Science Symposium

ABSTRACTS

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Presented by

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Session 1 • Tuesday • 25 March • 9:10 to 10:40 am

Combining Site and System-Wide Monitoring: The Importance of Landscape Context in Evaluating Salmon Habitat for Restoration Projects in the Snohomish River Estuary

Joshua Chamberlin,[1*] Casimir Rice,[1] Jason Hall,[1] Todd Zackey,[2] Frank Leonetti,[3] Mike Rustay,[3] Kurt Fresh,[1] and Phil Roni[1]

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Restoration monitoring is often restricted to the boundaries of a given project site and one or more similar reference sites. This approach typically only represents a small portion of a larger landscape, and understanding the landscape context for projects, alone and in combination, can improve assessment of restoration effectiveness. This is especially true in cases involving species with complex life histories rearing in large, dynamic ecosystems, such as juvenile salmon response to estuarine restoration projects. The Snohomish River estuary, like many estuaries throughout Puget Sound, has been drastically altered by human activity. In recent decades several restoration projects have been completed within the system, and several more are in various stages of completion, including the Qwuloolt restoration site, a 160-ha site near Marysville, Washington. We have developed a monitoring framework to include both intensive, site-level monitoring (Qwuloolt) and extensive, estuary-wide monitoring of a comprehensive suite of abiotic and biotic attributes. Beginning in 2010, we initiated work on landforms, hydrology, vegetation, invertebrates, birds, and fish at Qwuloolt. In 2012, we integrated this work with a fish-sampling program consisting of four fyke-trap sites and a combination of 36 random and index beach-seine sites throughout the estuary: sampling is conducted twice monthly from February through September. In addition to point measurements of temperature and salinity associated with fish sampling events, water level, temperature, and salinity are monitored continuously at 12 stations throughout the estuary. Elevation and sedimentation are currently monitored using rod surface-elevation tables at 4 locations, and installation of equipment is planned at 12-18 additional sites. Preliminary results indicate that landscape context has a major influence on both habitat and biota and should be a major consideration in restoration planning and monitoring. Furthermore, our extensive system-wide monitoring enables collaboration among agencies and groups and across project sites addressing salmon recovery/restoration within the estuary.

Classification of Benthic Habitats in the Southern California Bight

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Within the Southern California Bight, the *Southern California Shelf Rockfish Hook and Line Survey* uses rod and reel gear to sample hard-bottom habitats that are not effectively sampled during trawl surveys. Information collected during the survey is used to generate abundance indices and estimate biological parameters to support stock assessments for demersal rockfishes *Sebastes* spp. The survey, initiated in 2004, is conducted annually aboard vessels chartered from the local sportfishing industry. The survey design consists of 121 fixed stations sampled annually at sites spanning from Pt. Arguello (34.6°N) to the Mexican border (32.1°N) and within a depth range of 37-229 m. Benthic habitat observations are also collected during the survey via opportunistic deployment of a towed video sled consisting of a low-light analog color camera and a mini-DV recording system. Video is analyzed using established protocols to classify bottom types into major and minor substrata comprising eight habitat categories: mud, sand, pebble, cobble, boulder, continuous flat rock, diagonal rock ridge, and vertical rock-pinnacle top. Our primary objective is to compare the proportion of each habitat type within the survey sampling frame relative to its composition in the Southern California Bight as a whole, as determined by available habitat maps. To date, 72 sled dives have occurred, producing informative footage during 42 dives representing 39 unique stations. Preliminary findings suggest some smaller hard-bottom habitat features may not be adequately resolved within available habitat maps. If these features support significant abundances of fish and invertebrates, the survey may have implications for coast-wide biomass estimates of these rockfishes. Long-term objectives include incorporating habitat type as a covariate in population abundance models, identifying species and assemblage associations with specific habitat types, and ground-truthing habitat maps.

Habitats

Adult Coho Salmon Pre-Spawn Mortality is Caused by Urban Runoff and Prevented by Bioremediation

Julann A. Spromberg,[1*] David H. Baldwin,[1] Jennifer McIntyre,[2] Jay Davis,[3] Steve Damm,[3] and Nathaniel L Scholz[1]

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Urban streams in the greater Seattle area have been the focus of habitat restoration projects since the 1990s. Post-project effectiveness monitoring surveys have revealed anomalous behaviors among adult coho salmon returning to spawn in these restored streams. Behaviors included erratic surface-swimming, gaping, fin splaying, and loss of orientation and equilibrium. Affected fish died within hours, and female carcasses showed high rates of egg retention (> 90%). This phenomenon has been termed coho pre-spawn mortality. From 2002 to 2012, rates of coho pre-spawn mortality ranged from ~30 to 90% in monitored urban streams. The severity of pre-spawn mortality was closely associated with both the timing and amount of fall rains. Affected coho exhibited evidence of exposure to metals and petroleum hydrocarbons, both of which commonly originate from motor vehicles. The weight of evidence suggests that an as-yet unidentified toxic contaminant or contaminant mixture in urban stormwater runoff is killing coho spawners. Geospatial analyses point to urban land uses, impervious surfaces, and specifically road density as being directly related to the levels of pre-spawn mortality across watersheds. During autumn 2012 and 2013 we exposed adult coho recently returned to freshwater to collected urban road runoff. Across multiple rainfall events, untreated stormwater produced the familiar pre-spawn mortality symptomology in all fish within 4 h. These behavioral effects were eliminated when the runoff was filtered through a mix of sand and compost (60:40). These protective effects of simple bioremediation were also evident in coho exposed to treated runoff for longer durations (24 h). Our findings show that exposure to urban stormwater is sufficient to cause coho pre-spawn mortality. Moreover, although the causal chemical agent(s) have not yet been identified, conventional green stormwater infrastructure can effectively protect adult spawners from the acutely toxic effects of runoff. Integration of these types of infrastructure may protect salmonid habitat in urban watersheds.

Habitats

Characterizing Salt Intrusion and Mixohaline Habitat Zones in the Snohomish River Estuary using Extensive Field Data and Hydrodynamic Modeling

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Tidal circulation and river discharge are primary drivers of physical attributes such as salinity, elevation, channel morphology, and soil chemistry, which determine the biological characteristics of estuarine ecosystems, including vegetation and animal assemblages. However, few specific cause-and-effect relationships are well established. Uncertainties concerning restoration response and effectiveness, habitat-biota relationships, and climate-change impacts on estuarine ecosystems are often related to unquantified hydrologic parameters. The Snohomish River estuary is the focus of numerous restoration projects including 241 ha of completed projects; 529 ha of projects that are in process or have completed designs; 156 ha of projects with 30-60% completed designs; and an additional 1,067 ha of projects in the conceptual, feasibility, or preliminary design phase. To support restoration design and monitoring in the Snohomish River estuary, we synthesized data from multiple sources to improve our understanding of salt intrusion and habitat characteristics in the estuary. We used data collected from discrete surface-water sampling, discrete water-column profiling, continuous water sensors, and hydrodynamic modeling efforts to classify these four mixohaline habitats in the estuary: polyhaline (18-30 ppt), mesohaline (5-18 ppt), oligohaline (0.5-5 ppt), and freshwater (0-0.5 ppt). Previous descriptions of salt intrusion in the Snohomish River estuary suggest that salt intrusion is limited to areas downstream of the Steamboat Slough bifurcation and the Ebey, Union, and Steamboat Slough bifurcation/confluence complex at Otter Island. Our results indicated that salt intrusion was much more extensive in the Snohomish estuary and that oligohaline habitat conditions can extend through the entire estuary complex to approximately 2.0 km upstream from the first primary bifurcation along the mainstem, which forms upper Ebey Slough. Our results are being used to create detailed spatial maps of mixohaline habitat conditions within the estuary, which can be used to support restoration planning and effectiveness monitoring.

Habitats

Elwha Dam Removal Nearshore Monitoring

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Removal of two dams on the Elwha River began in late 2011 and will restore sediment processes to much of the river, its estuary, and the near-coastal environment. Since 2005, we have been collecting biological data on inter- and sub-tidal fish communities at sites near the mouth of the Elwha River and more distant reference sites. Samples were collected during spring and summer by beach-seining. Our objective has been to assess the responses of nearshore fish to sediment changes. This will likely be significant in inter- and sub-tidal habitats where ecologically important forage fish spawn and rear. Furthermore, juvenile salmon from listed populations migrate to ocean-rearing areas through nearshore areas. Trends in species richness and abundance were consistent prior to and following dam removal (2012 data only for post-dam removal), with reference areas possessing more species and higher overall abundance of fish than adjacent removal sites. Forage fish were the numerically dominate species group. Using multivariate analysis, we found considerable overlap in fish community composition between years, but there was some separation in fish-assemblage structure between different areas prior to dam removal. Regional differences were primarily a result of differences in abundance of several forage fish species and juvenile salmonid species. There were distinct seasonal differences in all regions, with salmonids and forage fish dominant in spring and flatfish, sculpins, perch, and greenlings as primary species occurring in summer. Inclusion of post-dam removal data from 2012 did not drastically change observed patterns. Our ability to detect responses of fish communities to sediment changes will ultimately depend on both biotic and abiotic factors, such as when sediment reaches the coastal environment; the quantity, composition and distribution of material that reaches Puget Sound; and how long it takes material to distribute from the river mouth.

Habitats

A Floating Bridge Disrupts Seaward Migration and Increases Mortality of Steelhead Smolts in Hood Canal, Washington State

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Habitat modifications resulting from human infrastructure such as roads, dams, and bridges can impede movement and alter natural migration patterns of aquatic animal populations. Such impediments may negatively affect survival and population viability. Full or partial barriers are especially problematic for migratory species whose life histories hinge on habitat connectivity. The Hood Canal Bridge is a floating structure spanning the northern outlet of Hood Canal in Puget Sound, Washington. The bridge extends to a depth of 3.6 m, forming a partial barrier for steelhead migrating from Hood Canal to the Pacific Ocean. We used acoustic telemetry to monitor migration behavior and mortality of steelhead smolts passing four receiver arrays and several single receivers within the Hood Canal, Puget Sound, and Strait of Juan de Fuca. Within the vicinity of the Hood Canal Bridge, 27 mortality events were detected, while only one mortality was recorded on the other 325 receivers deployed throughout the study area. Migrating steelhead smolts were detected at the Hood Canal Bridge array with greater frequency, on more receivers, and for longer durations than smolts migrating past three comparably configured arrays. Longer migration times and paths are likely to result in a higher density of steelhead smolts near the bridge in relation to other sites along the migration route, possibly inducing an aggregative predator response. This study provides strong evidence of substantial migration interference and increased mortality risk associated with the Hood Canal Bridge, and may partially explain the low early marine survival rates observed in Hood Canal steelhead populations. Understanding where habitat modifications indirectly increase predation pressures on threatened populations helps inform potential approaches to mitigation.

Habitats

Reconstructing the Juvenile Stage of Returning Adult Salmon

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Performance and success of individuals during early life history stages is an important driver in population dynamics. For the threatened population of Snake River fall Chinook salmon, effective management requires an understanding of where fish originate and rear, how long they reside within different freshwater habitats, and which life history strategies are employed. We used otolith microstructure and microchemistry of returning adult Chinook to reconstruct natal, rearing, and overwintering location; time spent and somatic growth in the Columbia River estuary; and life history strategy. The majority of adults (72-82%) originated and reared in the lower Snake River, followed by the upper Snake River (15-16%), and Clearwater/Salmon Rivers (2-11%). These results differed from an earlier study that showed a greater proportion of adults originating and rearing in the Clearwater/Salmon Rivers (25-35%). Fish entered the estuary, on average, at 75 d old (115 mm FL), and resided within the estuary for 27 d, during which they grew an average of 35 mm. The majority of adults were classified as yearlings (74%, n = 125), and we observed a lack of differences in both estuary age and somatic growth between life history strategies and among natal, rearing, and overwintering locations.

Species

Deepwater Horizon Crude Oil Impacts on the Embryos of Large Predatory Pelagic Fish

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Background: The *Deepwater Horizon* disaster released approximately 636 million L of crude oil into the northern Gulf of Mexico. The spill oiled the upper surface-water spawning habitats of many commercially and ecologically important pelagic fish species. Consequently, the developing embryos and larvae of tunas, swordfish, and other large predators were potentially exposed to polycyclic aromatic hydrocarbons (PAHs) derived from crude oil. Fish embryos are generally very sensitive to PAH-induced cardiotoxicity, and adverse changes in heart physiology and morphology can cause both acute and delayed mortality. Cardiac function is particularly important for fast-swimming pelagic predators with a high aerobic demand. Offspring of these species develop rapidly at relatively high temperatures, and their vulnerability to crude oil toxicity is unknown.

Results: We assessed the developmental impacts of field-collected *Deepwater Horizon* (MC252) oil samples on three pelagic species: bluefin tuna, yellowfin tuna, and a yellowtail amberjack. We show that environmentally realistic exposures (1-15 µg/L total PAH) caused specific, dose-dependent defects in cardiac function in all three species, with circulatory disruption culminating in pericardial edema and other secondary malformations. Each species displayed an irregular atrial arrhythmia following oil exposure, indicating a highly conserved toxic response.

Conclusions: Our results strongly suggest a widespread loss of pelagic fish larvae in the surface waters of the Gulf as a consequence of crude oil-induced lethal heart failure. Vulnerability assessments in other ocean habitats, including the Arctic, should focus on the developing heart of resident fish species as an exceptionally sensitive and consistent indicator of crude oil impacts.

Species

Developing Methods to Reduce Stray Rates of Barged Juvenile Salmon using Markers of Olfactory Imprinting

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Pacific salmon are known for their extraordinary migration between the ocean and the river of origin. Adult spawning migrations are governed by olfactory discrimination of home-stream odors that juvenile salmon learn (imprint to) prior to their seaward migration. Our previous studies indicated that one component of imprinting involves long-term sensitization of the olfactory system to specific odorants and changes in olfactory-receptor mRNA in the olfactory rosette. We have exploited these changes in olfactory gene expression to develop markers associated with imprinting success. We used these markers in recent studies to identify methods to reduce straying of salmon that are barged through the Columbia River hydrosystem. Barged salmon stray at higher rates than fish that migrate naturally. This presents significant conservation concerns because these strays represent a large percentage of fish on the spawning grounds of several ESA-listed populations. We hypothesize that barging juvenile salmon interferes with the natural process of sequential imprinting in juveniles as they migrate seaward through the Columbia River and therefore results in impaired homing ability and elevated straying by adults. To examine this, we 1) assessed barged and in-river migrants by monitoring imprinting-associated changes in physiological function and; 2) examined key environmental parameters important for imprinting success (e.g. novel tributary water, water exchange rates) to develop improved barging protocols. In-river migrants displayed increases in olfactory-receptor mRNA expression associated with successful imprinting during their downstream migration, while mRNA levels decreased in the barged groups. Parallel laboratory studies indicated that short exposures to novel tributary water were sufficient to elicit increases in imprinting-associated markers. These results suggest that alternative barging protocols that delay at tributary junctions for relatively short periods of time may ultimately reduce straying.

