabited by the largest colony of double-crested cormorants (*Phalacrocorax auritus*) on the Pacific coast of North America. East Sand Island cormorants prey on a broad diversity of fish species and consume millions of juvenile salmon each year. Bones and other diagnostic tissues recovered from the stomachs of lethally sampled cormorants are used to determine the family of fish consumed, but identification of fish species is less successful. Moreover, information on stock origins is only available when PIT or other fish tags are recovered.

In 2007 we conducted a pilot study to determine if partially digested fish tissues sampled from bird stomachs would yield adequate DNA to identify fish species and genetic stock-of-origin. Genomic DNA was isolated from frozen samples of salmon tissues collected from the fore-guts (stomach and esophagus) of double-crested cormorants on East Sand Island. Species identification using the mitochondrial DNA fragment COIII/ND3 was successful for 72 of 72 samples collected from 18 cormorants. Steelhead were the most frequent salmonid in the stomach samples (43%), followed by Chinook and coho salmon (26% each). Two cutthroat trout (3%) and one sockeye salmon (1%) were also identified. We also used the 13 standardized GAPS microsatellite loci to examine the stock origins of fish identified as Chinook salmon. Of 19 individuals, 15 were successfully genotyped at 8 or more of the 13 loci. GSI analysis indicated that our samples contained individuals from spring and fall runs and included fish from 6 different genetic stock groups. We identified Chinook salmon from the lower Columbia River as well as from the upper Columbia and Snake rivers suggesting that predation by East Sand Island cormorants impacts Chinook salmon from throughout the Columbia River Basin.

The Effects of Variable Oceanographic Conditions on Forage Fish Lipid Content and Fatty Acid Composition in the Northern California Current

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We evaluated the benefit of lipid and fatty acid content in four species of forage fish (northern anchovy, Pacific sardine, Pacific herring and whitebait smelt) to serve as biological markers of ocean conditions in the California Current large marine ecosystem (CCLME) during the contrasting oceanographic years of 2005 and 2006. Upwelling was severely curtailed in the CCLME in 2005, leading to delayed biological productivity, whereas upwelling was more normal in 2006, beginning during the spring period. Total lipid content range was lower for all forage fish species in 2005 (0.37-23.52% wet mass) than measured in 2006 (1.31-26.37% wet mass). Principal components analysis (PCA) described 78% of the variance within the multivariate lipid and fatty acid data set using just two PC axes and PC2 was sufficient to explain lipid and fatty acid variations by sampling season (r^2=0.22, p<0.01). Using ratios of fatty acid biomarkers docosahexaeonic acid (DHA) and eicosapentaeonic acid (EPA) we detected a transition from a diet composed primarily of dinoflagellate origin in early 2005 to a diet of diatom based productivity by late summer 2005, a shift due to prey availability which was corroborated through phytoplankton sampling. Moreover, we found higher levels of macrozooplankton carnivory, substantiated by the accumulation of monounsaturated eicosenoic and erucic fatty acids in Pacific herring and northern anchovy in 2006 relative to 2005. Lipid levels were negatively correlated (r^2=0.38, p=0.01) with DHA concentrations, and positively correlated (r^2=0.41, p<0.01) with EPA values. Accumulation of different lipid and fatty acid profiles in the forage fish community demonstrates how ocean conditions and productivity in the CCLME can affect food web structure. The implication of this variation to the health and success of the forage fish community and to subsequent user groups (e.g. salmon, important groundfish species) has yet to be determined.

Family competition in a selected strain of coho salmon (*Oncorhynchus kisutch*)

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The effect of diet regime on between and within family competition was tested using a domesticated strain of coho salmon (Dømsea strain, Aquaseed Inc., Rochester, WA, USA). Fish from ten full-sib families were individually tagged and reared in a pooled community tank and fed at a decreased ration to allow for study of competition within and between families for food. This design was repeated in a second set of tanks, but fish were fed ad lib to allow for maximum growth. A previous study (Neely et al. 2008) showed that Dømsea fish outperformed Wallace River coho salmon (the parental stock) when fed to satiation. Also shown was a tendency for the fish to exhibit a bimodal size distribution when food was restricted. Results from the current study will compare growth (weight, length, and condition factor) in families reared under the two regimes and assess whether family performance (rank) differs between treatments. Changes in family rank may indicate that selection programs may need to be tailored to rearing conditions.

Genetic Analysis of Southern Resident Killer Whale Feces Reveals Prey Selection

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Recovery plans for endangered Southern Resident Killer Whales (*Orcinus orca*) have identified reduced prey availability as a possible risk to the population. In order to assess this risk, we began a prey selection study in the whales' San Juan Island and Puget Sound range in 2004. By following the whales in a small boat and using a fine mesh net, we have collected more than 200 fecal samples over the last 4 years. Through molecular genetic analysis of the fecal samples, we are able to identify Southern Resident Killer Whale (SRKW) prey species. Prey detection from fecal samples has provided a new dimension in killer whale diet studies. Fecal samples represent prey consumed over an extended period of time and are therefore expected to be less biased, or at least have different biases, than fish remains collected immediately after a predation event at the surface. Fecal analysis indicates that Chinook salmon, a relatively rare species, is the primary prey species consumed during the whales' San Juan Island spring-summer range (May-September). Chinook salmon are present in nearly 80% of all fecal samples collected during the spring and summer months. This finding strongly supports previous and concurrent studies based on prey remains (fish tissue and scales) collected from the surface of the water. During the fall and winter months, when the whales' spend more time in central Puget Sound, fecal samples have shown that the diversity of their diet increases. During the fall and winter, other species such as Chum salmon, Coho salmon, Sole, or Lingcod are present in over half the total fecal samples. Although we have collected approximately one-third the number of fall-winter fecal samples as spring-summer samples, the increased diet diversity seen in the fall and winter months by fecal analysis is corroborated by analysis of fish remains. In addition to the aforementioned prey species, we have also identified Steelhead salmon, Pacific Halibut and Rockfish as prey items through fecal analysis. Future work includes analyzing fecal samples for the presence of additional fish species as well as squid and quantification of the relative amounts of different fish species when more than one species is present within a single scat. In summary, fecal samples have greatly improved our understanding of SRKW diet, giving us a look at the total picture of prey selection. While fecal samples help to illustrate diversity in the whales' diet, they support other studies in showing that Chinook salmon are the whales' primary prey item. These results are likely to be of significant value in guiding management actions to recover the Southern resident killer whale population.

