# Northwest Fisheries Science Center

# National Marine Fisheries Service

NOAA Fisheries

# Agency Report to the Technical Subcommittee

# of the Canada-U.S. Groundfish Committee

**April 2014**

## Review of Agency Groundfish Research, Assessments, and Management

### A. Agency Overview

The Northwest Fisheries Science Center (NWFSC) provides scientific and technical support to the National Marine Fisheries Service (NMFS) for management and conservation of the Northwest region's marine and anadromous resources. The Center conducts research in cooperation with other federal and state agencies and academic institutions. Four divisions, Conservation Biology, Environmental and Fisheries Sciences, Fish Ecology, and Fishery Resource Analysis and Monitoring, conduct applied research to resolve problems that threaten marine resources or that deter their use. The Center's main facility and laboratories are located in Seattle. Other Center research facilities are located in Pasco, Big Beef Creek, Mukilteo, and Manchester, Washington; Newport, Hammond, and Clatskanie, Oregon; and Charleston, North Carolina.

**The Fishery Resource Analysis and Monitoring Division** (FRAMD) is the source for most of the research reported by the NWFSC to the Technical Subcommittee of the Canada-US Groundfish Committee. The FRAMD works in partnership with state and federal resource agencies, universities, and the groundfish industry to achieve a coordinated groundfish program for the West Coast.

FRAMD consists of a multi-disciplinary team with expertise in fishery biology, stock assessment, economics, mathematical modeling, statistics, computer science, and field sampling techniques. Members of this program are stationed at the NWFSC facilities in Seattle and in Newport, Oregon, with some Observer Program staff located in California. Together, they work to develop and provide scientific information necessary for managing West Coast marine fisheries and strive to provide useful and reliable stock assessment data with which fishery managers can set ecologically safe and economically valuable harvest levels. FRAM researchers develop models for managing multi-species fisheries; design programs to provide information on the extent and characteristics of bycatch in commercial fisheries as they look at methods to reduce fisheries bycatch; characterize essential habitats for key groundfish species; and employ advanced technologies for new assessments.

During 2013, FRAMD continued to: implement a West Coast observer program; conduct a coast wide survey program that includes West Coast groundfish acoustic, hook and line, and trawl surveys; develop new technologies for surveying fish populations; and expand its stock assessment, economics, and habitat research. Significant progress continues in all programs.

For more information on FRAMD and groundfish investigations, contact the Division Director, Dr. Michelle McClure at Michelle.McClure@noaa.gov, (206) 860-3381.

**Other Divisions at the NWFSC are:**

**The Conservation Biology Division** is responsible for characterizing the major components of biodiversity in living marine resources, using the latest genetic and quantitative methods. It also has responsibility for identifying factors that pose risks to these components and the mechanisms that limit natural productivity. The Division's multi-disciplinary approach draws on expertise in the fields of population genetics, population dynamics, and ecology.

**The Environmental and Fisheries Sciences Division** conducts research to assess and reduce natural and human-caused impacts on environmental and human health, and to improve methods for fisheries restoration and production in conservation hatcheries and in aquaculture. Programs within this Division are focused on: aquaculture, ecotoxicology, environmental chemistry, environmental physiology, hatchery reform science, marine fish and shellfish biology and marine microbes and toxins. Environmental health and conservation research examine environmental conditions and the impacts of chemical contaminants, marine biotoxins, and pathogens on fishery resources, protected species, habitat quality, seafood safety, and human health. Fisheries restoration and aquaculture include research on the challenges associated with captive rearing, nutrition, reproduction, behavior, disease control, engineering, hatchery technology and larval/juvenile quality for protected, depleted and commercially valuable species.

**The Fish Ecology Division**'s role is to understand the complex ecological linkages among important marine and anadromous fishery resources in the Pacific Northwest and their habitats. The Division particularly places emphasis on investigating the myriad biotic and abiotic factors that control growth, distribution, and survival of important species and on the processes driving population fluctuations. The focus is also on helping local agencies evaluate stream, river and watershed restoration efforts with a goal to recover listed salmon stocks.

For more information on Northwest Fisheries Science Center programs, contact the Center Director, Dr. John Stein at John.Stein@noaa.gov, (206) 860-3200.