Species

Energetic Impacts of Delphinid Behavioral Responses to Vessel Disturbance Quantified Via Oxygen Consumption Measurements

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Several cetaceans, including Southern Resident killer whales, respond to marine vessels. Some perform surface active behaviors (including breaches and tail slaps) when in the vicinity of many vessels or when vessels approach closely. Individuals may also compensate for elevated noise from vessels by increasing their call amplitude (loudness), duration, repetition rate, and/or frequency. Although studies have shown that delphinid (dolphins) behavior and acoustic signals change in response to vessels, it is unknown whether these behavioral modifications are biologically significant. In order to assess the biological significance, we recorded respiration rates and measured oxygen consumption of trained adult Atlantic bottlenose dolphins via flow-through respirometry to determine metabolic rates during rest, immediately after performing surface active behaviors (tail slaps and bows, a breach-like behavior), and while producing stereotypical vocalizations. Respiration and metabolic rates varied by individual and differed across behaviors. Respiration rates were elevated following all surface active behavior bouts, particularly bows, but were not significantly different from resting values following slow swimming or periods of sound production. Metabolic rates measured after ten-bow and five-bow bouts were 2.2 and 1.8 times higher than resting values, respectively, while metabolic rates following a 30-second bout of tail slaps, during 2 minutes of sound production, and following slow swimming were all approximately 1.2 times resting values. Metabolic recovery following a ten-bow bout required 14 minutes or more, which is relatively long compared to the time required to perform the bout (≤1 minute). Similarly, recovery following a 2-minute period of sound production lasted up to 7 minutes. These results show that behaviors performed in response to vessel presence and noise have energetic costs that may be deemed biologically significant, supporting the need for management actions related to vessel disturbance. This research was funded by the Northwest Fisheries Science Center and the Office of Naval Research.

Species

Improving Adult Pacific Lamprey Passage Using Lamprey Passage Structures and Refuges

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Adult Pacific lamprey *Entosphenus tridentatus* experience difficulty in navigating large Columbia River hydropower dams using fishways intended for salmonids. Development of lamprey passage structures designed to attract lamprey and capitalize on their unique behaviors has improved passage performance. Efforts to increase adult Pacific lamprey passage in 2013 included structural and operational changes to improve lamprey access to and passage through lamprey passage structures at Bonneville Dam. Lamprey use of these structures was assessed by passage numbers from lamprey-activated counters and passive integrated transponder (PIT) detections. A total of 1,048 lamprey were implanted with PIT tags and released downstream from Bonneville Dam. Using PIT detections, we tested whether lamprey used refuge boxes placed in the Washington-shore auxiliary water supply channel to improve lamprey retention in this area. Of the lamprey implanted with tags, 15% were detected at a refuge box. A large percentage (59%) of these fish were subsequently detected in the Washington-shore lamprey passage structure immediately upstream from the refuge. Of the tagged lamprey detected exiting the Washington-shore fishway, 27% had previously used a refuge box. As in previous years, results indicated that lamprey are able to find and take advantage of these relatively small refuge areas. The Cascades Island lamprey passage structure is the first to extend from the tailrace to the forebay of Bonneville Dam. It was operational for the first time in 2013; lamprey use of this structure and passage success was evaluated. Being a new structure, we saw minimal use by tagged fish released downstream (0.1%), but experiments to determine passage success indicated that 79% of PIT-tagged fish released into the lower part of the structure successfully ascended to the newly extended section and exited to the forebay. Lamprey-specific passage facilities such as lamprey passage structures and refuge boxes help mitigate the impediments posed by hydropower dams for Pacific lamprey.

Species

A Management Strategy Evaluation for the Pacific Hake *Merluccius productus* Fishery

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There are multiple objectives when managing any fishery, and balancing these objectives can be difficult. Evaluating different management strategies for a fishery under various environmental and population assumptions is useful to stakeholders and managers. Such evaluations can be used to balance the objectives of many different user groups. *Management strategy evaluation* is a simulation tool that can be used to investigate the performance of various management procedures against the multiple objectives of a fishery. We describe a management strategy evaluation framework used to investigate various management procedures for the Pacific hake *Merluccius productus* fishery. Management procedures that were investigated include frequency of a fishery-independent survey, structural assumptions in the assessment, and upper and lower catch boundaries. The performance of each procedure is evaluated in terms of stock status, catch, and age-composition of the population. For example some management procedures reduce variability in the catch and result in higher stock status, but at the expense of lower average catch. Surprisingly, some management procedures that may appear to be precautionary can actually lead to higher average catch with less variability. Performance of various management procedures are presented, and the relationship of the management strategy evaluation to the assessment and management processes are discussed and compared to the management process of Pacific hake in 2014.

Species

Harmful Algal Blooms of *Alexandrium* in Puget Sound: Cyst Dynamics, Growth, Transport, and Climate Pathways

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The Puget Sound *Alexandrium* Harmful Algal Bloom program† seeks to understand environmental controls on the benthic (cyst) and planktonic life stages of the toxic dinoflagellate *Alexandrium catenella*. One objective is to disentangle the effects of climate pathways on the timing and location of blooms. Spatially detailed mapping of winter cyst distributions during 2011-2013 found the highest cyst concentrations in Bellingham Bay and Quartermaster Harbor. However, the viability of cysts at these seed bed areas is low, with fewer than 54% of cysts germinating when incubated at in situ temperatures. This may complicate potential relationships between cyst abundances and bloom magnitude the following season. Passive particles released from these seed beds were tracked using a high-resolution hydrodynamic simulation of Puget Sound and adjacent coastal waters (via simulations from *Modeling the Salish Sea*).‡ In 2 weeks, particles released from Bellingham Bay made it out of the Strait of Juan de Fuca to the outer Washington coast, whereas particles released from Quartermaster Harbor mostly stayed in the main basin of Puget Sound. No particles entered Hood Canal, suggesting that physical transport mechanisms may prevent toxic cells from contacting shellfish in this basin. Laboratory experiments showed that maximal growth rates (~0.3-0.5 μ d^{-1}) occur over a broad range of temperatures (~14-24°C) at salinities typical for Puget Sound (20-35 psu). These ranges were used to define favorable habitat for *A. catenella* using model output from the MoSSea simulation. A 40-year global climate projection was regionally downscaled and coupled to MoSSea to determine temporal and spatial changes to favorable habitat under the A1B greenhouse gas emissions scenario. A comparison between present-day and circa-2050 conditions allows us to disentangle the effects of three climate pathways on favorable habitat for *A. catenella* in Puget Sound: 1) changing ocean inputs (associated with upwelling winds), 2) changing streamflow magnitude and timing, and 3) increased direct insolation.

† Puget Sound *Alexandrium* Harmful Algal Bloom (PS-AHAB) website: www.tiny.cc/psahab
‡ Modeling the Salish Sea (MoSSea) website: http://faculty.washington.edu/pmacc/MoSSea

Common Effects of Chronic Domoic Acid Exposure in Zebrafish, Sea Lions, Mice, and Humans

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It is well known that acute exposure to high levels of the algal toxin domoic acid is responsible for a neurotoxic illness known as amnesic shellfish poisoning characterized by vomiting, diarrhea, seizures, memory loss, coma and death. Human seafood consumers are protected from high-level exposure via the monitoring of seafood and subsequent regulation of harvests based on toxin loads (≥ 20 ppm = harvest closure). However, there are no protections in place for low-level repetitive exposure (< 20 ppm = harvest open) because there is a critical knowledge gap regarding chronic exposure effects. Our research team has investigated the impacts of repetitive subclinical domoic acid exposure in two laboratory human disease model species (zebrafish and mice), one naturally exposed sentinel for human health species (California sea lions), and in "at risk" high seafood-consuming humans. Chronic subclinical exposure (below levels that show overt excitotoxic symptoms) has been shown to significantly alter gene expression in the central nervous system, elicit an immune response, and increase toxin sensitivity in zebrafish. Additionally, the presence of a domoic acid-specific antibody was indicated in zebrafish and validated in naturally exposed sea lions, thereby revealing a potential diagnostic biomarker for chronic exposure. Mouse and human studies are currently underway in an effort to verify the utility of the antibody biomarker and relate it to subclinical neurotoxic effects. A synthesis of results from all models will be presented.

Seafood Safety

Recreational Demand for Shellfish Harvesting under Environmental Closures

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The Puget Sound estuary provides one of the most valuable shellfish habitats in the Pacific Northwest. Shellfish are important economically, ecologically, and socially to the Puget Sound basin. The State of Washington manages shellfish harvest areas by assessing water quality on an ongoing basis and instituting management options (advisories and closures) based on particular water quality outcomes. While shellfish bed closures have decreased area-wide, persistent closures continue in certain locations, affecting local growers and restricting commercial and recreational harvest opportunities. The Puget Sound Partnership, a Washington State agency established to facilitate the conservation and restoration of Puget Sound, has set a priority to reduce the risks of shellfish growing area closures and adverse effects on human health.
In support of the partnership's efforts, we recently conducted a survey of recreational shellfish harvesters in Puget Sound in order to estimate the effect of environmental closures on behavior. The survey elicited the number of annual trips respondents would expect to take under alternative closure scenarios, including a baseline of no closure. We estimate the demand for recreational trips using a count model system. These models are used to quantify the economic value lost to shellfish harvesters when beaches are closed due to pollution or biotoxins, representing the first economic valuation of recreational shellfish harvesting in the region.

Seafood Safety

Water Quality in Tilapia Transport: From the Farm to the Retail Store

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Nile tilapia *Oreochromis niloticus* are routinely transported 1,200 to 1,400 km from Idaho to the greater Vancouver area, British Columbia for the live markets. Direct hauling mortality is typically very low, but significant economic losses occur during retail holding due to deterioration of physical appearance that results in fish that cannot be sold and mortality. To try to address this problem, information was collected on hauling systems and protocols, water quality in hauling tanks, holding systems and management, and water quality in the retail holding systems. During hauling, fish are exposed to high levels of dissolved oxygen, carbon dioxide, and bacteria. The transfer of fish from hauling systems to retail holding systems can subject fish to rapid changes in temperature, dissolved oxygen, carbon dioxide, and pH. Problem areas in retail holding include low water temperatures, high un-ionized ammonia concentrations, and elevated levels of gas supersaturation. Determination of the causes of high mortality in transportation and retail holding is difficult to clearly identify because of sampling difficulties and commercial restrictions; improvements in hauling protocols may depend on simulated hauling experiments followed by commercial verification.

Seafood Safety

The Relationship between Economic Impacts and Economic Benefits: The Case of the Pacific Coast Groundfish Fishery Individual Fishing Quota Program

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Management of the limited-entry trawl groundfish fishery on the Pacific Coast switched to a limited-access privilege program in 2011. The program, called "trawl rationalization," switched from a system of vessel-entry restrictions, gear restrictions, seasonal closures, and bimonthly catch limits to one of an individual fishing quota program for the shoreside trawl fleet. Recent research suggests that the program may result in a 50–66% reduction in the number of participating vessels with an annual cost-of-harvesting savings of $18–22 million. Thus, a policy that is intended to increase profitability and efficiency in the fishery might also have other potential economic effects, such as reduced local income or employment.

Trawl rationalization has already resulted in fleet restructuring through consolidation and gear switching. The number of vessels harvesting non-whiting groundfish with trawl gear declined from 96 in 2010 to 70 in 2011, and those harvesting with fixed gear increased from 6 in 2010 to 25 in 2011. There are economic impacts resulting from both the consolidation and gear switching, and this paper explores these impacts for the West Coast and port areas currently used in groundfish management. The paper develops counter-factual fleet revenue and costs, then estimates the difference in income and employment generated from the counter-factual scenario with the actual trawl-rationalization results. The counter-factual scenario is developed using data collected through the *Economic Data Collection Program*. Results indicate that the program has resulted in an income increase on the West Coast of $6.2 million in 2011. Port areas that experienced the highest income increase were South and Central Washington, Morrow Bay, and Astoria, while those with the sharpest decreases were Coos Bay and Puget Sound.

The Dynamic Role of Sablefish in a Multispecies, Multigear, Individual Fishing Quota Fishery

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Individual fishing quota systems are typically expected to increase the profitability of a fishery and improve sustainability by ensuring catches remain within quotas. They can also have important distributional and ecological implications that result from shifts in catch and effort between different gears, regions, and habitats. In multispecies fisheries, these changes may be hard to predict since the value of quota and the amount and distribution of catch of primary target species may be dependent on prices, abundance, distribution, and quota availability of other jointly caught species. We analyze how the implementation of individual fishing quotas in the Pacific groundfish fishery has, and may in the future, shift the distribution of catches, effort and revenue in the fishery. We focus on the most valuable component of the groundfish fishery that targets sablefish with fixed gear or jointly with dover sole and thornyhead rockfish using trawl gear. We simulate the effects of changes in prices of sablefish, dover sole, fuel, and sablefish quota on trip-level profitability. Our analysis suggests significant differences in the value of sablefish quota by gear and some regional differences that could lead to shifts in where and how sablefish quota is used. These shifts can have important ecological as well as distributional consequences. Our analysis also shows that relative profitability is quite sensitive to changes in fish and fuel prices within the range of changes seen in recent years. Thus, movement of sablefish spatially and between gears is likely to be dynamic going forward.

Ecosystem Science

Consistency, Efficiency, and Proficiency: The West Coast Groundfish Bottom Trawl Survey

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The Northwest Fisheries Science Center *West Coast Groundfish Bottom Trawl Survey* provides fishery-independent information on the distribution, abundance, and biology of a wide variety of fish and invertebrate species. Annual surveys occur coast-wide at depths of 55-1,280 m using four chartered fishing vessels. The survey team has employed an expanding array of environmental sensors to the trawl and vessel to measure variables known to affect the distribution of groundfish species. These sensors provide valuable information on the physical, chemical, and biological features of groundfish habitat, and will eventually help answer ecological questions and support research into ecosystem based management.

Since 2005, data from the survey have been used in 50 stock assessments on 27 different species. From 2011 through 2013, 86% of the groundfish assessments for the Pacific Fisheries Management Council have utilized data collected by the *West Coast Groundfish Bottom Trawl Survey*. The survey supplies data to multiple clients, contributes to outside research projects, and has been instrumental in identifying new species and range extensions for existing species. The survey has won awards for implementing technology. Team members participate in ongoing research focused on fish diet analysis, food web associations, histology, oceanographic conditions, and anthropogenic marine debris. Recently, the survey team began defining the bottom substrate, slope, and rugosity associated with each trawl. Utilizing a small crew of three scientists per vessel, the survey has sampled ~9,000 stations since 2003, with less than 1% loss in sampling effort. By implementing new technology and software, the survey team has streamlined both workflow and data capture operations.

It is important to note that the groundfish survey was developed to help foster cooperative research using commercial vessels. Collaborative research engages fishermen and allows stakeholders to contribute their knowledge and experience to data collection. This has proven to be a valuable method to fortify trust and gain respect between fishermen and scientists.

Ecosystem Science

The Legacy of a Crowded Ocean: Indicators, Status, and Trends of Anthropogenic Pressures in the California Current Ecosystem.

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As human population size and demand for seafood and other marine resources increase, the influence of human activities in the ocean (e.g., fishing and shipping activity) and on land (e.g., pollutants and runoff from industrial and agricultural activities) is increasingly critical to the management and conservation of marine resources. In order to make management decisions related to anthropogenic pressures on marine ecosystems, we need to understand the links between pressures and ecosystem components, and we cannot draw those linkages unless we know how pressures have been changing over time. We developed indicators and time series of indicators for 22 anthropogenic pressures at the scale of the U.S. portion of the California Current ecosystem. Time series suggest that seven pressures have decreased and two have increased over the short-term, while five pressures were above and two pressures were below long-term means. Cumulative indices of anthropogenic pressures suggest a slight decrease in pressures in the 2000s compared to the preceding few decades. Dynamic factor analysis revealed four common trends that sufficiently explained the temporal variation found among all anthropogenic pressures. Using this reduced set of time series will be useful when trying to determine whether links exist between individual or multiple pressures and various ecosystem components.