Education at NOAA's Northwest Fisheries Science Center

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The America COMPETES Act of 2007 mandates NOAA to educate the public about ocean, coastal, Great Lakes, and atmospheric science and stewardship. Northwest Fisheries Science Center (NWFSC) Education works on all levels of NOAA: with the NOAA Office of Education, NOAA West regional collaboration team, Northwest regional line offices, and with the NMFS National Education Coordinator and the Fisheries Education Council. The agency has adopted the Ocean Literacy principles which define an "ocean literate" person. The NWFSC Education Coordinators participate in diverse education activities including: teacher and student workshops, festivals, field experiences, classroom presentations, and events with partners such as the Seattle Aquarium and Washington Sea Grant. All NWFSC staff is encouraged to get involved in ACE - Active Center Educators, a group that meets regularly to discuss education activities and opportunities, and work toward a more ocean literate public.

Scientific Data Management at the Northwest Fisheries Science Center

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The Scientific Data Management Team (SDM), in the Operations, Management and Information division (OMI) at the Northwest Fisheries Science Center (NWFSC), develops and maintains a coordinated approach to managing data and enabling their use in scientific research related to endangered species recovery and marine species management in the Pacific Northwest. To this end, SDM provides expertise in database design, application development, and Geographic Information Systems (GIS), for desktop clients and over the internet. SDM works with internal and external researchers and staff to collect, synthesize, organize and report diverse sets of data, including restoration and recovery project data (PCSRF, PNSHP); monitoring and evaluation data (ISEMP, habitat, water quality); and biological and physical data (salmonid abundance, artificial propagation, genetics, bird predation, barge transport, oceanographic). Additionally, we offer tools , applications, and expertise to facilitate analysis and collaboration among Center staff and with external partners (ArcGIS Server and on-line mapping, Java and javascript programming, ArcSDE database project space, Matlab/STAR-P modeling, Oracle Collaboration Suite).

Gene expression profiles in zebrafish brain after acute exposure to domoic acid at symptomatic and asymptomatic doses

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Domoic acid (DA) is a neuroexcitatory amino acid that is naturally produced by some marine diatom species of the genus *Pseudo-nitzschia*. Ingestion of DA-contaminated seafood by humans results in a severe neurotoxic disease known as amnesic shellfish poisoning (ASP). Clinical signs of ASP include seizures and neuronal damage from activation of ionotropic glutamate receptors. However, the impacts of DA exposure at levels below those known to induce outward signs of neurobehavioral exicitotoxicity have not been well characterized. To further understand the mechanisms of neurotoxic injury associated with DA exposure, we examined the transcriptome of whole brains from zebrafish (*Danio rerio)* receiving intracoelomic injection of DA at both symptomatic and asymptomatic doses. A majority of zebrafish exposed to high-dose DA (1.2 μg DA/g) exhibited clinical signs of neuroexcitotoxicity (EC50 of 0.86 μg DA/g) within 5 to 20 min of intracoelomic injection. All zebrafish receiving low-dose DA (0.47 μg DA/g) or vehicle only maintained normal behavior. Microarray analysis of symptomatic and asymptomatic exposures collectively yielded 306 differentially expressed genes (1.5-fold, $p \leq 0.05$) predominately represented by signal transduction, ion transport, and transcription factor functional categories. Transcriptional profiles were suggestive of neuronal apoptosis following an overwhelming of protective adaptive pathways. Further, potential molecular biomarkers of neuropathic injury, including the zebrafish homolog of human *NDRG4*, were identified and may be relevant to DA exposure levels below that causing neurobehavioral injury. In general, DA-modulated gene expression was consistent with other model species thereby validating zebrafish as an appropriate vertebrate model to study mechanisms of DA neurotoxicity. These data provide a basis for identifying pathways of DA-induced injury as well as biomarkers of asymptomatic and symptomatic DA exposure levels.

Suppressive Subtractive Hybridization reveals differences between Vibrio parahaemolyticus isolates from the Puget Sound region and the pandemic strain

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Pathogenic strains of the common marine and estuarine bacteria, V. parahaemolyticus (Vp) can induce severe gastroenteritis in humans following the consumption of uncooked seafood. Similar to other Vibrios, Vp is generally involved in environmental nutrient cycling and is capable of substantial genetic exchange, allowing it to expand into diverse ecological niches. The full genome of a recently emergent pandemic serotype (O3:K6; tropical and subtropical waters, 1995-present) has been published; however, this serotype does not match isolates linked to outbreaks in the Pacific Northwest region of the United States.