## B. Groundfish Studies

### 1. Research

#### a) Quantitative video analysis of flatfish herding behavior and impact on effective area swept of a survey trawl

Investigators: D.R. Bryan, K.L. Bosley, A.C. Hicks, M.A. Haltuch, and W.W. Wakefield

Uncertainty in fish behavior can introduce bias into density calculations from fishery-independent bottom trawl surveys that provide relative abundance estimates and population trends for stock assessments. *In situ* video was used to quantify flatfish behavioral responses to a bottom trawl sweep to improve the understanding of survey and assessment results. The behavior of 632 flatfishes was recorded during four tows. More than 90% of fish were observed in a perpendicular orientation away from the sweeps indicating a herding response. There was no significant effect of fish length on fish orientation or whether it reacted or remained stationary during the observation. Only 1.3% of fish were observed escaping the sweeps. A generalized linear model was used to estimate that at a distance of 73.8 cm (± 3.4 SE) 50% of observed fish reacted to the sweep. The mean distance that stationary fish were first observed reacting to the sweep was 36.6 cm (± 2.0 SE). Quantitative analysis indicates that flatfish herding occurs along trawl sweeps and the effective area swept is greater than the wing spread. Thus, the use of wing spread to calculate relative abundance estimates explains bias in stock assessment estimates of survey catchability that are greater than expected.

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#### b) Feeding ecology of juvenile rockfishes off Oregon and Washington, based on stomach-content and stable-isotope analyses

Investigators: K. Bosley, T. Miller, R.D. Brodeur, K.M. Bosley, A. Van Gaest and A. Elz

The feeding habits of pelagic, juvenile rockfishes (*Sebastes* spp.) collected off Oregon and Washington during 2002 and 2006, were examined using stomach-content and stable-isotope analyses. The predominant species were darkblotched (*S. crameri*), canary (*S. pinniger*), yellowtail (*S. flavidus*), and widow (*S. entomelas*) rockfishes. Stomach-content analysis revealed that darkblotched rockfish had highly variable diets, and canary, yellowtail, and widow rockfishes exhibited a high degree of overlap. Multivariate analysis revealed significant differences in diet based on distance from shore, fish size, and species. Stable-isotope analysis showed all species were feeding at about the same trophic level within each year, with a 1.5‰ difference in $\delta^{15}N$ between years. Depleted $\delta^{13}C$ values indicate that the juveniles that were collected likely resulted from offshore spawning, and were subsequently advected or migrated onto the shelf, representing a potentially important cross-shelf transport of carbon to the shelf. Comprehensively, these results add to our understanding of some of the important environmental factors that affect young-of-the-year rockfish during their pelagic phase.

Bosley, K.L., T. Miller, R.D. Brodeur, K.M. Bosley, A. VanGaest and A. Elz. (In revision) Feeding ecology of juvenile rockfishes off Oregon and Washington based on stomach contents and stable isotopes. Mar. Biol.

For more information, please contact Keith Bosley at Keith.Bosley@noaa.gov

**c) Relating groundfish biomass, species richness and community structure to the presence of corals and sponges using NWFSC bottom trawl survey data**

Investigators: K.L. Bosley, K.M. Bosley, C.E. Whitmire and A.A. Keller

Some cold-water corals and sponges occur in such dense aggregations that they provide structurally complex habitats which support a diverse assemblage of associated invertebrates and fish. In many cases, marine fishes have been linked to the presence of epibenthic invertebrates, although the specific nature of this relationship is often unknown. The Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey has collected approximately 250 coral specimens per year since 2006, and has identified, on average, 200 sites (of 750) per year where sponges are present. For this study we investigated the relationship between these two groups of epibenthic invertebrates and their associations with demersal fish using trawl survey data from 2003-2010, when the survey covered continental shelf and slope waters from Cape Flattery, Wash., to the Mexican border. Regression models were used to correlate fish biomass and species richness with coral and sponge densities. Fish biomass was correlated with sponge density, but the relationship was not precise ($P<0.0001$, $R^2=0.043$). No other significant correlations were uncovered among these variables. Multivariate analyses were used to assess fish community structure in relation to coral and sponge densities, and to environmental parameters including depth, latitude and bottom temperature. There were strong correlations between species composition and both depth and bottom temperature, but no strong correlations with coral or sponge densities. Indicator species analysis was done to determine species that were associated with four levels of sponge and coral densities (high, medium, low and zero). Shortspine thornyhead, rosethorn rockfish and greenspotted rockfish were associated with high sponge catches, while flatfishes were typically associated with the absence of sponges. Shortspine thornyhead, Dover sole, longspine thornyhead, aurora rockfish and darkblotched rockfish were associated with high coral catches, and rex sole, English sole, and greenstriped rockfish with the absence of corals. These results provide information about broad-scale associations between corals, sponges and demersal fish that may be useful for developing studies that are specifically focused on the function of corals and sponges as habitats for fish, and the role they may play in their life-histories.