Ecosystem Science

Rapid Assessment of Risk Due to Climate Change for Marine Forage Species: An Example from the California Current Ecosystem

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In the ocean, forage species such as squid, anchovies, and sardines play a crucial role, serving as dominant lower trophic-level consumers. These forage species are targets of some of the largest fisheries in the world, and essential food for higher trophic-level species like marine mammals, seabirds, and larger fishes. Contemporary climate change has already changed the distribution and abundance of some forage species, while also modifying the timing and synchrony of important ecological and life history events. However, it has been challenging to predict *a priori* which species, in which places and under which conditions, are most likely to be affected. Using projections of changes in oceanographic climate, we assessed risk to marine forage species in the California Current to the year 2100. We ranked the relative risk to 10 species that are or were valuable fisheries targets. Risk was assessed based on expected changes in the mean and variability of sea surface temperature and chlorophyll concentrations, as well as on species-specific sensitivity to these changes. We found that exposure to changes in oceanographic climate varied much less across the California Current than the sensitivity of individual species to those changes. Furthermore, more forage species appeared to be at risk in northern, nearshore areas than in southern, offshore areas of the California Current. By separating exposure and sensitivity components of risk to marine forage species, we provide insights into how to proactively develop climate change adaptation and mitigation strategies.

Ecosystem Science

Underlying Trends and Relationships among the Ecological Indicators in the California Current Integrated Ecosystem Assessment

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A central goal of the California Current integrated ecosystem assessment† is to develop and evaluate indicators that capture the status and trends of various ecological components to aid in ecosystem management. To this end, over 200 indicators were described and analyzed in the 2012 California Current integrated ecosystem assessment region. A subset of these indicators has been selected by the Pacific Fishery Management Council Ecosystem Plan Development Team to inform the council annually on the status of California Current. The goal of our study is to understand how these time series of indicators can be simplified to fewer trends that capture ecosystem dynamics and reflect known ecological relationships within the ecosystem. We used multivariate autoregressive state-space models to estimate correlations between climate drivers such as the Pacific decadal oscillation, El Niño southern oscillation, and upwelling, and groups of species tracked in the California Current assessment region: copepods, coastal pelagic fishes, groundfish, salmon, and marine mammals. We used dynamic factor analysis, a multivariate time-series approach, to describe shared trends among the set of indicators selected for monitoring by the council. Model results indicated that three shared underlying trends were the most parsimonious simplification of the indicators. One trend largely describes climate and copepod indicators. A second trend describes central California forage fish and the fall Chinook time series. A third trend describes southern California forage fish and California sea lion pup counts. These results highlight the importance of region-specific food web linkages within the California Current large marine ecosystem. Our findings suggest ways in which a large suite of indicators can be simplified to fewer dominant trends that may offer insight to managers.

† NOAA *Integrated Ecosystem Assessment Program* (www.noaa.gov/iea)

Ecosystem Science

Social Indicators of Community-Level Vulnerability for the West Coast

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In fisheries and ecosystem social science, we see an emerging effort to test methods for examining and characterizing coastal communities, as well as the relationships between these human communities and their adjacent marine environments. Fisheries management decisions often require consideration of impacts to fishing and coastal communities. A broader objective of ecosystem-based management concerns the ways in which potential shifts in an ecosystem, in addition to those in policy and management, might affect people and human communities as integrated components of marine ecosystems. In a research effort for the U.S. West Coast, we employed a methodology that incorporates a diverse range of secondary data and proxy measures of community attributes with the aim of considering multiple social and ecological community dimensions simultaneously. We analyzed demographic, geographic, meteorological, quality-of-life and fisheries-specific data for a set of 2,529 coastal communities in Washington, Oregon, and California. A factor analysis approach to these data allowed us to examine relative similarities among variables for a set of proposed indices of community vulnerability. This approach offers policy-makers and ecologists a potential means of incorporating human communities into ecosystem-based research and management approaches.

Rapid Fire: Ecosystem Science

Who's Crapping in Puget Sound?

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Puget Sound is a repository for managed and unmanaged waste streams. Water quality agencies use several indicators for biological contamination, and fecal bacteria are favorites. However, the standard bacterial species and analyses have some drawbacks in sensitivity and yield no information about host source. The order *Bacteroidales* is abundant in the gastrointestinal tracts of terrestrial mammals, and host-specific assays for these bacteria are now available. We applied human-specific and bovine-specific assays to DNA extracted from nearshore, subsurface waters of Puget Sound that were collected over a 7-month period and from more than 75 sites per month. Human- and bovine-sourced *Bacteroidales* were widely detected and displayed distinctive temporal trends. Spatial patterns of *Bacteroidales* were frequently associated with land uses or human activities that could be points of origin for these indicators. The utility of these types of microbial source-tracking assays may be as screening tools for origins of fecal contamination.

Rapid Fire: Seafood Safety

Dynamics of Microbial Communities in the Puget Sound

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Complex relationships exist within the microhabitats of marine environments. Within these micro-ecosystems, bacteria number between 10^5 and 10^7 per mL of water where they are key participants in primary production, nutrient recycling, and oxygen consumption. Using a broad-based fingerprinting technique, automated ribosomal intergenic spacer analysis, we were able to compare bacterial community structures across six major basins of the Puget Sound between April and October 2011. We found community compositions between basins were statistically similar within 3 sets of months: April and May; July, August, and September; and June and October. Significant habitat qualities associated with community similarities included the percentage of adjacent upland that is developed ($P < 0.002$) and sites that are deltas ($P < 0.001$). By identifying relationships of bacterial communities with seasonal time points, geographic and geomorphic habitats, and environmental parameters we are able to build the groundwork for future studies that seek to understand how impacts of changing climates and watersheds may impact microbial community structures.

Rapid Fire: Habitats

Effect of Elevated CO_2 on Larvae of Dungeness Crab *Cancer magister*

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Dungeness crab *Cancer magister* is a commercially, culturally, and ecologically important marine organism inhabiting coastal and estuarine waters of the Pacific Northwest. This species may be susceptible to reductions in seawater pH brought about by absorption of atmospheric carbon dioxide (CO_2). Our study consisted of a series of experiments exploring the potential impacts of ocean acidification on the early life stages of *C. magister*. Larvae from three broods of *C. magiste*r zoeae were exposed to three levels of CO_2 dissolved in seawater: 400 µatm, representing open-ocean concentrations of today; 1600 µatm, representing concentrations recently recorded in Hood Canal, WA; and 3200 µatm, representing an extreme future concentration (yet one that has also been recorded in deep-water samples of Hood Canal). Concentrations of CO_2 were controlled by bubbling pure CO_2 via a computer-automated feedback loop with gas solenoids and a pH probe. Discrete water samples from the experimental system were measured weekly for spectrophotometric pH, total alkalinity, and dissolved inorganic carbon to validate readings from system probes. Individually housed larvae (n = 42 for each brood) were fed and assessed for survival every three days for 45 d. On the 45th day, 57.9, 13.5, and 21.1% of the zoeae had survived in the 400-, 1600-, and 3200-µatm treatments, respectively. Survival analysis revealed that the 400-µatm treatment was significantly different from both the 1600- and 3200-µatm treatments, while there was no significant difference between the two elevated treatments.

Rapid fire: Ecosystem Science

Use of Electrophysiological Techniques in Evaluating Sensitivity to Various Feeding Stimulants and the Effects of Diet on Olfactory Function in Sablefish *Anoplopoma fimbria*

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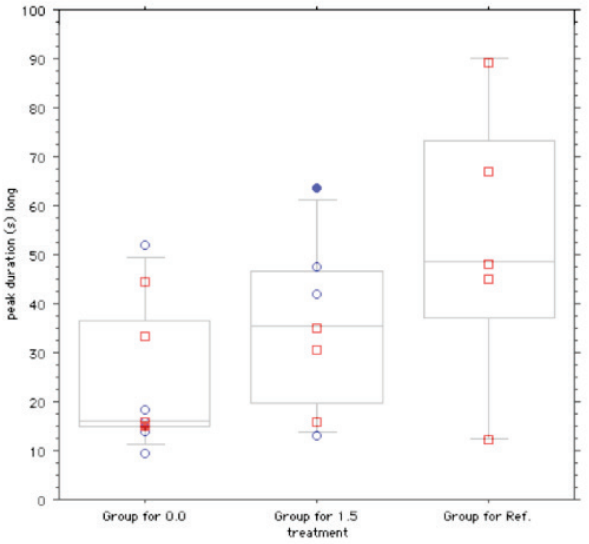
The sense of smell is important to fish, connecting them to the environment by relaying chemical information that plays a role in triggering behaviors associated with feeding, predator avoidance, reproduction and migration. Understanding how fish respond physiologically to different odors can help inform what components are beneficial in inducing these behaviors and how factors such as diet and ambient water chemistry may affect functioning of the olfactory system. Elecrophysiological techniques make it possible to measure physiological responses to various substances. Amino acids are essential nutrients and are important stimulants of searching and feeding behaviors. Sensitivity to different types of amino acids has been shown in fish and varies among species. Using the electro-olfactogram and the electroencephalogram, it is possible to measure the neurological responses to these compounds at receptor sites in the olfactory bulb. Development of alternative, terrestrial plant-based feeds raises issues with the proper balance of essential amino acids. Taurine functions very similarly to an amino acid and is absent in plant proteins. The figure shows an example of how electrophysiological techniques can be used to study a diet lacking in taurine. In this pilot experiment, Sablefish were fed diets with either 0 or 1.5% taurine or a reference diet. Fish receiving the diet with 0% taurine tended to have electroencephalogram responses that were shorter in duration than diets with taurine.



Rapid Fire: Seafood safety

Characterizing Migration and Survival for Juvenile Snake River Sockeye Salmon between the Upper Salmon River Basin and Lower Granite Dam

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Snake River sockeye salmon *Oncorhynchus nerka* was listed as endangered under the Endangered Species Act in 1991 due to extremely low adult returns. Its recovery strategy includes a safety-net hatchery program that utilizes captive broodstock to aid in rebuilding the population. We monitored release groups of PIT-tagged juvenile Snake River sockeye salmon between release in the upper Salmon River basin and arrival at Lower Granite Dam. Estimated survival during spring has been highly variable among release locations, rearing strategies, origin, and years (11.4 to 77.6%). Determining where and why mortality occurs is a critical element towards successful rebuilding and recovery of endangered Snake River sockeye salmon. To estimate survival and characterize the migration of juvenile sockeye salmon, we marked fish with both PIT and radio telemetry tags. Tag detection data was used to determine the magnitude and locations of mortality between the upper Salmon River basin and Lower Granite Dam. Results from this study have indicated several reaches of concern relative to travel time and survival. We have documented occurrences of native bull trout *Salvelinus confluentus* chasing juvenile sockeye schools as they migrated through Little Redfish Lake. We have located transmitters deposited by various avian predators. Our estimates indicate that survival rates have been 7-10% lower for hatchery fish released during the day. Based on these findings, biologists from the Idaho Department of Fish and Game are planning for nighttime releases of production fish from the new Springfield Hatchery facility. By examining key uncertainties and filling data gaps, we have gained information that contributes directly to actions that will play an important part in the recovery of Snake River sockeye salmon. By pinpointing the locations where mortality occurs, we can determine the causes of mortality, providing direction for resource managers and informing their strategies to optimize survival for these fish.

Rapid Fire: Ecosystem Science

Travel Time of Migrating Juvenile Steelhead with Associations to Spill and Surface-Bypass Structures at Hydroelectric Dams on the Snake River

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During their seaward migration, juvenile steelhead originating in the Snake River Basin must pass through up to eight major hydroelectric dams and associated reservoirs. Surface bypass structures have been installed at several of these dams in recent years and are designed to facilitate quicker and safer dam passage by taking advantage of the surface orientation of migrating juveniles. Amount of water spilled at dams during spring and summer has been increased in recent years as another measure to improve dam passage. Migration travel time is biologically important as it determines duration of exposure to predators and affects arrival timing at the estuary. Our objective was to quantify potential changes in travel time associated with surface bypass operation and with proportion of water passing through spillways. We used data from fish implanted with passive integrated transponder (PIT) tags. Passage times through a hydroelectric project (reservoir and dam) include potential delay at the dam forebay, but reservoir and forebay transit times are not separately observable for PIT-tagged fish, because detection is limited to juvenile detection systems at dams. We developed a method to jointly model reservoir transit and dam-delay times as functions of covariates using convolutions of separate probability distributions for each passage-time category. We fitted models in a Bayesian framework and incorporated estimates of forebay residence times from radio-tag studies to inform priors on parameters related to dam delay. We found that surface-bypass operation and proportion of water passing through spillways were both important predictors of dam delay. Spill management and development of structures to speed dam passage are valuable tools for decreasing migration times to the ocean for threatened Snake River steelhead.

Rapid Fire: Species

Captive Propagation of Odd-Year Pink salmon from the Elwha River: A Method of Gene Rescue and Stock Preservation in Response to the Elwha Dam Removal

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In accordance with the *Elwha River Pink Salmon Preservation and Restoration Program*, we are working to prevent the extirpation of pink salmon *Oncorhynchus gorbuscha* from the Elwha River. Our objective is to provide a genetic source for brood cycles during the Elwha Dam removal (2011-2015). Staff at the Manchester Research Station manage a captive stock of odd-year class pink salmon smolts during the ocean portion of their life cycle. In anticipation of siltation and additional environmental effects of the removal, the captive stock would act as a gene rescue and supplementation source in case wild fish were unable to reproduce. With limited growth and survival information available regarding pink salmon in captive propagation, data from the 2011 brood year class marked a seminal opportunity. Being odd-year spawners with a 2-year life cycle, the pink salmon held at Manchester have since spawned at the Lower Elwha Klallam Tribe Fish Hatchery. Ocean returns of the same brood year were also spawned at the tribal facility. A retrospective comparison of captive and ocean-returning fish from brood year 2011 is presented. From the captive stock 134 females and 210 males contributed 51.7% of the eyed eggs for brood year 2013. Despite a reduced size and delayed spawning time, the captive stock showed egg data relative to body size that was similar to those of ocean returns. A delay in seawater entry is suspected to be the cause of the size disparity between the captive brood and ocean-run fish. Further implications of this delayed entry and modifications to the captive program for the next rearing cycle are discussed.

Rapid Fire: Species

Applying Information from Major Trawl Bycatch and Mesh-Size Studies to Fishery Data using Post-hoc Fishing Strategies and Geographical Areas

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The aim of this project is to provide a consistent framework for using the discard rates and length compositions of the Pikitch et al. discard and mesh studies† in U.S. West Coast fishery stock assessments. These assessments include groundfish species that are recovering from an overfished state and are in rebuilding. The mesh study involved 40 commercial groundfish trawl vessels operating under production conditions out of the ports of Newport, Astoria, and Coos Bay, Oregon from June 1985 through December 1987. A total of 1,470 tows were conducted during 139 cruises, the majority of which were conducted off Oregon; some areas off Washington were included. The mesh study involved 48 vessels departing from 20 different ports in Washington, Oregon, and California. A total of 836 tows were conducted over 102 cruises. This study was performed under Experimental Fishing Permits, which contained provisions allowing for the sale of commercially caught fish in excess of existing trip quota limits. The method we developed entails using previously defined post-hoc fishing strategies based on species catch composition within a trip and geographical location to match discard rates and length composition from the Pikitch et al. studies onto fishery catch data (PacFIN).§ This approach allows data from a study of limited duration to be used to inform discard rates and length compositions beyond the limits of the study itself by using fishery data ranging over many years. The accuracy of this method is, of course, dependent upon the consistency of the fishery across the period for which it is used.