We utilized Suppressive Subtractive Hybridization (SSH) to compare the genomic content of three Puget Sound (PS) Vp isolates (two environmental and one clinical) with the global pandemic strain. SSH libraries were created for each strain using genomic DNA from the tester (PS) strain and driver genomic DNA from the pandemic strain. An average of 275 clones were sequenced from each library, revealing features of the PS isolates that are absent from the genome of the global pandemic strain. While approximately one third of the features identified encode proteins of unknown function, the remaining features represent a wide variety of functions, with major representation of genes involved in metabolic processes, nucleic acid modification and DNA mobilization. Very few genes were shared among the three libraries, highlighting the diversity of Vp in the PS region. This study expands our current understanding of the potential scope of the Vp genome while revealing some genomic characteristics of local subpopulations.

Microgeographic variation of reproductive timing under different thermal regimes: local adaptation despite dispersal?

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Gene flow generally prevents local adaptation, and hence the relative strength of natural selection and dispersal is a key for understanding microevolutionary processes. Partially connected populations faced by different selective regimes are good system to study contrasting forces of selection and gene flow. I investigated the difference in reproductive timing of stream-dwelling Dolly Varden among 32 tributaries of the Sorachi River (-50 km) in central Hokkaido, Japan, which are supposed to be under different thermal regimes (temperature-constant spring-fed tributaries vs. temperature-variable non spring-fed tributaries). Spawning season lasted up to four months (mid-August to mid-December), resulting in the total of 1206 records of spawning activities (271 spawning behaviors, 935 spawning nests). There was no strong peak for the spawning activities, suggesting a weak stabilizing selection at the watershed level. At the tributary level, some tributaries showed different reproductive timing, indicating local adaptation. In most tributaries, however, spawning lasted continuously without clear peak regardless of the thermal regimes. This indicates that the gene flow prevents local adaptation, or, alternatively, small population size might constraint adaptive divergence among tributaries due to strong genetic drift.

All together now: demographic synchrony and population structure in spring/summer Chinook salmon (*Oncorhynchus tshawytscha)* and steelhead (*O. mykiss*) in the interior Columbia River basin

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Efforts to conserve species can be hampered by a lack of understanding of the composition and structure of population units, which may be important for long-term species persistence and recovery. Demographic data, such as spawning counts, are one of several lines of evidence useful in determining population structure. We examined pairwise Pearson correlations between time series of abundance estimates of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) spawners in streams across the interior Columbia River basin to look for synchronous patterns as evidence of population structure and demographic independence. The population structure of these fishes was delineated largely using other evidence (genetic markers, proximity between spawning aggregations, morphological and phenotypic traits, habitat and ecoregion similarities, etc.) because inferring population structure from demographic synchrony using estimates of adult spawner abundance can be problematic. This life stage integrates the fish response over several common and potentially synchronizing influences that act at both small and large spatial scales (climate, ocean conditions, the 4 H's), and over several life history stages. Cognizant of these potential difficulties, we used pairwise correlations as distance measures in a hierarchical cluster analysis. Overall, we found that the majority of correlations were positive, and the percentage of positive correlations was slightly higher for Chinook salmon (75%; 6% were significant) than steelhead (72%; 0% were significant). Chinook salmon stream counts largely clustered within existing population structures, but the clustering structure of steelhead was less clear. We also investigated the "Moran effect," the relationship between pairwise correlations and their geographical distances. For Chinook salmon, there was a well-defined decline in correlation with geographic distance for stream count comparisons within Major Population Groups (MPGs), and a significant but gradual decline within Evolutionarily Significant Units (ESUs). There was no relationship between correlation and distance among comparisons outside of their ESUs. For steelhead, there was no discernable relationship in stream count comparisons within MPGs or ESUs, and in comparisons outside of ESUs correlations slightly increased with distance. Despite the complicating factors with using demographic data to assess population structure, the degree of population synchrony as measured by the patterns of correlations, the results of the clustering, and the relationships between distance and correlation generally supported the population MPG/ESU designations for Chinook salmon but results for steelhead were inconclusive.

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Construction of a habitat map for Heceta Bank, Oregon, USA for use in estimates of groundfish assemblages on the bank.

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Heceta Bank, (offshore Oregon), is one of the largest rocky banks along the US west coast and contains a diverse array of habitats supporting numerous species of commercially important groundfish, including a diverse assemblage of rockfishes (*Sebastes* sp.). In 1998 we collected high-resolution bathymetry and backscatter imagery of the bank using a *Simrad* EM 300 multibeam echo sounder, and returned in 2000 and 2001 to conduct strip transect video surveys of habitat, fish, and invertebrates using the remotely operated vehicle *ROPOS*. These *in situ* data have been analyzed for fish habitat relationships. One of the critical elements of this project was to create the first comprehensive lithological habitat map of the bank. Polygons of uniform habitat were constructed by analyzing the image data (bathymetry, backscatter, topographic position index and slope) and reconciling with the video data. Habitat areas identified include: high relief ridge sediment complex, heavily eroded ridge complex, pinnacle, boulder/cobble, and unconsolidated sediment (mud and sand). This map, combined with the fish observations made in the ROV video, may be used as a tool to extrapolate groundfish abundances for the entire bank and adjacent areas surveyed by dive transects.

Are west coast groundfish observer data just collecting dust?

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The West Coast Groundfish Observer Program collects fisheries independent data from the west coast commercial groundfish trawl and fixed gear fleets. Data collected include fishing effort information, estimates of retained and discarded catch, including species composition, biological data from discarded catch, and interactions and sighting of protected species.

Observers and fishermen tend to believe that observer data are not used, that after collection, data sit in a database somewhere, gathering dust. That is not the case with west coast observer data. Data users include fisheries managers, stock assessors, marine mammal scientists, and seabird scientists, to name a few. West coast groundfish observer data, in conjunction with other datasets, are used to set quotas, estimate historical catch, estimate bycatch of protected species, and estimate stock abundance. In addition, observer data can inform scientists conducting research on fish migration, gear efficiency, and fish and invertebrate distributions.