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**d) A stable isotope-based perspective on the contribution of prey to Humboldt squid (*Dosidicus gigas*) in the northern California Current**

Investigators: T.W. Miller, K.L. Bosley, J. Shibata, R.D. Brodeur, K. Omori and R. Emmett

Diet studies have shown Humboldt squid *Dosidicus gigas* to be aggressive opportunistic predators, yet this approach has provided only a limited and potentially biased view of their trophic feeding behavior. As an alternative, the authors measured the $\delta^{13}C$ and $\delta^{15}N$ of *D. gigas* and their prey from the northern California Current ecosystem (NCC) and applied stable isotope Bayesian mixing models (Stable Isotope Analysis in R [SIAR]) to assess if *D. gigas* isotopically matched NCC or southern California Current (SCC) migratory end-members and to examine the proportional trophic contributions of prey groups from the NCC to their diet. For the trophic SIAR model, cluster analysis of prey taxa by their respective $\delta^{13}C$ and $\delta^{15}N$ values was first applied to consolidate prey into groups, which were then incorporated into the model as source groups to the diet mixture. Model results from examination of NCC and SCC migratory end-members indicated greatest contributions from the NCC system, indicating *D. gigas* was more integrated with the regional NCC isotopic signature. From the trophic SIAR model, the results indicated mixed but lower trophic-level feeding by *D. gigas* relative to previous diet-based studies, with greatest contributions from macrozooplankton, ichthyoplankton, and nekton such as juvenile rockfish, market squid, sand lance, and juvenile Pacific hake. Sensitivity analyses of the SIAR model based on varying isotopic fractionation factors of $\delta^{13}C$ and $\delta^{15}N$ showed that proportional contributions of prey to squid diets were resilient to change.

Field et al. (2014; Mar Ecol Prog Ser) comment on the authors' application of a Bayesian isotope-mixing model (SIAR) to examine the relative contribution of prey from different regions to *Dosidicus gigas* diet, and point out that the model violated assumptions of *D. gigas* feeding. The authors agreed in part with their position that use of SIAR for assessing contributions of sources from different regions for an omnivorous species may be unreliable. However, the results from the study and from the prevailing literature and data indicate that *D. gigas* collected in the Northern California Current (NCC) isotopically matched the NCC baseline and were isotopically distinct from prey resources in the Southern California Current. Field et al.'s (2014) comments on the distribution and abundance of *D. gigas* in the NCC missed results from the primary literature which show that *D. gigas* and their purported prey are predominantly distributed along the shelf-slope waters of the NCC, well within the offshore extent of the study. The discrepancy of not finding myctophids as significant sources to *D. gigas* diet may lie in the fact that isotope values of myctophids came from adults only, and that smaller conspecifics with lower relative $\delta^{15}N$ values would have shown a greater contribution from this trophic group. The conclusion reached of lower trophic level feeding by *D. gigas* relative to previous diet studies remains valid.

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### e) Calculating target spawning potential ratio rates for West Coast Elasmobranch species

Investigators: M. Dorn and V.V. Gertseva

The Pacific Fishery Management Council (PFMC) uses biological reference points to determine whether a stock is in an overfished state, and whether overfishing is occurring. The former is determined using estimated depletion level, which is the ratio of spawning stock output (number of eggs or embryos) in the fished condition, to the spawning output in the unfished condition. The latter is determined by a fishing mortality rate (F), expressed based on spawning potential ratio (SPR). This ratio is the number of eggs produced by an average recruit over its lifetime when the stock is fished divided by the same metric when the stock is unfished. The SPR is based on the principle that a certain proportion of fish need to survive to spawn and replenish the stock at a sustainable level.