† Mesh studies refer to the contribution of Pikitch, E., M. Bergh, D. Erickson, J. Wallace, and J. Skalski. 1990. Final report on the results of the 1988 west coast groundfish mesh size study. Fisheries Research Institute FRI-UW-9019. School of Fisheries, University of Washington, Seattle.

Discard studies refer to the contribution of Pikitch, E. K., D. L. Erickson, and J. R. Wallace. 1988. An evaluation of the effectiveness of trip limits as a management tool. Processed Report 88-27. National Marine Fisheries Service, Northwest and Alaska Fisheries, Seattle.

‡ PacFIN database available from Pacific States Marine Fisheries Commission (pacfin.psmfc.org)

Rapid Fire: Species

The Relationship between Vessel Traffic and Noise Levels Received by Killer Whales

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Cetaceans that rely on their acoustic environment for key life history strategies are susceptible to noise effects from anthropogenic activities such as ecotourism. Endangered Southern Resident killer whales are the primary target for vessel-based whale-watching in the Salish Sea. Vessel interactions and associated noise have been identified as potential stressors for these whales. Previous research has indicated that both stressors negatively impact Southern Resident killer whales; however, there is a missing link between vessel characteristics/behavior and noise levels actually received by individual whales. To investigate this relationship, data were collected concurrently using mobile remote sensing survey equipment packages and digital acoustic recording tags. This allowed us to obtain precise geo-referenced vessel data and noise levels received by the whales. We used linear regression to summarize patterns in vessel characteristics and relate them to received noise levels. Received noise levels were correlated with the number of vessels. Received noise levels also increased when larger vessels were present or when vessels were traveling at relatively high speed. These findings facilitate improved understanding of the contributions of vessel characteristics to the noise levels received by individual cetaceans. Results from this study can be used to refine existing vessel regulations in order to better manage Southern Resident killer whales to recovery.

Rapid Fire: Species

Passage Performance of Juvenile Spring Chinook Salmon During the Drawdown of Fall Creek Reservoir

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Fall Creek Reservoir is one of 13 flood-control reservoirs in the Willamette River drainage operated by the U.S. Army Corps of Engineers. Fish managers at Fall Creek were interested in understanding the effects of reservoir drawdown on passage of juvenile Chinook salmon *Oncorhynchus tshawytscha*. In 2012, we conducted a study to understand how juvenile Chinook are influenced throughout different levels of the reservoir drawdown. For this evaluation, we radio-tagged and released two groups of juvenile hatchery spring Chinook salmon and evaluated their survival and performance metrics during two different reservoir treatments. Radio-tagged Chinook salmon smolts were monitored between the upper end of Fall Creek Reservoir and the confluence of Fall Creek and the Middle Fork Willamette River. Performance varied greatly between treatments, with median forebay delay ranging from 8.4 d under the first treatment to only 4.3 h under the second treatment. Project and dam survival rates were 79 and 80%, respectively, for fish released under the first treatment, while both survival metrics were 98% for fish under the second treatment. Survival through the regulating outlet was 89% for fish released under the first treatment vs. 99% for those released under the second. Upon submission of these results, corps managers modified the drawdown operations in 2013 to better facilitate optimal conditions for migrating juvenile salmon.

Ecosystem Science

Using Stable Isotopes to Infer Ecosystem Dynamics within the Context of Salmon Restoration: Lessons Learned from the Cedar River, Washington, and the Salmon River, Idaho

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Most metrics developed to guide salmon recovery are population-based (e.g., abundance, spatial structure); however, robust Pacific salmon populations once shaped a variety of ecosystem processes that likely influenced populations of other species. Although population-based metrics are fundamental to inferring salmon recovery, a species may remain functionally extinct despite achieving a predetermined abundance metric. This functional extinction may ultimately set constraints on recovery, indicating the need for ecosystem-based recovery metrics. We examined the potential for using natural abundance levels of stable isotopes as one such ecosystem metric, namely $\delta^{13}C$ and $\delta^{15}N$ measured in aquatic and terrestrial food webs from watersheds in Idaho and Western Washington. Our objective was to improve our understanding of how salmon populations influence temporal and spatial variation in $\delta^{13}C$ and $\delta^{15}N$ of these organisms so that we might inform restoration and recovery planning. For example, experiments in the Cedar River revealed a non-linear relationship between adult salmon biomass (saturation occurring at ~1-2 kg/m^2) and $\delta^{13}C$ and $\delta^{15}N$ in invertebrates. However, adult salmon spawning densities in our study area were orders of magnitude lower than densities associated with trophic productivity in three separate experiments. Moreover, there is no evidence that $\delta^{13}C$ and $\delta^{15}N$ in stream organisms collected from the Cedar River have changed almost 7 years following salmon recolonization. In the Salmon River, stable isotope monitoring has demonstrated both short- and long-term contributions of marine-derived nutrients to stream food webs. Juvenile Chinook salmon are influenced by their "maternal nutrients" well into summer, and in some years we can detect marine-derived nutrients in stream organisms shortly after spawning. Riparian invertebrates indicate enrichment that is likely the legacy of marine-derived nutrient contributions occurring over a much longer time frame. Our results have several implications for salmon recovery including identifying the salmon spawning densities necessary to saturate marine-derived nutrient flux in stream organisms.

Ecosystem Science

Steelhead *Oncorhynchus mykiss* Genetics in the Salmon River Region of Central Idaho

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As one part of our Snake River Basin salmonid genetic monitoring program, we non-lethally sampled wild *Oncorhynchus mykiss* populations from each of several major drainages of the Salmon River sub-basin in Central Idaho. We genotyped 2,589 fish from 23 locations using 15 standardized SPAN[†] microsatellite loci. A fairly high degree of genetic structure was seen both among and between river drainages in the region. Over all collections, the average fixation index value was 0.034, with an R^2 (tree topology) estimate explaining about 92% of the observed genetic data. Interestingly, a couple of sample locations from different drainages in this study show an unexpected genetic affinity, suggesting a possible limited gene-flow corridor between headwaters belonging to two very geographically distinct river drainages: the Middle Fork Salmon River and the upper (mainstem) Salmon River. Mapping the genetic results onto the river geography suggests that the landscape of central Idaho has played an important role in shaping the genetic diversity of *O. mykiss* populations in the region.

[†] Steven Phelps allele nomenclature

Ecosystem science

Forage Fish, Jellyfish, Plankton, and Microbes across Puget Sound: Has it Always Been This Way?

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Puget Sound is an oceanographically diverse and urbanized fjord estuary where understanding of pelagic ecology is poor and systematic monitoring and assessment of living systems has long been neglected. We are exploring current patterns of community composition in surface waters across six oceanographic sub-basins of greater Puget Sound and comparing them with historical data. Our focus is the lower-to-middle trophic levels, including microbes, phytoplankton, zooplankton, small pelagic fishes, and jellyfish. As part of this project, we looked at biomass composition of fish and jellyfish assemblages and related that structure to other trophic levels and to environmental variables. In data from monthly sampling of 79 sites from April to October 2011, biological composition differed geographically and seasonally, and assemblage structure from each trophic level correlated with the other trophic levels and with a suite of abiotic attributes. With respect to middle trophic levels, fish dominated communities in the two northern basins, whereas jellyfish dominated in the three southern basins. Comparing our fish and jellyfish catches with those from the 1970s and 1980s suggests that in central and south Puget Sound, herring and smelt abundance has declined, and jellyfish abundance has increased, but has not occurred in the northern basins of the Sound. In addition, sediment-core paleoecological indicators (e.g., diatoms) from central Puget Sound and Hood Canal indicate that pelagic and benthic food webs may have undergone major changes in the mid-20th century, possibly as a result of human activity. Strong biotic and abiotic spatial structure observed in our results, combined with historical information, indicates that different pelagic food webs exist across the Puget Sound ecosystem and that this may be, at least in part, a modern phenomenon related to human activity.

Ecosystem Science

Assessing the Status Pacific Coast Estuaries and their Roles for NOAA Trust Resources

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Estuaries are highly productive and critically important ecosystems that are prone to modification by human activities. Along the Pacific coast, estuaries serve as habitats for a number of species managed by the National Marine Fisheries Service, such as English sole and Chinook salmon. To enhance understanding of the role of estuaries for these species and for ecosystem health of the California Current Ecosystem, the Pacific Marine and Estuarine Partnership is coordinating three related efforts to assess West Coast fish habitats. The focus of each of the three assessments is:

1) Nursery Habitat Assessment: Nursery functions of estuaries for juvenile fishes, and the role of estuaries in the health and production of offshore commercial fisheries; led by the Pacific Marine and Estuarine Partnership.
2) National Estuary Assessment: Status and key threats to West Coast habitats supporting important commercial and recreational fish stocks, as a regional component of the National Fish Habitat Partnership National Fish Habitat Assessment; led by NOAA Fisheries.
3) Nearshore Forage Fish Assessment: Habitat-related changes over time in the distribution and abundance of forage fish species in nearshore and estuary habitats which are not routinely the subject of stock assessments; led by the Northwest Fisheries Science Center.

Although the focus and specific analytical methodologies of these assessments differ, each effort shares several steps in common. These include an inventory and common classification scheme for near-shore and estuarine habitats; development of a spatial framework; collection of data on physical habitat, fish abundance and distribution, and anthropogenic threats; identification of high-priority data gaps; and creation of shared tools and products. By combining efforts, the Pacific Marine and Estuarine Partnership and its assessment partners will be able to integrate data and share outcomes, leading to greater impact of overall assessment efforts and contributions to several other key regional needs.

Poster 18: Habitats

Pacific Northwest Salmon Habitat Project Tracking Database: So You Have Some Data, Now What?

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Across the Pacific Northwest, both public and private agencies are working to improve riverine habitat for a variety of reasons, including improving conditions for threatened and endangered salmon. Restoration projects account for almost **$2 billion** spent just within the Pacific Northwest, yet there seems to be little knowledge of the linkages between restoration actions and the responses of targeted species or an ecological need. The Pacific Northwest Salmon Habitat Project database[†] was designed specifically to address the needs of regional monitoring programs that evaluate the effectiveness of restoration actions and to also improve data standardization and help with project planning/design and prioritization. Currently the data is being used to compare restoration projects with data sets of ecological needs and asking if projects are being places to address these ecological needs. Currently, the database contains over 31,000 restoration actions at the project-level, and over 51,000 spatially referenced project locations within Oregon, Washington, Idaho and Montana. Data sources include, state, federal, local, and non-governmental organizations and tribal contributors.

[†] Salmon Habitat Project Database available from Northwest Fisheries Science Center (webapps.nwfsc.noaa.gov/pnshp).

Poster 1: Habitats

Metabolic Interactions and the Toxic Potency of Complex Polycyclic Aromatic Hydrocarbon Mixtures

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Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous non-point-source aquatic contaminants derived from a variety of combustive and fossil-fuel sources, and are the main drivers of toxicity to fish following oil spills. These compounds always exist in complex mixtures of families containing 2 to 6 aromatic (benzene) rings, with other modifications (e.g., additional alkyl groups) within any given family. We have taken a bottom-up approach to understanding the toxicity of complex mixtures by studying the effects of individual PAHs in zebrafish embryos. So far, no single PAH compound has shown the same potency as a complex mixture, with mixtures orders of magnitude more toxic. Polycyclic aromatic hydrocarbons induce their own metabolism by cytochrome P450 enzymes, and different PAH families are more or less better inducers. At the same time, individual PAHs can differ in their rates of metabolism, or suitability as a P450 substrate. Metabolic interactions are well known to enhance or reduce the toxicity of a variety of drugs and chemicals. To determine if metabolic interactions could explain the potency of PAH mixtures, we used zebrafish embryos to test pairwise combinations of PAHs with both different individual toxic potency and different P450 induction potency. The toxicity of phenanthrene to the developing fish heart was increased in combination with chrysene, a non-toxic PAH with potent P450-inducing activity. The use of high-performance liquid chromatography with fluorescence detection may allow the measurement of PAH metabolites in exposed fish embryos, providing a method to characterize metabolic interactions. These preliminary data support the hypothesis that potency of mixtures is due in part to metabolic interactions, and the approach should allow a relatively high throughput assessment of factorial PAH combinations.

Poster 2: Habitats

Behavioral Response of Juvenile Chinook Salmon *Oncorhynchus tshawytscha* to Combinations of Dissolved Copper and Submerged Structure in Freshwater and Seawater

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Dissolved copper is one of the more pervasive and toxic constituents of stormwater runoff and is commonly found in stream, estuary, and coastal marine habitats of juvenile salmon. While stormwater runoff does not usually carry copper concentrations high enough to result in acute fish kills, exposure to sublethal concentrations of copper is known to both impair salmon health (e.g. olfactory function) and alter behavior. To evaluate behavior of juvenile Chinook salmon *Oncorhynchus tshawytscha* in the presence of sublethal concentrations of dissolved copper, I conducted laboratory studies using a multi-chambered experimental tank. The circular tank was divided into six segments so that water flowed outward from the center of the tank through each of the segments separately, yet fish could move freely between them. The presence of individual fish in each of the segments was recorded at 3-second intervals for 1 h. The number of occurrences in each segment was counted before and after introduction of a sublethal and environmentally realistic concentration of dissolved copper (< 20 µg/L) to one of the segments (exposure segment). Use of exposure segment by each fish was compared before and after introduction of dissolved copper in both freshwater and seawater. To address whether use of preferred habitat is altered by the presence of copper, experiments were also conducted with a submerged structural element. Juvenile Chinook salmon avoided segments with dissolved copper in both freshwater and seawater with no structure present. Fish preferred physical structure in freshwater without copper but that preference disappeared when copper was present. There was no preference for structure in seawater. The presence of sub-lethal levels of dissolved copper altered the behavior of juvenile Chinook salmon in both freshwater and seawater and could potentially affect behaviors beneficial to growth, survival and reproductive success.

Poster 40: Habitats

Taking Stock of Fish Stocking in the Western U.S.

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Over the past 30 years at least 59 species of non-native fishes have been stocked into seven western states: Arizona, California, Idaho, Nevada, Oregon, Utah, and Washington. These same seven states are home to 60% (89/149) of the freshwater and anadromous fishes listed under the U.S. Endangered Species Act. We obtained fish-stocking records from state agencies across the West to ask whether states have changed non-native stocking strategies or moved toward conservation stocking, given these 89 listings. For example, historically, fish-stocking along the West Coast was characterized by introductions of warm-water species such as bass, walleye, catfish, and northern pike—all documented salmon predators—as well as stocking of native salmonids. We looked at current (1993-2008) and historical stocking records (1978-1992) with respect to the species, biomass, and locations stocked. From 1978 to 1992, the seven states stocked 59 non-native species, decreasing to 49 species stocked from 1993-2008. Utah has increased the number of non-natives stocked, while all other states decreased their number of non-native species stocked over the current period. Over the same two periods, 1978-1992 and 1993-2008 the species stocked for conservation increased from 23 (all of which are also sportfish species, e.g., salmon, trout) to 38, 17 of which were stocked for conservation alone (e.g. sucker and dace spp.). The 40-plus non-natives still stocked suggests that state fisheries programs are not fully incorporating concerns about non-native species into stocking decisions, but at the same time they have adopted conservation stocking practices.