Science to support complex decisions: US west coast groundfish fisheries

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The management of US west coast groundfish fisheries is increasingly complex and spatial analysis plays an important role in the science which supports management decisions. A variety of data sources are used in the decision making process and the spatial component of these data can enhance understanding of both the fishery and fish resources. The major types of data in this process are 1) fishery independent resource surveys, which are used to determine fish population, abundance and distribution, 2) fishery dependent data, which are reported by the fishery, fish processors, or through observation of the fishery, 3) environmental factors, which can influence fish populations and their distribution, and 4) regulatory, management and jurisdictional boundaries, which are the final derived product of the decision making process and also play a significant role in future spatial review of fishery activities and fish resources. The ability to spatially overlay, query, and extract information related to fish resources, fishing activities, fish landed in ports, fish discarded at sea, environmental factors, and regulatory measures is critical to expanding our knowledge of dynamics in the groundfish fisheries and to provide the best available science for management.

Pilot work using a codend video camera for improved groundtruthing of fisheries acoustic data

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One of the difficulties in fisheries acoustic surveys is determining what organism or combination of organisms is causing the echo return at a given depth in the water column. Assignment and proportioning of areas of backscatter to particular species influences the biomass estimate of the species targeted by the survey. Therefore, accurate groundtruthing of the acoustic signal is crucial. Typically, groundtruthing consists of using midwater trawls with a target depth corresponding to the area of interest. However, this can be problematic because it may not provide information about the depth at which the species were caught and most likely will miss small scatters which could be important contributors to the echo intensity. To address this concern we carried out pilot work using a video camera mounted in the codend of an open midwater trawl. For each of our eight successful test tows conducted during the 2008 hake Inter-Vessel Calibration cruise we were able to examine several different backscatter layers in the water column. The recorded video tapes were analyzed and the percent and size composition of the species in these different layers was determined. Additionally, we conducted closed codend tows with no camera at the same location, which enabled us to calculate and compare backscatter measurements between the two tow types. We conclude that this method appears to provide improved groundtruth information and we plan to integrate this technology into our future acoustic surveys.

The effects of temporal variations in fishing effort in the at-sea hake fishery

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Recent regulations limiting the bycatch of particular rockfish species in the Pacific hake (*Merluccius productus*) fishery have driven several changes in the fishery, including documented changes in fishing depths. Concerns about rockfish bycatch have led to speculation that tows made during daytime hours have reduced rockfish bycatch rates in comparison to nighttime tows. For the 2006 and 2007 seasons, in an effort to reduce widow rockfish (*Sebastes entomelas*) bycatch, a voluntary agreement between the vessels was proposed to focus fishing primarily during daylight hours and minimize nighttime fishing when possible. Fishing during nighttime hours was still conducted, but the data show a distinct effort shift towards increased fishing effort during daylight hours. Explorations into the historical differences in bycatch rates by time of day and the impact of reduced nighttime fishing effort will be presented.

Hook and line survey of shelf rockfish in the Southern California Bight: summary of 2004-2008 data

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The Fisheries Resource and Analysis and Monitoring Division of the Northwest Fisheries Science Center conducts an annual hook and line survey for shelf rockfish (Genus: *Sebastes*) in the Southern California Bight. The project, which began in 2002, targets demersal rockfish species associated with rocky, untrawlable habitats that are generally not sampled well by the division's other groundfish monitoring cruises. The hook and line survey is a collaborative effort with Pacific States Marine Fisheries Commission and the sportfishing industry in southern California. The 2008 field season was the fifth year in a time series of catch-per-unit-effort data and other biological parameters that are used to calculate an index of relative abundance for several important rockfish species including bocaccio, vermilion rockfish, greenspotted rockfish, and speckled rockfish.

During the first four years of the survey, 43 unique species have been caught, including 33 rockfish species. Bocaccio and vermilion rockfish are the most commonly observed species, accounting for 61% of all individuals encountered during the first four years of the survey. The length composition for bocaccio from the 2008 survey is characterized by several above-average year classes which contrast with results from 2004 where a single year class accounted for the vast majority of the biomass. Length frequency data for vermilion rockfish suggest this species experiences more stable recruitment than bocaccio. A Generalized Linear Model was developed to track population trends for several rockfish species, and preliminary analyses suggest generally flat trajectories for bocaccio, vermilion rockfish, and greenspotted rockfish.

Future efforts include expanding the collection of environmental and oceanographic data during sampling including the acquisition of seawater temperature, dissolved oxygen, salinity, pH, and light intensity information at depth from all survey sites. These data may provide informative covariates reducing uncertainty around population estimates and may also be useful in tracking shifts in oceanographic regimes in the region. Hook and line survey data are also being analyzed for their utility in studying the efficacy of marine protected areas. The survey is improved by its collaboration with the sportfishing industry and has strengthened the working relationship between NOAA Fisheries and stakeholders in the region.