Poster 16: Species

Observers as a Research Platform: How the West Coast Groundfish Observer Program Helps Green Sturgeon Research

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In 2006, the southern population of green sturgeon *Acipenser medirostris* was listed as an endangered species. With this listing, scientists at the Northwest Fisheries Science Center began collaborating with biologists at the National Marine Fisheries Service West Coast Regional office to develop a research strategy that includes biological data collected by the *West Coast Groundfish Observer Program*. In 2007, observers on the west coast began to collect length, weight, sex, tissue samples, and photographs of scute patterns from trawl-caught green sturgeon. I will explore how these data are used in research and showcase the biologists and projects that rely on observer data. In 2014, center and regional scientists will expand the green sturgeon data-collection project to include a tagging study in the California halibut fishery. The goal of this new project is to assess the recapture rate of green sturgeon individuals and provide much-needed data on post-release mortality. Our sampling protocol, observer training, and the gear used will be on display. I will also include recommendations on how our program can broaden its involvement in green sturgeon research and why working cooperatively with outside groups to increase our knowledge about trawl fisheries impact on green sturgeon is important.

Poster 28: Species

Assessing the Impact of West Coast Groundfish Fishery Policy Management on Elasmobranchs: A Prospectus

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The regulatory and management regime for U.S. West Coast fisheries is built around the complex, multispecies groundfish fishery. The Pacific Fisheries Management Council manages this fishery within the constraints of mandatory rebuilding of overfished rockfish *Sebastes* spp. stocks and compliance with the U.S. Endangered Species and Marine Mammal Protection Acts. Ninety-four species fall under the umbrella of the West Coast Groundfish Fishery Management Plan. Nevertheless, many more species, including a number of sensitive taxa such as elasmobranchs (sharks and rays and skates) that interact with the groundfish fisheries, are not included in the fishery management plan. Furthermore, most species of sharks and skates in federal waters are outside the umbrella of protective legislation. Our objective is to review the impact of changes in groundfish fisheries-management strategies on sharks and skates. We focused on a subset of elasmobranch species that meet three criteria: species are of global or regional conservation concern; species overlap with some sector of the West Coast groundfish fishery; and species are outside the management plan framework. We compared this subset with elasmobranchs species bycaught in groundfish fisheries and conducted a preliminary examination of elasmobranch bycatch observed by the *West Coast Groundfish Observer Program* since 2002. We explored the relationship between the composition and interaction rates of elasmobranch bycatch and time periods that represented important policy changes in groundfish management. These results will help determine whether the current monitoring framework has significant gaps in assessing the impact of management and policy changes on elasmobranch populations. Additionally, we discuss our ability to predict the potential impact of major policy and management shifts, such as the introduction of individual fishing quotas, on the non-groundfish components of West Coast marine ecosystems.

Poster 39: Species

The Northwest Fisheries Science Center Forensic Laboratory in Charleston, South Carolina

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The Charleston laboratory of the Northwest Fisheries Science Center Forensics Unit is located on the campus of the National Ocean Service Center for Coastal Environmental Health and Biomolecular Research in Charleston, South Carolina. The lab is housed in a dedicated, limited-access 2,100-ft^2 facility and includes a secure evidence storage room, a separate polymerase chain reaction lab, an extensive archive of voucher specimens collected over 30 years, and dedicated equipment for genetic and morphological analyses. The majority of our casework involves genetic identification of species, but we also conduct morphological identification of sea turtle and marine mammal parts.

Our laboratory is situated on a 90-acre campus with several other research facilities, including the College of Charleston Grice Marine Laboratory; the Medical University of South Carolina *Marine Biomedicine and Environmental Sciences Program*, and the South Carolina Department of Natural Resources Marine Resources Division. Our campus is also shared with the Hollings Marine Laboratory and other affiliates of the National Ocean Service National Centers for Coastal Ocean Science, as well as the National Institute of Standards and Technology. This location gives our forensics laboratory ease of access to additional diverse expertise and equipment at no cost to the laboratory.

Poster 34: Species

Morro Bay Fixed-Gear Sablefish: Fishing Harder

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According to a recent economics report, Morro Bay had the highest average price per pound of fish and the lowest landings since 1990. Sablefish *Anoplopoma fimbria* was the number-one earning species in Morro Bay from 2008 through 2012 and accounted for over $4 million in ex-vessel value, or nearly 60% of overall ex-vessel value in 2011. Shifts in the market in late 2011 and 2012 led to a drop in earnings and landings. Sablefish accounted for only $1.86 million (30% of ex-vessel value) in 2012, but had the most pounds of landed fish in 15 years. This rebound in the fishery has been caused by new entries into the sablefish fishery, opened up by 1) allowing the previously unfished trawl quota of The Nature Conservancy to be fished with a fixed-gear exempted fisheries permit in 2009, 2) implementation of the catch-share quota being fished by fixed-gear in 2011, and 3) huge quota differences above and below the 36-degree latitude line for open-access and limited-entry sablefish. According to an economic report in 2007, there have been 17 new and returning commercial fishing vessels in Morro Bay; however, that does not include the five large vessels that since 2011 have come from out-of-state yearly to fish their southerly sablefish quota. While this may initially seem positive, we propose to look at the effect this boom has had on sablefish stocks in the area. By looking at changes in distance from port, depths fished, delivered fish size, catch per unit effort, and reduction in discard, we will show that fishermen have to go further and fish deeper to get smaller fish for a lower price. These changes can be achieved by looking at observer, port sampler, and economic data collected from 2007 to 2012.

Poster 8: Species

Evaluating Uncertainty for Population Viability Analysis Under Climate Change Scenarios

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Incorporating climate-change projections into conservation planning and endangered species consultations has become a management imperative. However, uncertainty in our biological conclusions stems from many different sources: general stochasticity in population dynamics, biological sensitivity to climate, and projections in driving factors such as stream flow and temperature. Climate projections themselves contain uncertainty from hydrological modeling, downscaling techniques, global climate model process error, and emissions futures. For migratory species, additional uncertainty stems from differential impacts at multiple life stages (e.g., freshwater vs. ocean stages). We characterized these various sources of uncertainty in a case study of population viability for Snake River Chinook salmon. We explored over 100 climate scenarios for each of 9 populations with varying sensitivity to climate drivers. We identified the most important areas of uncertainty in targeting restoration or management decisions. For all populations, uncertainty in future ocean projections outweighed that from all other sources. The next most crucial factor was biological assessment of the relative population sensitivity to temperature vs. stream flow. Uncertainty in climate projections from downscaling methods, global climate models, or emissions behavior was much less important to management decisions for most populations. However, a subset of populations might either increase or decline depending on future patterns in precipitation. This ranking of uncertainty was useful because it facilitates focused research on studies that will most affect management decisions and thus have the greatest conservation impact.

Poster 43: Species

Phenotypic Plasticity and Divergence in Steelhead: Common Garden Experiment Reveals Differences in Growth-Mediated Life History Traits, Morphology and Behavior between two Hood Canal Populations

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Growth-mediated early life history traits affect an individual's fitness and reflect both evolutionary adaptations and phenotypic responses to environmental conditions. We conducted a reciprocal transplant 'common garden' experiment at two temperature regimes to test for phenotypic plasticity in growth rate, proportion of age-1 smolts, proportion of age-1 mature males, morphological and behavioral traits between and within two populations of steelhead *Oncorhynchus mykiss* from Hood Canal, Washington. We found phenotypic plasticity in growth rate, and proportion of age-1 smolts in both populations. Growth rates were highest in the warm temperature treatment for both populations. More Dewatto River individuals smolted in their first year than Duckabush River individuals, which is consistent with data from the natural populations and provides evidence for phenotypic divergence in this life history trait. However, direct tests of neutrality provided no evidence that this divergence had resulted from diversifying selection, suggesting instead that the divergence may be largely plastic. All age-1 mature males were observed in the warm temperature treatments for both populations, indicating that temperature plays a large role in determining age-1 male maturation under these conditions. Broad-sense heritability estimates for growth rate and smolts at age-1 were generally high, revealing the potential opportunity for selection to act on these traits in both populations. The two populations exhibited asymmetric changes in body morphology in response to the two temperature regimes, suggesting both between- and within-population variation in morphological plasticity. In most cases, within population variation in body shapes was less than between temperature regimes. The warm temperature regime caused more exploratory behavior, more charging behavior, and higher fin erosion, and population effects included slight differences in feeding aggression frequency. Understanding the effect of temperature on life history differences between populations is important for management decisions and conservation, including anticipating responses to changing environmental conditions.

Poster 10: Species

At-Sea Pacific Hake Fishery Timelines: Have Catch Levels of Overfished Bycatch Species Changed Through Time?

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Certain species caught as bycatch in the at-sea Pacific hake fishery are currently classified as overfished. Regulatory mandates have been put in place to limit catch of these overfished species to allow for them to rebuild to healthy stock levels. The incidental catch of these species in the at-sea Pacific hake fishery has occurred against the backdrop of evolution from a foreign fishery to today's catch share system. Our time series of catch data dates back to the 1970s, when fisheries observers were first deployed aboard at-sea hake fishing vessels. A retrospective look at the fishery—visualized as catch levels across timelines spanning the decades—reveals the changing landscape as it has moved towards a sustainably managed fishery with increased emphasis on bycatch avoidance and reduction, as well as individual vessel accountability.

Poster 12: Species

Deep-Sea Coral Genomics: Sequencing Deep-Sea Corals at Two Scales

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To better understand the biology of deep-sea corals in the Northeast Pacific, we are using two DNA-sequencing techniques to identify and create a catalog for individual species, and subsequently to develop population-level markers for select species. Samples are obtained via the coastal survey and observer programs run by our Fishery Resource Analysis and Monitoring Division and by the Resource Assessment and Conservation Engineering Division of the Alaska Fisheries Science Center. Samples of deep-sea corals caught during these surveys are sent to the Northwest Fisheries Science Center for DNA sequencing. We use DNA bar-coding to identify individuals to species and develop a set of voucher sequences to facilitate future identification. Two mitochondrial genes are being used for coral species identification: the coral-specific MutS, and COI, including the intergenic region between COII and COI. To establish voucher sequences, a number of samples have been sent to coral taxonomists to confirm morphological identification. To date, sequences from 44 vouchers have been uploaded to the National Center for Biotechnology Information *GenBank* database.[†] These, as well as a catalog of sequences with confirmed morphological identifications, have been used as a reference library for DNA bar-code identification of the remaining deep-sea coral samples. Using this library, initial genetic identification has been completed for samples collected from the 2006-2010 trawl survey programs. We are using next-generation sequencing to develop a set of population-level markers to examine population structure in two species, *Primnoa pacifica* and *Swiftia simplex*. Individuals from putative populations of each species were sequenced using restriction-site associated DNA sequencing, resulting in hundreds of thousands of reads per individual. From these sequences, single-nucleotide polymorphism markers are being developed for use in population genetic analysis. This work is funded through the National Marine Fisheries Service *Deep-Sea Coral Research and Technology Program*.

[†] Available from www.ncbi.nlm.nih.gov/genbank/

Poster 27: Species

Trends in the Maturity of Darkblotched Rockfish *Sebastes crameri* on the U.S. West Coast

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Prior research indicates that changes in reproductive biology of commercially exploited fish stocks affect recruitment estimates and the subsequent determination of harvest levels by fisheries managers. For heavily depleted species, shifts in parameters such as age and size at maturity may occur over a relatively short period due to selective pressures induced by fishing or compensatory responses to reduced population densities. We examined the reproductive biology of darkblotched rockfish *Sebastes crameri*, a commercially and ecologically important groundfish, which is currently listed as "rebuilding" after years of intense overfishing (1980s to late 1990s). Ovaries and age structures were collected during the 2011 and 2012 Northwest Fisheries Science Center groundfish bottom-trawl surveys. We used histological examination to define oocyte developmental stages and classify maturity status for this species. Our results indicate a 29% decrease in age at 50% maturity (from 8.4 to 6.0 years) over the past 25 years. This shift moderately impacted the depletion of spawning stock biomass in a recent darkblotched stock assessment and indicates that it is essential to periodically update life-history data used in stock assessment models. Our current study also revealed spatial patterns in darkblotched maturity along the coast, including a notable decrease in the proportion of mature fish encountered south of central Oregon, information also of interest to assessment scientists.

Poster 15: Species

Seasonal and Interannual Patterns of Smolt-to-Adult Return Rates for Chinook Salmon and Steelhead after Hydropower System Passage

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Barging spring/summer Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* through the Federal Columbia River Power System (Washington and Oregon) is a successful mitigation strategy in that it greatly increases survival of fishes passing through the hydropower system. However, post-hydrosystem smolt-to-adult return rates can be lower for barged smolts than their run-of-river counterparts. In this study, we determine that using real-time, environmental data can help inform decision makers on when and under what conditions it is best to barge smolts while minimizing uncertainty of predicted SARs. We used a hierarchical approach with generalized linear mixed-effects modeling, model averaging, and Akaike information criterion model selection. At each level, we included more predictors: Model 1 had day-of-year of passage through the last dam and day-of-year squared; Model 2 added residuals of river temperature and flow; Model 3 added cumulative upwelling index, residuals of sea surface temperature, and multivariate indices of plume conditions; Model 4 added categorical prediction of the Pacific decadal oscillation (May-September). For Chinook and steelhead smolts migrating in 1999–2009, day-of-year and day-of-year squared were the most important predictors of smolt-to-adult returns throughout the season for fish of both wild and hatchery origin and for barged and run-of-river fish. That is, all smolts showed bell-shaped patterns throughout the season, wherein smolts that migrated early and late had lower adult returns than those that migrated mid-season. Model 4 was best for Chinook, and Model 3 was best for steelhead for all rear and passage types. Thus, for Chinook, the Pacific decadal oscillation was important in reducing interannual uncertainty in predicted smolt-to-adult return rates, but for steelhead this uncertainty was accounted for by other environmental variables. Without the Pacific decadal oscillation in the model, the best model in our hierarchical approach was different for Chinook by rear type and passage type. Overall, real-time data on freshwater and marine conditions, in addition to time of passage, can help predict adult returns rates of Chinook and steelhead throughout the season and interannually.

Poster 44: Species

Variation in Minijack Rate among Columbia River Basin Chinook Salmon Hatchery Populations

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In Columbia River spring and summer Chinook salmon *Oncorhynchus tshawytscha*, timing of male maturation ranges from age-1 (microjack), age-2 (minijack), age-3 (jack), to age-4 or-5 (adult) years. The presence of minijacks has been noted in several experimental studies and documented for a few hatchery programs, but a comprehensive survey of their occurrence in hatchery production programs has never been conducted. We measured the proportion of minijacks among males released from several spring- and summer-run Chinook salmon hatchery programs throughout the Columbia River Basin among brood years 1999 to 2010. Hatchery programs surveyed were both segregated, using only hatchery-origin spawners in broodstock, and integrated, using some degree of natural-origin spawners. Minijacks were found in all programs monitored, and rates of occurrence varied approximately tenfold across release groups ranging 7.9-71.4% of males in spring Chinook programs and 4.1-40.1% of males in summer Chinook programs. Cumulative growth (i.e., size at release) was found to be positively correlated with minijack rate, but for only the integrated spring Chinook salmon programs. Domestication selection may have occurred in segregated spring Chinook programs, increasing the threshold size for maturation and lowering minijack rates. Elevated minijack rates in Chinook salmon hatchery programs result in a direct reduction in both the number of male smolts released and the number of potential adult males available for harvest and spawning.

Poster 11: Species

Can Using Historic Makah Fishing Gear Improve Present-Day Fisheries Management?

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Rockfish catches on the west coast are currently restricted to protect the health of the stocks. Fisheries management currently uses time and area closures, but healthy fisheries, such as the longline fishery for Pacific halibut *Hippoglossus stenolepis*, are still constrained due to bycatch. The purpose of this project was to test whether the traditional halibut fishing hooks of the Makah Tribe, called čibu·d (pronounced chi-bood) could be an effective tool to reduce rockfish bycatch. The first step of the study was to replicate the shape of the traditional čibu·d using brass and stainless steel. After more than 200 čibu·d were made, the second stage was to deploy longline gear with čibu·d and circle hooks to determine if čibu·d reduce bycatch and select for a different size halibut. There were many factors regarding how the čibu·d were fished that may have made them less effective at catching halibut than they were historically, but results show that the čibu·d caught a higher percentage of halibut than circle hooks. There was no significant difference in the size of halibut caught by each hook type. There may be value in continuing to explore design and implementation of čibu·d for use in commercial fisheries and for recreational fishing, especially in areas where bycatch rates are high.

Poster 29: Species

Population Genomics of West Coast and Alaskan Sablefish *Anoplopoma fimbria*

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The sablefish *Anoplopoma fimbria* is a wide-ranging species in the Northern Pacific Ocean. It is the target of a multinational fishery, and there has been recent interest in commercial aquaculture of the species. It is generally accepted that two stocks of sablefish exist: a northern population that inhabits waters north of Vancouver Island, British Columbia, and a southern population that is found off the West Coast of the United States south to Baja California. Delineation of these two stocks is based on growth rates, size at maturity, and migration rates inferred from tagging studies. With little knowledge available on the population genetics of this species, this study uses next-generation sequencing technology to survey the sablefish genome in order to characterize sablefish population structure and identify genomic regions that may be under selective pressure. We sampled sablefish from the Bering Sea to Southern California and used restriction-site associated DNA sequencing to identify thousands of single-nucleotide polymorphisms throughout the sablefish genome. A better understanding of the natural genetic variation in sablefish populations and selective forces that they are subject to may help guide management efforts of this species.

Poster 45: Species

Application of Hatchery Science to the Recovery of Endangered and Depleted Stocks

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We have participated in several interagency and tribal cooperative captive-rearing projects aiding in the recovery of sockeye *Oncorhynchus nerka*, Chinook *O. tshawytscha*, and pink salmon *O. gorbuscha* stocks throughout the Pacific Northwest. This work began with a gene rescue program for Snake River sockeye salmon that probably prevented extinction of a listed evolutionarily significant unit. This program pioneered the marine culture of sockeye salmon, demonstrated that proper spawning protocols can minimize inbreeding in captive broodstocks, and now yearly returns hundreds of fish from the sea. Programs were then developed for Snake River Chinook salmon that served both as safety nets and learning tools on the efficacy of different approaches to captive rearing. These early Chinook programs demonstrated sourcing fish as eyed eggs, rather than parr, reduced bacterial kidney disease issues during rearing. They pioneered the application of ultrasound for identifying the maturation of spring Chinook salmon in seawater so they could be transferred to freshwater facilities around the time they would naturally enter freshwater. Most importantly, the comparative success of captive broodstock and captive rearing programs provided guidance on which approach amplifies the reintroduction population more rapidly. Working with collaborators, the experience gained from these three programs was utilized to develop the foundation for the South Fork Nooksack spring Chinook and Stillaguamish fall Chinook salmon programs being conducted in Puget Sound. The center is participating in pioneering a safety-net program for Elwha River odd-year pink salmon.

Poster 14: Species

Understanding the Genetic Basis of Age at Sexual Maturity in Hatchery and Natural Populations of Chinook Salmon

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Chinook salmon *Oncorhynchus tshawytscha* exhibits tremendous diversity in life history traits, among which is variation in age at sexual maturity. Fish that achieve maturation at a later age attain a greater body size and are generally more competitive and fecund spawners than smaller and younger fish, though fish that delay maturation trade-off higher reproductive success with lower survival. It is known that non-heritable environmental factors contribute to this variation, though there is support for a substantial heritable genetic component underlying this trait in this species. However, the number and distribution of associated genetic loci underlying this trait are unknown. In order to detect genetic regions associated with variation in age at maturity, we present here an experiment to perform a genome-wide association analysis of thousands of restriction-site-associated DNA-tag, single-nucleotide-polymorphism markers distributed throughout the genome in two populations of wild and hatchery origin Chinook salmon from the Wenatchee River (n = 523) and Johnson Creek (n = 384), both tributaries of the Columbia River. In order to determine the relative genetic position and distribution of associated loci, we align restriction-site-associated DNA-tag loci in this study against those from two Chinook salmon linkage maps. Understanding the genetic basis of age at maturity in this species will assist in shaping the age-class distributions of populations to meet fisheries and conservation management goals.

Poster 42: Species

The Effect of Live Prey Extracts on the Feeding Response and Behavior of Sablefish *Anoplopoma fimbria*

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Commercial-scale sablefish *Anoplopoma fimbria* aquaculture in the U.S. is a nascent enterprise with potential for domestic and foreign markets. One of the most critical aspects of sablefish aquaculture is weaning larvae from live to artificial diets. Larval survival rates improve with early weaning because artificial feeds are more nutrient-dense than live foods. At the Northwest Fisheries Science Center Manchester Research Station, we have been developing a technique to improve weaning of sablefish larvae from live to artificial diets by adding natural prey extracts to stimulate a feeding response. We tested whether the addition of a highly concentrated natural prey extract would stimulate larvae to swim towards the surface where artificial diets are dispensed. We froze approximately 200 g (wet weight) of *Artemia* overnight, macerated the frozen *Artemia* in a blender, and isolated the liquid portion by sieving the *Artemia* through a 35 µM mesh. We centrifuged the extract for 10 minutes to remove any remaining particulates. The resulting extract had a concentration of approximately 3,500 µg/mL. On 9 May 2013, we stocked three 1,000-L tanks with Sablefish larvae and reared them under protocols previously established at the research station. A total of 9 trials (3 per tank) were conducted at 504, 516, and 528 degree days post-hatch. We used overhead videography to quantify net movement of larvae toward the water surface for 2 minutes before slowly adding the extract. Video recording resumed after 2 minutes for an additional 3 minutes. The number of fish in the video recording was counted every 30 seconds. The average number of fish near the surface 30 seconds after the addition of water did not increase, but the addition of artemia extract increased by 1.5× the number of fish 30 seconds post-extract at the surface over pre-odorant levels (Kruskal-Wallis test; N = 3; $P = 0.016$). Two minutes thereafter, the number of fish near the water surface went back to pre-odorant levels. Although the addition of *Artemia* extract elicited a strong initial response, the brevity of the response may indicate limited usefulness in weaning larvae to artificial diets. Because it has been shown that live-extracts can enhance digestibility of prepared foods when co-fed to fish larvae, the next step would be to investigate if co-feeding of *Artemia* extracts improves growth or survival of larval sablefish.

Poster 26: Species

Early Maturing Male Chinook Salmon Caught at Sea

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Variation in age of maturity of male Chinook salmon *Oncorhynchus tshawytscha* has been apparent at freshwater spawning sites from the earliest studies of this species. It is less well understood whether early maturing males leave the rivers as yearling smolts and then return to natal streams to spawn within the same year, and if so, whether they undergo ocean migrations in the same manner as immature smolts. Study of fish rearing in the ocean is difficult, as is assessing male maturation status. Sampling of fish may occur at seasonal times when maturation status is not easily visible and, consequently, may not be easily quantified. A sampling program for juvenile salmon in the Northern California Current has occurred over the past 13 years. In this study the maturation status of the Chinook salmon captured has been directly assessed by measuring plasma androgen levels. Maturing age-2 (minijack) Chinook salmon are commonly captured. The occurrence and distribution of this life history variant at sea has not been previously described. We will assess how minijacks may follow stock-specific migration patterns and how early male-maturation may confound estimates of early ocean growth, migration rate, and juvenile survival beyond the first ocean year.

Poster 41: Species

Environmental Effects on Smolt Quality and Early Male Maturation in Spring Chinook Salmon *Oncorhynchus tshawytscha*

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A 3-year study was conducted to assist managers with determining rearing strategies for in-basin production of Hood River spring Chinook salmon. Hood River stock spring Chinook salmon from brood years 2008-2010 were assessed for smolt quality and early male maturation while being reared at three different hatcheries in the greater Hood River area. Each facility combines a unique set of rearing conditions with differences in temperatures, feeding regimes, water flow, and raceway design. These circumstances allow us to directly examine the impacts of this environmental variation on growth and development. For each brood year, sampling occurred as follows: an initial size check (n = 300) was conducted in October, with more in-depth monthly physiology sampling (n = 25) starting in January and continuing until release in April. Size data, gill tissue for determination of adenosinetriphosphatase activity, and plasma for determination of insulin-like growth factor levels were collected during sampling. In addition, a large collection of fish, (n = 300), were sacrificed just prior to release for assessment of plasma 11-ketotestosterone levels to determine rates of early male maturation. Differences were observed, and were often consistent, between the treatment groups for most of these endpoints, indicating that the external rearing environment does significantly affect smolt quality.

Poster 13: Species

Impacts of Dam-Altered Thermal Regimes on Development and Emergence Timing of Chinook Salmon *Oncorhynchus tshawytscha*

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Dams supply services that cultivate and sustain civilization such as flood control, navigation, electricity, and even recreation. Due to thermal stratification in reservoirs, the water released by dams is often a different temperature from environments further upstream on both daily and seasonal time scales. The impacts of flow regulation on temperature are important because of the influence that temperature has on development and distribution of species. Salmon are particularly vulnerable to anthropogenic habitat and temperature changes because their reproductive and early development life phases are spent in freshwater systems. Since salmon return to their native stream to spawn, localized regime changes may influence genetic and phenotypic expression and possibly spur local adaptation. Using a common garden-type laboratory incubation experiment, I measured hatch and emergence timing of eggs from four spring Chinook populations originating from Oregon and Washington river systems affected by hydropower dams. Four family groups were created from each of the four populations (Clackamas, McKenzie, S. Santiam, and Yakima). Each family was exposed to four different thermal regimes from fertilization to emergence to test the following hypotheses: 1. Altered temperature regimes can cause disparity in development timing between families and across populations. 2. Reaction norms for development timing under different temperature regimes are unique depending on family and population origin. 3. The condition of fry at emergence (amount of yolk remaining) differs across thermal regimes, and may depend on local adaptation of a population. Results from this experiment will be presented.

Poster 6: Species

Applying a Length-Frequency Based Analysis to Inform Regional-Scale Fisheries Management

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Changes in population fecundity are typically used to inform fishery management. *Spawning potential ratio* is a method often used to reflect individual lifetime fecundity; however, this requires modeling the population age structure, which is difficult in data-limited situations. An analogous method that can be used in data-limited situations is *fractional lifetime egg production*. Fractional lifetime egg production quantifies the between-year change in fecundity from the change in the length-frequencies of the catch in those years. This estimation method has been shown to be relatively unbiased and less sensitive than the spawning potential ratio to estimates of natural mortality. We present results of an analysis based on fractional lifetime egg production for fisheries in Oregon performed at the state-wide and regional levels to investigate the potential of this method to inform regional management.

Poster 3: Species

Challenges Affecting Adult Migration of Snake River Basin Sockeye Salmon *Oncorhynchus nerka*

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Snake River sockeye salmon was listed as endangered under the Endangered Species Act in 1991. Efforts to recover this evolutionarily significant unit have focused on improving conditions for juvenile and adult migration and on implementation of a captive broodstock program. In recent years, high losses have been observed for returning adult sockeye salmon during their upstream migration from Bonneville Dam to the Stanley Basin. We quantified migration characteristics and estimated the effects of environmental and hydrosystem operations on PIT-tagged adult sockeye that returned to the Stanley Basin in 2008-2012. We found that

1) Median migration time through the hydrosystem was less than 2 weeks
2) Between 15 and 40% were lost below McNary Dam, primarily due to fisheries
3) Survival was 90-100% from McNary to Lower Granite Dam
4) Between 20 and 40% never made it to the Stanley Basin from Lower Granite Dam

However, the same analysis in 2013 showed significantly more mortality in all migration segments, as well as slower migration timing. Additionally, the temporal component was much more dramatic, with mortality from Bonneville Dam to the Stanley Basin estimated at 54, 83, 95, and 100% for fish beginning their respective migrations in the third and fourth week of June, the first week of July, and later in July. The presumed mechanism of mortality was an interaction of run timing, harvest, unusually high water temperatures throughout the basin (particularly in lower Snake River reservoirs and/or ladders at dams), and possible stock-specific effects. Our results can inform potential adaptive management plans designed to avoid future losses of adult salmon in an expected warmer climate.

Poster 17: Species

Using Acoustic Recording Tags to Measure Vessel Noise Exposure and Effects on Behavior in Southern Resident Killer Whales *Orcinus orca*

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Vessel traffic from commercial shipping, whale-watching, and other boating activity is common in Southern Resident killer whales critical habitat. Southern Resident killer whales face several threats, including vessel and noise effects and prey quality and availability. In this collaborative investigation, acoustic recording tags equipped with hydrophones, accelerometers, magnetometers, and pressure and temperature sensors, were temporally attached with suction cups. The tag allowed us to collect data about what an individual killer whale experienced in its acoustic environment, as well as its vocal and movement behavior subsurface. Our research goals include:

1) Quantifying noise levels experienced by individual whales
2) Determining relationships between noise levels and detailed vessel traffic variables obtained from precise geo-referenced data collected concurrently
3) Investigating whale acoustic and movement behavior during different activities including foraging, to understand sound use and behavior in specific biological and environmental contexts
4) Determining potential effects of vessels and associated noise on behavior

We have collected over 80 h of tag data from 23 tags deployed over three field seasons. Noise levels recorded from killer whales were variable, with maximum levels attributed to individual vessels passing in close proximity. Vessel variables that predict noise levels included size, speed, and distance. In addition, average vessel distance observed from the tagged whale increased after vessel regulations went into effect, but some vessels continued to approach closer than the minimum viewing distance stipulated by the federal rule. Additional data obtained from the tags shed light on the (otherwise) dark and subsurface world of Southern Resident killer whales, particularly on the importance of acoustics and specific movement patterns during foraging. These data are critical for addressing research goals related to multiple population risk factors of these endangered whales.