Benthic marine debris sampled during the 2007 and 2008 Northwest Fisheries Science Center's West Coast Groundfish Trawl Surveys

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We investigated the composition and abundance of benthic marine debris collected during the 2007 and 2008 West Coast Groundfish Trawl Surveys. The Northwest Fisheries Science Center's Fishery Resource Analysis and Monitoring Division conducted the surveys along the west coast (55 – 1280 m) from May to October of both years. Four chartered West Coast trawlers participated in the survey with two passes down the coast, from north to south. The survey area was partitioned into ~12,000 equal-area cells (1.5 by 2.0 nm) with each vessel assigned an annual subset of 188 randomly selected cells to sample. An Aberdeen-style net with a small mesh (1.5" stretch) liner in the codend was used for sampling. Target tow duration was 15 minutes. Marine debris was recorded in 200 tows in 2007 and 269 tows in 2008. Total debris recorded from all tows weighed 5,318 kg (range 0.01–2,000 kg/tow). The largest item taken during the survey was a fishing net (2,000 kg) retrieved by the F/V Ms. Julie off CA. Debris was subdivided into broad categories (plastic, metal, fabric, glass, rubber, Styrofoam and unsorted), and further categorized as military or fishing debris as needed. Plastic and metal debris were encountered most frequently with 484 kg of plastic taken in 218 tows and 984 kg of metal taken in 208 tows. Fabric (346 kg) was present in 146 tows while glass debris (100 kg) was present in 123 tows. The unsorted category included items that spanned multiple categories, were found in sealed trash bags, or were too big to sort. This category was the largest by weight at 3176 kg, and occurred in 76 tows. Preliminary results indicate that benthic marine debris is more frequently encountered in the southern portion of the survey, occurring in 65% of the southernmost tows versus 25% overall.

A record of *Aldrovandia oleosa* (Notacanthiformes: Halosauridae) from the Eastern North Pacific

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In 2007 a specimen of *Aldrovandia oleosa* Sulak was captured by scientists of the National Marine Fisheries Service in the Pacific Ocean off southern California. Although *A. oleosa* has been found in the deep waters of the western Atlantic, the tropical eastern Atlantic in the Gulf of Guinea region, the western Indian Ocean, the eastern central Pacific and Chile, it had not previously been recorded in the North Pacific.

Drop Acoustic Information SYstem (DAISY)

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Target strength (TS) is a measure in dB of the ability of a target to scatter sound. Knowing the relationship of TS to fish size is necessary to generate biomass estimates from acoustic surveys. The US and Canada jointly conduct surveys to measure the acoustic echo returns from Pacific hake (*Merluccius productus)* using 38kHz echosounders. Numbers of hake are derived from the total backscatter measured for the species by applying a 38kHz TS-length relation of 20 log L – 68, where L is fork length in cm of a single fish. However, variability observed in TS of hake introduces uncertainty in assessment estimates. Stock assessment scientists have therefore focused research efforts to reduce uncertainty in the hake TS-length relation. Acoustic survey operations are conducted during daylight hours however fish are generally too deep to collect accurate TS measurements from ship-mounted acoustic systems. Potential TS biases from various sources of interference and from detection of multiple targets at depth required us to develop a tethered Drop Acoustic Information System (DAISY) which contains two echosounders and motion sensors. DAISY can be lowered closer to target depth to obtain daytime *in situ* TS measurements on hake. The system was calibrated at the surface using a standard 38.1 mm tungsten carbide sphere. Preliminary results of TS from juvenile hake indicate good agreement with the currently used TS-length relation.

Diel patterns of behavior in sixgill sharks, spiny dogfish and ratfish: patterns, causes and ecosystem consequences.

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Understanding life histories of apex predators is crucial for understanding how marine ecosystems respond to human perturbations as well as for effectively conducting ecosystem-based management. Even so, we lack basic knowledge of many large predatory fishes. In Puget Sound, we are investigating diel vertical movement patterns of sixgill sharks, the largest resident predatory fish in Puget Sound, to determine what drives changes in their behavior. We acoustically tagged 39 sixgill sharks with pressure sensor acoustic transmitters and monitored their movement patterns via passive and active acoustic tracking methods in Puget Sound, WA. Sixgill sharks show very consistent diel patterns of vertical movement where they inhabit shallower waters at night and move into deeper waters during the day. This pattern is consistent between both sexes and across the entire size range of individuals collected (100-300 cm total length). Seasonally, sixgill sharks inhabit deeper waters in the fall and winter, while moving to shallower waters during the spring and summer. The sixgill shark also shows much more activity at night and during the summer. In addition, pairs of sharks tracked simultaneously made synchronous ascents and descents throughout entire 24-hour tracking periods. These behaviors are consistent with the hypothesis that sixgill sharks are responding to similar stimuli and that they are using these periods of increased activity to forage for prey. Potential prey of sixgill sharks that make similar diel patterns of vertical movement include ratfish, Pacific hake and Dungeness crabs. We have begun to monitor the movements of spotted ratfish and spiny dogfish in the same waters as sixgill sharks to investigate interactions within the community.

Using ecological thresholds to inform benchmarks for ecosystem-based management in Puget Sound

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One of the major challenges to implementing a plan for ecosystem-based management (EBM) in Puget Sound is a lack of scientifically-based approaches for defining ecosystem-level management targets. We outline an approach for identifying management benchmarks that is based on the existence of nonlinearities in the relationship between fundamental attributes of the ecosystem and human-induced perturbations. In this approach, we 1) identify a set of ecosystem attributes; 2) use a food web model to simulate increasing levels of perturbation to the ecosystem, and measure the response of the attributes to those perturbations; 3) locate a threshold on the ecosystem attribute-perturbation curve when the relationship between attribute and perturbation is nonlinear; 4) identify empirically-tractable indicators for the ecosystem attributes which are tightly correlated with the attribute values observed in the simulations; and, 5) suggest methods for designating management benchmarks. We illustrate this approach using a marine food web model, which allows us to measure the response of seven attributes (total consumption, the community respiration to biomass ratio, mean trophic level, Shannon diversity, resilience, total fisheries yield, and total fisheries value) to varying levels of fishing-induced mortality. Using these relationships to locate ecological thresholds can aid in determining the level of perturbation at which various aspects of ecosystem structure and function will be diminished. Thus, this method for identifying ecological thresholds also draws attention to the trade-offs inherent to implementing EBM, and in so doing enhances the ability of policymakers to understand and manage natural ecosystems.