Poster 24: Species

Rockfish Catch in Oregon Resurrected: Reanimating 20th-Century Commercial Catch for Stock Assessments

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Historical catch information is essential for fisheries stock assessment. Without knowing an accurate catch history, it is difficult to understand how a stock responds to exploitation. On the West Coast of the United States, recent catch data (from 1981 on) are available from the Pacific Fisheries Information Network (PacFIN)[†] a regional fisheries database. However, catch information prior to 1981 is sparse, and there is no database analogous to PacFIN to house the data. Coastal state agencies (California, Oregon, and Washington) have reported their historical catches separately, as different sources. They have also employed their own individual sampling programs to inform species composition of catches landed in mixed-species market categories. Therefore, reconstruction of catch history prior to 1981 in stock assessments has been always conducted for each state individually, and assessment authors have often approached the problem differently, using different data sources and a variety of methods. We reconstructed time series of historical catches of rockfish landed in Oregon, from the beginning of rockfish fisheries, to the 1980s. Our estimates improved the reliability of historical landings by identifying and drawing on preferred data sources, as well as by applying a standardized method across all species. These reconstructed time series also reduce duplication of effort by assessment authors in catch reconstruction and facilitate development and review of stock assessments. During the presentation, we will overview data sources and methods used for the catch reconstruction, discuss market categories in which the rockfish have been landed since the early 20th century, describe the dynamics of rockfish catches over the years, and place these dynamics in the context of rockfish fisheries and management efforts on the U.S. West Coast.

[†] Database available from the Pacific States Marine Fisheries Commission (pacfin.psmfc.org)

Poster 38: Species

Dinophysis and Diarrhetic Shellfish Poisoning: Developments and Collaborations for Early Detection and Public Safety in the Salish Sea

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Diarrhetic shellfish poisoning is an emerging health threat to the people who consume shellfish from the Salish Sea. The toxins responsible for causing diarrhetic shellfish poisoning in humans are collectively called the diarrhetic shellfish toxins (DSTs) and include okadaic acid and dinophysistoxins. Diarrhetic shellfish toxins are produced by dinoflagellates in the genus *Dinophysis*; heterotrophs that can feed through myzocytosis or "cellular vampirism." Although *Dinophysis* have been observed in the Salish Sea for many years, the first confirmed case of diarrhetic shellfish poisoning occurred in 2011 after a family consumed mussels harvested from Sequim Bay. *Dinophysis* typically are observed in low cell densities (10-40 cells L^{-1}), and diarrhetic shellfish poisoning events documented in Europe and North America have been associated with cell densities as low as 100-200 cells L^{-1}. A critical component of a monitoring program for diarrhetic shellfish poisoning is rapid and early detection and enumeration of *Dinophysis* cells in seawater at these low densities. A quantitative polymerase chain reaction assay under development for bench-top use will be adapted for field deployment with an environmental sample processor. Preliminary data suggest that the genus-specific probe under development will allow for near real-time detection and enumeration of *Dinophysis* cells. The environmental sample processor is a robotic, autonomous sampler that can analyze samples immediately after collection or store them for later analysis. The processor can be placed strategically in areas known to have experienced high concentrations of *Dinophysis* and DSTs for focal monitoring with high temporal resolution. The bench-top quantitative polymerase chain reaction assay can also be used by complementary programs, such as *SoundToxins* and the *Olympic Region Harmful Algal Bloom* partnership in Washington State, as well as the *Harmful Algae Monitoring Program* in British Columbia, to provide early warning of *Dinophysis* species. Partners can then collect follow-up seawater and shellfish samples for confirmation of toxicity at state and federal laboratories.

Poster 47: Seafood Safety

Monitoring Diarrhetic Shellfish Poisoning in Washington

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Monitoring for diarrhetic shellfish toxins was initiated in summer 2011, when the first illness due to diarrhetic shellfish poisoning was reported in the state of Washington. Monitoring strategy includes collection of whole seawater for identification and enumeration of *Dinophysis* and several shellfish species collected from two sites in Sequim Bay, Washington, as well as other sites throughout Puget Sound during summer 2012. Shellfish samples were analyzed for the okadaic acid toxin group including DTX-1, DTX-2, and DTX-3 using rapid screening methods based on functional assays. These were the protein phosphatase 2A inhibition assay; the anti-okadaic acid antibody in an enzyme-linked immunosorbent assay, and a lateral flow test strip (Jellett Rapid Test), as well as the chemical method of liquid chromatography coupled with tandem mass spectroscopy. The application of a rapid screening method, along with *Dinophysis* cell counts, can provide quick assessment of toxin levels, and the results of this study suggest that the protein phosphatase 2A inhibition assay is better at screening for the okadaic acid group of diarrhetic shellfish toxins. Diarrhetic shellfish toxins in Washington consist mostly of DTX-1; therefore, test kits with antibody-based application tend to underestimate toxin levels present because the antibody used in these tests is specific to Okadaic acid (100% cross-reactivity) and only 50% to DTX-1.

Poster 48: Seafood Safety

Risk-Taking Before and After Individual Fishing Quota Implementation

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There has been a growing movement in fisheries management from "open access" or "limited entry" fisheries towards quota-based management regimes. One hypothesized benefit from quota-based management is that the incentives to "race to fish," present in many limited entry fisheries, are eliminated. It is speculated that this would lead to an increase in fishing safety. However, data on actual safety incidents for a particular fishery is limited. Rather than modeling incidents to test whether quota-based management has made fishing safer, we model a captain's decision to fish with nested logistic regression. The decision to fish is a function of variables that proxy for risk and expected profits. The probability of fishing in poor weather conditions (maximum wind speed taken from nearby weather buoys is used as a proxy weather conditions), conditional on expected profits, describes a captain's propensity for risk taking. As a case study, we used the fixed-gear sablefish fishery off the western United States, which moved from a limited-entry fishery to a quota-based system in 2001-2002. We find average maximum wind speed had a negative effect on the probability of fishing in all management regimes. However, the effect of maximum wind speed was greater under quota-based management, implying that captains are more risk-averse when the race-to-fish incentives are eliminated.

Poster 7: Seafood Safety

Variability of the *tdh*-Related Hemolysin (*trh*) gene of *Vibrio parahaemolyticus* in Pacific Northwest Isolates: Implications for Detection of *trh*+ strains

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Vibrio parahaemolyticus is the most common cause of illness related to the consumption of raw or undercooked seafood. Globally, the O3:K6 serotype comprises the majority of clinical strains and is often referenced as a "pandemic complex." Strains belonging to this complex encode the thermostable direct hemolysin (*tdh*), which is widely considered a reliable virulence marker. In the Pacific Northwest, the pandemic complex is abundant in the estuarine environment; however, no clinical cases have been associated the O3:K6 serotype in this region. Clinical cases in the Pacific Northwest are largely associated with the geographically isolated O4:K12 serotype, which carries the similar but phylogenetically distinct *tdh*-related hemolysin (*trh*). We have recently shown that *trh* may be a more accurate marker of virulence in the Pacific Northwest. Further, recent O4:K12 outbreaks in New York and Spain suggest that *trh* could become a globally important marker for virulence. Unfortunately, sequence variability in the *trh* gene is an obstacle to the development of reliable detection methods. Therefore, to identify suitable conserved regions for primer development, we evaluated *trh* sequence variability in over 50 trh^+ isolates of *V. parahaemolyticus*. Preliminary results show the *trh* gene exhibits significant interstrain variation and is likely too variable for accurate detection. We propose the less variable urease R gene (*ure*R), which is genetically linked to *trh*, and could serve as a useful proxy for the detection of *trh*+ strains. Current efforts are focused on the validation of *ure*R as a marker of virulent strains. Additionally, we are conducting an evolutionary analysis of the *trh* gene to identify the mechanisms responsible for the observed sequence variability. We hypothesize that the recent positive selection is shaping the evolution of this gene, and we discuss how key non-synonymous mutations may affect *trh* functionality.

Poster 46: Seafood Safety

Enhancing Seafood Safety Monitoring in Developing Countries

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Recent increases in harmful algal bloom events have caused damage to fisheries and disturbance of ecosystems in the Pacific Rim. As the first step to minimize the impact of harmful organisms and lower the occurrence of fisheries damage, The North Pacific Marine Science Organization[†] is assisting developing countries to identify the established and increasing presence of harmful algal organisms and to develop databases for a free exchange of this information. A key aim in this pilot program is to obtain the support of key national and local regional officials in the target countries to help ensure sustainability of the efforts into the future. The program comprises both lectures and laboratory instruction on the life history, environmental setting, and oceanography of common harmful algal organisms in their regions. The training uses participatory learning approaches for:

1. Design of monitoring programs
2. Choosing sampling strategies
3. Establishing data handling and database construction
4. Learning principals and obtaining practical experience in toxin analysis and quality-assurance/quality-control techniques
5. Operation of environmental monitoring kit

Two training programs conducted in the Philippines and Guatemala are described, each tailored to the specific needs and harmful algal bloom issues for each country. The overall project goal is to empower local communities by providing both an initial sentinel expertise in harmful algal bloom issues and a long-term data record suitable for detecting possible harmful algal species migrations or invasions.

[†] North Pacific Marine Science Organization, PICES (www.pices.int)

Poster 4: Seafood Safety

A Potential New Virulence Marker for *Vibrio Parahaemolyticus*

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Vibrio parahaemolyticus is a naturally occurring halophilic gram-negative bacterium found in the marine environment. This bacterium concentrates in shellfish, can cause acute gastroenteritis in humans through ingestion of raw or poorly cooked shellfish, and is responsible for about 50% of bacterial seafood-borne illnesses world-wide. Incidents of these illnesses, both in the Pacific Northwest and world-wide, have been on the rise since the late 1990s. The majority of these illnesses have been traced to strains belonging to serotype O3:K6 and its serovariants, referred to as the pandemic complex, whereas illnesses in the Pacific Northwest have been caused by strains belonging to other serotypes. Two markers that are currently used to determine virulence in *V. parahaemolyticus* are the thermostable direct hemolysin (*tdh*) and the *tdh*-related hemolysin (*trh*). Our previous studies show that a large number of environmental isolates in the Pacific Northwest encode *tdh*, diminishing its utility as a virulence marker for strains from this region and emphasizing the need for additional virulence markers. We have identified a hemolysin, *hly*A, in a subset of clinical isolates with homology to genes in the RTX toxin cluster of enteropathogenic *Escherichia coli* by comparative genomic analysis of several *V. parahaemolyticus* strains from the Pacific Northwest. We are currently determining the distribution of *hlyA* in clinical and environmental isolates from the Pacific Northwest and other geographic regions and assessing its role in determination of virulence.

Poster 5: Seafood Safety

Marine Forensics at the Northwest Fisheries Science Center Forensics Laboratory, Charleston: Capabilities, Cases and Challenges

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As the laws regulating marine species have become more numerous and complex over the years, the need for forensic analyses has dramatically increased. From a "bird's nest" of shark cartilage to whale bacon to a 400,000-lb shipment of frozen fish fillets, the constantly shifting nature of illegal activity and target species has dictated significant growth and associated challenges in the field of marine forensics. Forensic support can be critical in identifying evidence seized from suspected poachers or smugglers, serving both to help safeguard the nation's consumers from fraud and as a deterrent to future illegal use of marine resources.

Previously housed within National Ocean Service facilities, the Marine Forensics Program in Charleston, South Carolina has worked with the Northwest Fisheries Science Center Forensics Unit for years to address the forensic needs of the National Marine Fisheries Service Office of Law Enforcement. The vast majority of forensic capabilities within the National Oceanic and Atmospheric Administration have finally been consolidated under one virtual roof, as the Charleston program has been transitioned to the Northwest Fisheries Science Center. While forensic activities may be familiar to many at this center, our presentation aims to provide a brief overview of the previous and ongoing work at the newly incorporated Marine Forensics Program in Charleston.

Poster 49: Seafood Safety

Recent Developments: Southern California Shelf Rockfish Survey

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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 2013 field season was the 10th year in a time series of catch-per-unit-effort data and other biological parameters used to calculate an index of relative abundance for several important rockfish species including bocaccio, vermilion rockfish, greenspotted rockfish, and speckled rockfish. Bocaccio and vermilion rockfish, two primary species of interest, have been encountered at over 65% of survey sites in every year of the survey. Survey personnel are currently working with our *Genetics & Evolution Program* to develop separate indices of abundance for vermilion and sunset rockfish by analyzing fin clips collected from each of the vermilion rockfish complex specimens collected.

Recent efforts include expanding the collection of environmental and oceanographic data during sampling, including the acquisition of seawater temperature, dissolved oxygen, salinity, and turbidity information at depth from survey sites. These data may provide informative covariates reducing uncertainty associated with the model used to estimate indices of abundance and may also be useful in tracking shifts in oceanographic regimes in the region. In addition, the past two years work has been conducted to estimate size at maturity for the vermilion, sunset, and bocaccio rockfish, with collections of maturity samples from several other species beginning in the 2013 survey. The 2013 sampling year included a third vessel to address the needs of comments from a 2012 review by the Center for Independent Experts. Efforts to collect video habitat information and further develop genetic biopsy hooks continue to move forward. The survey is improved by its collaboration with the sportfishing industry and has strengthened the working relationship between the Northwest Fisheries Science Center and stakeholders in the region.

Poster 30: Ecosystem Science

Diet Studies of Select Groundfish Species Captured by the Northwest Fisheries Science Center Bottom Trawl Survey

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The need to characterize fish diets for a better understanding of trophic dynamics is frequently cited in the "Research and Data Needs" section of groundfish stock assessments. Scientists on the Northwest Fisheries Science Center *West Coast Groundfish Bottom Trawl Survey* began collecting stomachs from target species in 2005 to address this need. The goal of this ongoing study is to gather information on the diets of many important groundfish species and to provide this information to stock assessors and managers. Stomachs and muscle tissue samples are collected at sea and preserved for gut content and stable isotope analysis. In the laboratory, stomachs are assessed for fullness, and contents are examined. Prey species are identified to the lowest taxonomic level possible, weighed, and enumerated.

The diets of yellowtail, darkblotched, canary, sharpchin, and stripetail rockfishes are largely zooplanktivorous, with euphausiids making up 48.0 to 84.7% of their total prey weight. Darkblotched and canary rockfishes also feed on shrimp, which comprise 34.2 and 39.5% of their diets by weight, respectively. Greenstriped and rosethorn rockfishes show a strong preference for benthic prey; various shrimp species make up 80.8% of greenstriped diets by weight, while rosethorn consume 52.1% shrimp and 20.3% galatheid crab. Sablefish, yelloweye, chilipepper, and bocaccio rockfishes are piscivorous, with fish making up between 50.7 and 91.4% of their total prey weight. Finally, widow and Pacific ocean perch rockfishes exhibit a more omnivorous feeding strategy, respectively eating a variety of zooplankton including euphausiids (14.3 and 30.9%), amphipods (4.3 and 3.4%), shrimp (0.9 and 5.3%) and gelatinous prey (2.6 and 60.9%). These results show groundfishes are significant consumers in both benthic and pelagic habitats and feed across multiple trophic levels. Results of a preliminary multivariate analysis will be presented as well.

Poster 25: Ecosystem Science

Training Biologists to be Fisheries Observers

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Fisheries observers are independent field biologists who work aboard commercial fishing vessels. They collect data that fishery scientists and managers depend on for analysis, stock assessments, management decisions, in-season quota tracking, and scientific research. The *West Coast Groundfish Observer Program* trains observers to work in the *Trawl Catch Share*, *Non-Catch Share*, and *At Sea Hake Programs*. Together these programs cover a variety of fishing gear types, and 10 fishery sectors. Placement of observers ranges from small vessels, such as skiffs, to very large ones such as motherships, which can be hundreds of feet long. The diversity of the fishing fleet makes training observers challenging, since they must be prepared for a variety of vessels, gear types, and fisheries.

New observers must successfully pass a 3-week training course before heading into the field. Observer training includes sea safety, species identification, sampling theory, form documentation, database entry, and gear maintenance. By the end of the class, all observers must pass a species-identification and written test.