Trophic relationships and movement patterns of sixgill sharks (*Hexanchus griseus*) in the Puget Sound - Georgia Basin: Inferences about their ecosystem role from stable isotope analysis

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The sixgill shark (*Hexanchus griseus*) is a large predator and passive scavenger thought to forage across the entire marine food web, making it a good candidate as an indicator species for the overall health of the Puget Sound-Georgia Basin aquatic ecosystem. However, persistent questions remain about sixgill shark population demographics, diet information that clarifies energy flow, and movement patterns of the breeding population within the region. We compared stable isotope ratios ($\delta^{15}N$ and $\delta^{13}C$) of white muscle tissue collected from over 70 sixgill sharks to describe their trophic level within the aquatic food web and to clarify broad movement patterns. Nitrogen stable isotope ratios of sixgill sharks (mean $\delta^{15}N$: 16.5‰) were enriched relative to most other aquatic species, confirming that sixgill sharks represent one of the top trophic levels in the Puget Sound food web. Carbon stable isotope ratios of sharks, which are indicators of the sources of food web production, reflect strong spatial patterns of resource use. Sharks from central Puget Sound were exclusively subadults (150 cm to 315 cm TL) with highly enriched $\delta^{13}C$ ratios (mean $\delta^{13}C$: -12.8‰), possibly reflecting dependence on benthically-derived nearshore primary production and suggesting little movement outside the Sound. Clustering of $\delta^{13}C$ ratios revealed two distinct groups of subadult sharks that could not be differentiated based on time of capture, size, or sex. We are analyzing acoustic tag movements from a subset of animals in each group to determine if the distinctive $\delta^{13}C$ signatures reflect differences in foraging behavior with depth or spatial extent of movement within central Puget Sound. In contrast, $\delta^{13}C$ ratios of a mature female (430 cm TL) and her neonates found stranded in south Sound were highly depleted (mean $d^{13}C$: -20.0‰), reflecting the phytoplankton based food web typical of marine waters on the outer coast. This strongly supports the nursery hypothesis that pregnant females migrate from offshore to protected inshore waters for parturition. Finally, $\delta^{13}C$ ratios of subadult sharks collected from the Strait of Juan de Fuca (mean $\delta^{13}C$: -18.4‰) were intermediate between the Puget Sound subadults and the stranded adult female. Together these studies aid our understanding of the ecology and behavior of large apex predators in the Puget Sound – Georgia Basin, progress that is crucial to clarifying a broad range of ecosystem interactions and a critical component of any rigorous ecosystem-based management plan.

Acoustic characterization of scattering layers of dominant fish and zooplankton species off the West Coast of the United States and Canada

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Pacific hake, *Merluccius productus*, is an important commercial and ecological marine fish off the West Coast of United States and Canada. Acoustic surveys of Pacific hake involving scientists from the United States and Canada have been conducted on either a triennial or biennial basis since 1977. In recent years the Simrad EK series echo sounders (EK500/EK60) consisting of multiple frequencies have been the primary acoustic sampling instrument. Ground truthing was obtained by biological sampling using mid-water and bottom trawls at various depths from about 100 m to as deep as 500 m. The intercomparison of trawl data to the acoustic signatures, including the volume backscattering strength, an absolute quantity, and the frequency dependence, a relative quantity, allow us to verify the commonly accepted theoretical interpretations and advance towards establishing automated identification and classification algorithms. We will present a variety of echograms with distinct acoustic signatures, representing two stages of identification and classification. The first is to determine whether the echograms are hake or non-hake, while the second is to further classify what type of marine organisms corresponds to the non-hake echograms. Most of the characteristics of the hake echograms can be explained based on the scattering physics. However, some hake echograms are different from the theoretical predictions of swimbladder-bearing fish and require additional investigation and interpretation.

Renibacterium salmoninarum infection in Chinook salmon – how widespread is it outside of the hatchery?

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Infection by *Renibacterium salmoninarum* can result in bacterial kidney disease (BKD), a chronic and debilitating condition that is recurrent in hatchery stocks. Disease monitoring programs are typically directed at adult females returning to the hatchery in order to cull infected broodstock. As a result, few efforts have been directed at assessing other life history stages or at naturally spawning adults. To track fluxes in infection prevalence, efforts to monitor multiyear cohorts of Chinook salmon at different life history stages have been initiated. Pre-release hatchery smolts, in-river outmigrants, and returning adults (hatchery and natural spawn) were sampled from two Columbia River populations (Yakima River and Lostine River), whereas pre-release hatchery smolts, early marine post-smolts, and returning adults (hatchery and natural spawn) were sampled from a Puget Sound hatchery population (Skagit River). The first year's data reveals significant differences in prevalence among the populations, ranging from 3.1% to 62.5%. Because infection data was collected in concert with physiology and ecology field studies, parameters such as maturation state and broodstock year can be assessed as risk factors. This type of fundamental data can inform disease management strategies, and can identify significant epidemiological factors.

SoundToxins: A Harmful Algal Bloom and Vibrio Monitoring Program for Puget Sound

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Harmful algal bloom (HAB) species and *Vibrio* outbreaks are becoming increasingly numerous and widespread throughout Puget Sound. Every year since the 1950s, shellfish harvesting has been halted in this region as a result of concentrations of paralytic shellfish toxins, produced by the dinoflagellate *Alexandrium*. The first documented closure of the shellfish harvesting due to high concentrations of the neurotoxin domoic acid, produced by the diatom *Pseudo-nitzschia*, occurred in Puget Sound in September 2003. Disease outbreaks and shellfish closures due to the bacterium *Vibrio parahaemolyticus* occurred initially in 1997-1998 and again in 2006-2007. The flagellate, *Heterosigma akashiwo,* has caused severe economic losses to fish farming operations in Puget Sound over the last decade. Several species of *Dinophysis,* a known toxin producer, are present in Puget Sound and yet there is no formal testing program for its associated toxins in Washington State. Attaining a predictive capability for these harmful events, and identifying steps to mitigate their effects, depends on quickly gaining an understanding of the conditions that promote their occurrence. To this end, the Partnership for Enhanced Monitoring of HABs and *Vibrio* in Puget Sound (SoundToxins) was established in the fall of 2007 as a regional forum for collaboration and cooperation among federal, state and local agencies, tribes, marine resource-based businesses, public interest groups, and academic institutions to manage the prediction of and response to HAB species and *Vibrio* in Puget Sound using a practical blend of emerging and proven technologies. Data from the past year's coastal monitoring efforts at 10 sites in Puget Sound and the EPA-sponsored OSV Bold cruise showed measurable numbers of *Alexandrium, Pseudo-nitzschia* and *Dinophysis* at several locations in Puget Sound. The ultimate goal of SoundToxins is to provide sufficient warning of HAB and *Vibrio* events to enable early or selective harvesting of shellfish, thereby minimizing risks to both human and fish health and reducing economic loss to Puget Sound fisheries.

Impacts of Reduced Stream Flow on Growth and Movement of Juvenile Steelhead in an Artificial Stream Channel.

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While stream flow and temperature are widely recognized as important determinants of habitat suitability for salmonids in freshwater systems, the degree of importance varies with species and life stage. Furthermore, while flow and temperature have been strongly implicated in viability, productivity, and distribution for salmonid populations, it is difficult to discern negative impacts caused by changes in stream flow from those caused by changes in temperature because the two are often closely correlated. A better understanding of how flow and temperature affect juvenile salmonids would benefit fisheries, land use, and water management practices.

We examined the acute impacts of flow and temperature on growth and movement in steelhead fry, Oncorhynchus mykiss. We experimentally reduced stream flow and increased water temperature using Manchester's artificial stream system. Juveniles were stocked in four treatment sections and were subjected to changes in water temperature and flow levels following an acclimation period. Treatment sections consisted of flow reduction only, temperature increase only, simultaneous flow reduction and temperature elevation, and a control. Depth and discharge under low flow conditions averaged 7 cm (±1.78) and 3 cms^{-1} (±1.6), which constituted a reduction of 33% and 72% from control conditions, respectively. Temperature manipulations were highly weather dependent due to a surprising lack of summer solar energy; they did not approach levels which would be considered detrimental to steelhead.

We found that growth was positive (2.5–9.4% increase in mass) across treatments in all but the fourth trial, which was consistently negative (7.5-14% decrease) across treatments. There was a significant difference in growth between treatments (P 0.019; one-way ANOVA). Movement downstream was strongly dependent on reductions in depth and flow in the stock unit, and movement into collection pools was influenced by reductions in depth in the stock unit.

Our results indicate that reductions in stream flow may result in less predictable micro-habitat shifts and movement of juvenile fish, as well as differences in growth. Future work is needed to determine how these responses to stream flow interact with density dependence, and to successfully assess the effect of elevated temperature.

Genomic biomarkers for assessing fish reproductive health

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Urbanization, coastal population growth, agricultural practices, and climate change have greatly affected water quality throughout our aquatic ecosystems. Many chemicals contaminating fish and aquatic ecosystems are known to disrupt endocrine function, potentially leading to impaired development and reproduction of wildlife and humans. To evaluate relationships between environmental conditions (e.g., reduced food availability, hypoxia, endocrine disrupting chemicals) and fish reproductive health, researchers require modern, comprehensive bioassessment tools. Thus the aim of this research is to develop tools to measure large-scale gene expression in the gonad as a way to assess salmon reproductive health. In this study, we focused on the effect of feed restriction over a 17-week period on the reproductive health of immature salmon. Prolonged fasting caused regression of the gonads and disrupted the reproductive axis, as fasted salmon showed significantly lower gonad weights and plasma estradiol levels relative to fed animals by week 14. Using suppression subtractive hybridization (SSH), we have identified genes that are putatively up- or down-regulated in normally growing versus regressing ovaries. We have also developed quantitative PCR methods to monitor transcripts for genes involved in programmed cell death that are being measured in ovary samples from this study. Ultimately as we continue this work, including future experiments with other environmental stressors, we plan to utilize the suite of genes identified by SSH and other candidate genes to construct a custom oligonucleotide microarray that will serve as a 'fingerprint' for assessing salmon reproductive health in the wild.

Zooplankton biomass and biodiversity in Puget Sound
Naomi Yoder and Paul McElhany

Zooplankton are the primary food source for all fish larvae, invertebrates, and many adult fish and mammals in Puget Sound. Yet, despite their importance in the food chain, we know very little about their distribution, abundance, biomass availability and population variability in Puget Sound. NOAA Fisheries is collaborating with the University of Washington and King County to study variability in zooplankton populations in Puget Sound. Current monthly sampling is conducted in the main basin of Puget Sound, and bi-annual samples are collected throughout Puget Sound and the Strait of Juan de Fuca with the Puget Sound Regional Synthesis Model (PRISM) sampling effort. This effort is the first of its kind, and is critical to increasing our understanding of zooplankton and their contribution to the Puget Sound ecosystem. This in turn helps us to better evaluate, manage, and protect Puget Sound.