West Coast Groundfish Observer Program safety training has served as a model for other programs. Instructors are certified by the Alaska Marine Safety Education Association and lead trainees through hands-on drills. The program also partners with the U.S. Coast Guard, who guides trainees through operating a de-watering pump and stopping a leak. Spread throughout training are 10 h of species identification presentations and 20 h of lab time with frozen fish and invertebrate specimens. By the end of training, observers are expected to be able to use dichotomous keys and other identification materials to correctly identify the fish, invertebrates, marine mammals, seabirds, and sea turtles they may encounter at sea.

Poster 32: Ecosystem Science

Environmental DNA: Detection Tools and Limitations

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One goal of fisheries and ecosystem management is to inventory and monitor species composition, abundance, and distribution. Traditional field-monitoring methods do not reliably assay difficult-to-detect or rare species. New techniques using environmental DNA (eDNA) may provide an additional means of assessing species in the marine environment. Organisms leave detectable biological traces in their immediate environment (often skin cells, mucous, or feces). We can extract DNA from environmental samples (seawater, river water) and analyze the DNA associated with an area as an indicator of species presence/absence. Sampling and assay design need to take into account the likelihood of false-positive and false-negative results. Potential applications of this technique range from assessing simple presence/absence of a specific species of interest at a given site to quantitation of multiple unknown species in an area over time. We present preliminary data on samples taken from a river where the presence of spawning adult salmon was visually confirmed. A species-specific, single-nucleotide polymorphism assay was able to detect the Chinook salmon using a single liter of water. We also used a general DNA bar-code marker to detect the presence of any other species in the sample. We are still exploring the limitations of this technique, however we feel eDNA has a huge potential as a management tool for the National Marine Fisheries Service.

Poster 19: Ecosystem Science

Salmonid Life-Cycle Modeling in Support of Management Decisions Across Columbia River Domains

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Life-cycle models of salmonid populations are being used in many contexts throughout the Columbia River Basin. These models provide a structured framework for translating changes in conditions affecting specific life stages into population-level impacts. Stage-specific life-cycle models are able to evaluate combined impacts across multiple life stages. Current model development has been driven by the need to support management decisions from the National Marine Fisheries Service Biological Opinions for the Federal Columbia River Power System and for the Willamette Projects in the Willamette River Basin. Life-cycle models developed to address key management needs in these initiatives can also be directly applied to support regional recovery planning efforts. Other motivations for salmonid life-cycle modeling include: understanding freshwater and ocean climate-change impacts, hatchery management strategies, integrated food-web modeling, and for prioritizing freshwater restoration actions. Here we highlight several aspects of these efforts to illustrate some of the management questions being addressed with life-cycle models. Model development is being led by teams of federal, state, and tribal scientists and consultants collaborating to parameterize models and to develop alternative scenarios of management actions and environmental conditions. In the Willamette River Basin, models are being developed to understand how alternative dam operations and/or modifications and hatchery management are impacting Chinook salmon and steelhead populations. In the interior Columbia River Basin, several modeling teams have been tasked with enhancing existing and building new models of Chinook salmon and steelhead populations to evaluate the impacts of hatchery operations, freshwater habitat restoration, mainstem hydropower operations, avian predation, ocean conditions, harvest management, and climate change, among other factors.

Poster 23: Ecosystem Science

Creating Knowledge using Integrated Electronic Fishery Information Systems

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Electronic fishery monitoring, observing and, more generically, "information systems" can have multiple functions depending on their design. Besides use for fishery regulation, these systems can have applications as "knowledge-based fishery tools". If comprehensively designed they can utilize a single core data set to serve multiple audiences, protect privacy, and share costs and benefits. The *FishTrax* fishery information system[†] was developed to support use of data collected by and from small vessel operations for application in science, marketing, vessel operations, fleet management, resource management, and public relations and education. Raw data collected by the fishing fleet are compiled, summarized, combined with related data sets, and presented in map-based internet portals tailored to various user communities. This poster describes the operating principles and design philosophy of the FishTrax system, showing how it facilitates data sharing, integration, analysis, and synthesis to support the needs of fishermen, scientists, fishery managers, and the general public. Concepts from FishTrax highlight core issues vital for developing successful electronic reporting and monitoring systems including 1) collaboration, 2) concepts of fishing community, 3) integrated development, 4) need for standards, 5) applications for multiple objectives and multiple audiences, 6) creation of knowledge-based portals, and 7) sharing costs and benefits.

[†] Available at www.fishtrax.org and www.pacificfishtrax.org

Poster 21: Ecosystem Science

From Commodity to Gift: The Informal Economy of Seafood Among Commercial Operations in Washington and California

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Fishing is a commercially important activity along the West Coast, yet little has been written about the cultural and informal economic role played by coastal fisheries. This poster discusses noncommercial wild ocean food practices through a focus on subsistence fish and shellfish landings from commercial vessels kept for personal use. We examine PacFIN† data collected from Washington and California between 1990 and 2010. During this 20-year period, over 37.5 million pounds of fish were kept for subsistence and community share systems. In this poster, we highlight the salient species kept for community food systems and analyze spatial, temporal, and species-richness trends across fishing ports in the study area. This study demonstrates the presence of diverse economies, including nonmarket subsistence, in 21st-century tribal and nontribal fishing communities.

† Available from the Pacific States Marine Fisheries Commission (pacfin.psmfc.org)

Poster 31: Ecosystem Science

Pathways to the Public: Connecting Scientists with Society

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Science does not exist in a vacuum; it serves an important role by increasing our collective knowledge and advancing society. There is an increasing need for scientists who can communicate effectively with non-technical audiences, yet scientists are rarely trained in specialized communications. By engaging with the public, scientists can help increase scientific literacy, promote understanding of complex environmental issues, contribute to a positive image of science and its value to society, improve science education, and inspire future scientists. Sharing the Northwest Fisheries Science Center's science increases awareness about the value of our work and opens up new opportunities and resources. Scientists can also benefit personally and advance their careers by gaining new skills, growing their professional network, and potentially attracting more funding for scientific research. Scientists are the best people to communicate their science, and the Northwest Fisheries Science Center Communications Program can help. We will share approaches that can help scientists connect with various audiences, such as social media, press, educational activities, mentoring, events, and partnerships with informal learning centers. We will also highlight a few successful examples of how center scientists are already engaging with society in a meaningful way.

Poster 35: Ecosystem Science

When you Listen to Fishermen, What do you Learn?

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The Pacific Coast groundfish trawl fishery transitioned to a catch-shares management regime in 2011. The Pacific Coast Groundfish Trawl Fishery Social Study is a multi-year study designed to document and assess the social impacts of transition to a catch-shares program on the West Coast fishing industry and related communities. The study utilizes both quantitative and qualitative methods to fully explore the impacts and perceptions of catch shares. Qualitative data is particularly useful for conveying rich, complex and context-specific information. This poster describes the results of interview data collected in 2010 prior to the implementation of catch shares, as well as preliminary results of data collected in 2012 post catch shares. In 2010, 150 interviews were conducted, and in 2012, an additional 200 were collected. Interviews were conducted with quota owners, vessel owners, captains, crew, industry suppliers, spouses of fishermen, and West Coast observers. The data was recorded, coded and analyzed into research themes. The qualitative data collected sheds light on complex topics such as why participants might support or not support catch shares and how they were personally impacted by the program. Preliminary 2012 interview themes suggest that perceptions of catch shares have improved since 2010; however, there are some caveats to success of the program. These include paying for 100% of observer coverage and to a lesser extent, removing previous gear restrictions that were management tools prior to the implementation of catch shares. This data also is useful for exploring unintended consequences of the catch share program, as well as understanding concerns and effects of the transition that may not be readily apparent to management. Finally, qualitative data collected reflects the quality of relationships that participants have with the National Marine Fisheries Service and the Pacific Fishery Management Council.

Poster 36: Ecosystem Science

Data Management to Facilitate Scientific Research

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Most researchers recognize the importance and value of data management in their work, but what is data management? The formal definition, from the *Data Management Association*, is "The development, execution and supervision of plans, policies, practices, and programs that control, protect, deliver, and enhance the value of data and information assets." Data management includes governance; architecture, analysis, and design; database management; data security; data quality; reference and master data; data warehousing and business intelligence; and metadata.

Data alone are individual facts and figures that, out of context, have no meaning. You might recognize 3D9.1C2CC8492F as the code from a passive integrated transponder (PIT) tag, but this code does not tell you much without some context. Data in context are raw data wrapped with meaning. Tag 3D9.1C2CC8492F was placed in a coho salmon in the mainstem West Twin River in summer 2008. Raw data wrapped with meaning can be properly understood, managed, and used.

In this talk, we will present some practical applications of these principles to the PIT-tagging of juvenile salmonids and recording their movement and migration timing in the Strait of Juan de Fuca *Intensively Monitored Watershed* complex. We will go over some of the tasks undertaken by *Scientific Data Management Program* researchers to meet their data management objectives and facilitate the maintenance and analysis of the data they are collecting. These tasks include data process flow diagramming, metadata documentation, data cleanup, data migration from a desktop application to a web-enabled application, automated machine processing of raw field data, automated analysis, query, and extraction, and enhanced presentation of analyzed outputs. We will demonstrate how this process has improved the management of 10 years of existing data and will save time in collection and process of new data.

Poster 9: Ecosystem Science

Management Measures and Changes in the At-Sea Pacific Hake Fishery off the U.S. West Coast Result in Ecosystem Benefits

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The at-sea fishery for Pacific hake *Merluccius productus* off the U.S. West Coast has two sectors operating off the Washington and Oregon coasts: a mothership sector, which receives catch from a fleet of smaller catcher vessels; and a catcher-processor sector. We administer the *At-Sea Hake Observer Program*, which deploys two fisheries observers on each vessel for real-time data collection. Management measures and recent changes in the at-sea hake fishery have had the benefit of producing positive changes for the health of the fishery and the ecosystem in general. Some examples of this include:

1. Low bycatch quotas for several important species have led to a precautionary effect on fishing, resulting in lower bycatch rates
2. Regulations that prohibit bottom contact protect against impacts to benthic habitats
3. Trawl rationalization program provides individual vessel accountability for bycatch
4. U.S.-Canada treaty was formally adopted to agree on division of total allowable catch and end overfishing of hake
5. Chinook salmon bycatch threshold reduces impacts on ESA-listed species

In addition, while the at-sea hake fishery is a single-species fishery, data collected by observers from this fishery are currently used in eight different stock assessments. While we are still learning how to incorporate ecosystem benefits into our management and assessment methods, there has been progress towards a healthier fishery and ecosystem.

Poster 37: Ecosystem Science

Predicting Sardine Habitat Quality in the Northern California Current based on Regional Climate Models

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A seasonal ocean prediction system, *Seasonal Coastal Ocean Prediction of the Ecosystem*, was developed through the University of Washington Joint Institute for the Study of the Atmosphere and Ocean. Its objective was to provide quantitative 6-9 month forecasts of physical, chemical and biological ocean conditions for the coastal waters of the Pacific Northwest. Our primary goal was to link these forecasts to upper-level trophic responses in the California Current ecosystem, specifically based on spatial distributions of Pacific sardine. Using several sardine surveys available from the Pacific Northwest and Vancouver Island, Canada, we used generalized additive models to predict the relationship between sardine presence/absence under hindcasted ocean conditions for 2009, and for ocean forecasts made during 2013. The best models identified significant relationships between sardine presence and physical properties of ocean surface conditions, including salinity, temperature, chlorophyll concentration, and dissolved oxygen levels. For the top models, we were able to correctly predict the presence of sardines in a given pixel of water in 2009 with accuracies 80% or higher, and each model explained sardine distributions in each of the three individuals surveys at a higher-than-random rate. The 2013 forecast maps also correctly predicted the relative absence of sardines in coastal waters of Vancouver Island, where a $32 million commercial fishery collapsed. These simple predictive forecast models hold promise not only for guiding decisions by fishery managers but also for participants in regional fisheries.

Poster 22: Ecosystem Science

Teachers in the Laboratory at the Mukilteo Research Station: Classroom Techniques for describing Genetic Variability in a Marine Species

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At the Mukilteo Research Station genetics laboratory, we conduct a summer program called *Teachers in the Laboratory*. This program is funded by the National Oceanic and Atmospheric Administration to provide 1-2 high school teachers each year with hands-on experience in the use of molecular tools for conservation genetics of marine species. Its goal is to increase the number of educators in the Puget Sound basin that can teach population genetics and conservation of marine organisms. As an offshoot of this program, we intend to collect and synthesize genetic information for a diverse array of vertebrates and invertebrates in the Salish Sea. To monitor and manage the biodiversity of the Salish Sea, we will need to know the population genetic structure of many more species than killer whales, salmon, and rockfish.

This year, over 300 students will be using microsatellite DNA markers to discover if population differences exist in English sole collections in the southern Salish Sea and/or between offshore collections. Each classroom is processing 48 fish from a unique location in the Salish Sea and will do polymerase chain reaction amplification of two microsatellite characters. Polymerase chain reaction products are sent to the Mukilteo DNA laboratory to be analyzed on a gene sequencer. The microsatellite information is sent back to the classrooms for interpretation, and eventually, for comparison among other classrooms via Skype. The *Teachers in the Laboratory* program at Mukilteo is highly visible to the public, is annually covered in local newspapers, and provides an excellent opportunity to showcase Northwest Fisheries Science Center research in Puget Sound. This high-profile, community-based program runs throughout the school year and is unique among laboratories within the National Marine Fisheries Service. *Teachers in the Laboratory* is being considered as a model for a similar program at the Southeast Fisheries Science Center in the Gulf of Mexico. It clearly demonstrates commitment of the National Oceanic and Atmospheric Administration to using technology to understand and conserve marine resources and to supporting hands-on science education.

Poster 33: Ecosystem Science

Monitoring the Migrations of Wild Snake River Spring/Summer Chinook Salmon Juveniles

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Since 1991, we have monitored annual migration timing and growth and have estimated parr-to-smolt survival rates for wild spring/summer Chinook salmon *Oncorhynchus tshawytscha,* from the Salmon River basin to the lower Snake River. Each summer fish are collected from up to 17 streams and tagged using passive integrated transponder (PIT) tags. As fish migrate from their native streams in the head waters of Idaho, migratory data are collected on instream PIT-tag monitoring systems, smolt traps, and monitoring systems in the juvenile bypass systems of federally operated dams on the Snake and Columbia Rivers.

From 1993 to 2013, estimated parr-to-smolt survival to Lower Granite Dam has ranged 8-25% (yearly average 16%) for all streams combined. Although parr-to-smolt survival is based on a number of different factors, density is a major factor that has direct effects on survival. Years of low parr density correspond with higher rates of parr-to-smolt survival (24.4% in 1998), while years of high parr density tend to correspond with lower rates (8.1% in 2004). Growth of individuals is positively related to elapsed time between tagging and recapture and negatively related to fork length at time of tagging. From 1992 to 2013, passage of the middle 80% of combined wild Chinook populations at Lower Granite Dam ranged 23-43 d (average 37 d). Median passage date was negatively related to fall temperature, spring temperature, and spring river flows and positively related to elevation of the tagging site. Data provided by this project establishes a foundation for understanding ecological factors that may play a critical role in recovery of threatened and endangered Snake River spring/summer Chinook salmon.

Poster 20: Ecosystem Science

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