The Southern Resident Killer Whale (SRKW) Watching Industry of the Greater Puget Sound, WA – Who Are They? What have we learned?

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Orca whales, also known as killer whales *(Orcinus orca),* are cultural icons for the human residents of the Pacific Northwest's Puget Sound. The Southern Resident Killer Whales (SRKW) recently received an endangered listing under the Endangered Species Act, and are protected under the Marine Mammal Protection Act. In a research atmosphere where ecosystem science is emphasized, it is instinctive to discuss the biological elements of an ecosystem. However, when reflecting on an ecosystem, it is important to understand that humans are part of the ecosystem as well. In this case, while biological research on the SRKW itself is beginning to answer ecosystem questions, there is little information on the connection of these animals and humans.

As social scientists, we study the human dimension of ecosystems, working to better understand people and their relationship to marine resources. In this instance, we are interested in better understanding the relationship of people to the SRKW. Specifically, we have identified a unique relationship between the whale watching industry of the Greater Puget Sound and the SRKW. We aim to more clearly understand this connection. As with fishermen who depend on healthy fish stocks, this industry depends on a healthy and resilient population of Southern Resident Killer Whales. This paper discusses results of our social science research which aims to describe the people involved in the industry. Data was collected using a survey tool and interviews. Demographic information, employment history, insights into the reasons people participate in the industry, and descriptions of whale watching company characteristics are examples of the type of information collected. Together this information contributes to a greater understanding of the connection industry members have to the significant marine resource that is the SRKW.

Evaluating aquatic invertebrate food quality using Carbon and Nitrogen: a comparison among salmon-bearing streams in the Salmon River Basin in central Idaho, US.

Pelekis, V.A. and B.L. Sanderson

Prey availability and prey quality clearly impact growth and survival of juvenile salmonids, yet studies have rarely quantified these prey characteristics and their implications for juvenile fishes. This study examines both the quality and availability of aquatic invertebrate prey from salmon-bearing streams in the Salmon River Basin in central Idaho, US. We hypothesized that greater nutritional quality (reflected by increased N content) and availability of invertebrate prey would positively affect the local fish community as observed through increases in average fish size and abundance. First, we evaluated the efficacy of using whole body nitrogen content and C:N ratio as measures of the nutritional quality of invertebrates from the orders Ephemeroptera and Trichoptera. Then we quantified prey availability with benthic and drift aquatic invertebrates density. Last, the abundance and size distribution of juvenile salmon populations were quantified using snorkel surveys and used to investigate the effect of food quality and quantity on local fish assemblages. Our results indicate that the nitrogen content and C:N of Ephemeroptera and Trichoptera varies among streams and may be a useful surrogate for food quality.

Annual residency patterns of southern resident killer whales in the inland waters of Washington and British Columbia.

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Southern resident killer whales are listed as 'endangered' in both the United States and Canada. Both countries have recognized the importance of the trans-boundary inland waters of the Puget Sound Georgia Basin as core summer habitat for these whales by designating this area as critical habitat. However, these whales, comprised of three pods or family groups, only spend a portion of their time here, ranging to the outer coast throughout the year. While summer occurrence patterns have been studied, it is important to assess year round patterns of occurrence and how these patterns vary annually, seasonally, and by pod.

Sightings were compiled from January 2003 to December 2007. This time period was chosen due to a marked increase in year round sighting effort as compared to previous years. Sightings came from a wide variety of sources including the public, commercial whale watch operators, and researchers and were reported to Orca Network. Sightings were compiled by pod, and those with uncertain pod identifications were compiled separately (adding these sighting did not alter patterns of residency). For a given day the whales' location was assigned to one of four areas: Puget Sound, San Juan Islands, Eastern Strait of Juan de Fuca, and the Fraser River/ Gulf Islands. This location represents the area in which the whales spent the majority of their time on that day based on sighting reports. Additionally, the amount of time between sightings was calculated to begin to assess potential range when not in the inland waters.

For the five-year period southern residents were reported in the inland waters on average 46% of days, ranging from 39% in 2006 to 56% in 2003. There has been a decline in the number of days spent in the inland waters, but there is a substantial amount of variability between years. Sightings are relatively rare from January to March (0-20% of days/month), increasing in April and May, peaking in June (75-100% of days/month), and then declining through December to levels slightly higher than those in January. Occurrence also varied between pods. J pod occurred more often in inland waters than K and L pods (40.5%, 20%, 22% respectively). J pod was most commonly present from May-July (>70%) compared to K and L pods who were most commonly present from June-September (>50% and >60% respectively).

Sightings were most common in the San Juan Islands representing 29-41% of all sightings in inland waters. While increased effort may have positively biased these numbers, they are consistent with previous summer habitat studies. Sightings in Puget Sound only occurred from October to January, while sightings occurred in the other three areas throughout the year.

Time periods between sightings for all three pods were shortest during the summer months averaging 1-3 days and increasing to upwards of 90 days from January to April for K and L pods. In all months J pod had shorter absences from the inland waters suggesting a smaller coastal range than K and L pods.

Analysis of Pacific Sardine Stocks Derived from Number of Vertebrae

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It is critical to successful management of the Oregon and Washington Pacific sardine fisheries to know if fish caught in the Pacific Northwest are a discrete population. Previous research has hypothesized that the Pacific sardine has three sub populations based off California. One method used for defining Pacific sardine populations is vertebral counts. It is accepted that many species of fish from warmer waters have lower average number of vertebrae than fish of the same species from colder waters. This study uses this assumption to examine vertebral counts of Pacific sardine captured from San Pedro California to Willapa Bay Washington. We found no significant difference in vertebral counts between any of the samples ($P>0.01$).