The default proxy fishing mortality rate for spiny dogfish shark (*Squalus suckleyi*) used by the PFMC has been $F_{SPR45\%}$. However, the most recent assessment of this species conducted in 2011 predicts that fishing at this proxy rate will severely reduce the spawning output of spiny dogfish over the long term, due to the low productivity and other reproductive characteristics of the stock. The spiny dogfish Stock Assessment Review (STAR) Panel suggested that the PFMC's Scientific and Statistical Committee (SSC) consider the appropriateness of using the current proxy fishing mortality rate for spiny dogfish. The SSC agreed that the PFMC's $F_{MSY}$ proxy of $F_{SPR45\%}$ may be too aggressive for spiny dogfish, and suggested a revision of the currently used target SPR value for this species, as well as other elasmobranches (sharks, skates, and rays) managed under the Groundfish Fishery Management Plan, since they share similar life history characteristics.

The appropriateness of using the current proxy fishing mortality rate for elasmobranches managed by the PFMC was evaluated using information reported in Zhou et al. (2012). They compiled fishing mortality reference point's data for more than 200 species and stocks worldwide that have been assessed with different methods and conducted a meta-analysis to link fishing mortality based reference points to natural mortality and other life history traits. The results indicated that $F_{SPR50\%}$ is a more appropriate proxy fishing mortality rate for elasmobranch species along the West Coast of the United States.

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### f) Spine-based ageing methods in the spiny dogfish shark, *Squalus suckleyi*: How they measure up

Investigators: I.G. Taylor, V. Gertseva and S.E. Matson

The second dorsal spine has historically been used for age determination in the spiny dogfish shark. The dorsal spines are located on the external surface of the body and are subjected to natural wear and breakage. Two methods have been developed to account for the worn portion of the spine and extrapolate the lost annuli. The authors compared the performance of these methods using a large data collection assembled from multiple sources, and evaluated their utility for stock assessment and management of the spiny dogfish shark *Squalus suckleyi* in the Northeast Pacific Ocean. Results showed that the two methods produced very different age estimates for older fish with worn spines. Both methods raised significant questions about some aspects of the age estimates produced, and further exploration of techniques to account for worn spine annuli is needed. It is therefore important to develop alternative methods for shark age determination, including those using stained vertebrae.

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**g) Assessing the quality of life history information in publicly available databases**

Investigators: J.T. Thorson, J. Cope and W.S. Patrick

Single-species life history parameters are central to ecological research and management, including the fields of macro-ecology, fisheries science, and ecosystem modeling. However, there has been little independent evaluation of the precision and accuracy of the life history values in global and publicly available databases. The authors therefore developed a novel method based on a Bayesian errors-in-variables model that compared database entries with estimates from local experts, and illustrated this process by assessing the accuracy and precision of entries in FishBase, one of the largest and oldest life history databases. This model distinguishes biases among seven life history parameters, two types of information available in FishBase (i.e., published values and those estimated from other parameters), and two taxa (i.e., bony and cartilaginous fishes) relative to values from regional experts in the United States, while accounting for additional variance caused by sex- and region-specific life history traits. For published values in FishBase, the model identifies a small positive bias in natural mortality and negative bias in maximum age, perhaps caused by unacknowledged mortality caused by fishing. For life history values calculated by FishBase, the model identified large and inconsistent biases. The model also demonstrates greatest precision for body size parameters, decreased precision for values derived from geographically distant populations, and greatest between-sex differences in age at maturity. The authors recommend that bias and precision estimates be used in future errors-in-variables models as a prior on measurement errors. This approach is broadly applicable to global databases of life history traits and, if used, will encourage further development and improvements in these databases.

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**h) Distribution and life history characteristics for vermilion rockfish (*Sebastes miniatus*) and its cryptic pair, sunset rockfish (*S. crocotulus*) in Southern California**

Investigators: J.H. Harms, J. Hempelmann, O. Rodriguez, M. Head, R.M. Barnhart, P. McDonald, J.A. Benante and A.A. Keller

Recent genetic research by Hyde et al. (2008) at NOAA Fisheries' Southwest Fisheries Science Center identified a cryptic pair of the vermilion rockfish from specimens collected along the U.S. West Coast and suggested some depth and biogeographic partitioning between the two species. NWFSC researchers are analyzing tissue samples taken from specimens captured during the survey to taxonomically separate vermilion rockfish and its cryptic twin, the sunset rockfish, to compare depth and distributional patterns between the two species. In addition, this research is developing separate life history parameters for each species including age at length, annual growth estimates, length-weight relationships, and age at maturity. This information can be combined with species-specific abundance indices using the methods described in Harms et al. (2010) to determine whether separate stock assessments for vermilion and sunset rockfish are warranted.

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**i) A fishery-independent multi-species examination of recent population trends for key species of shelf rockfish (Genus: *Sebastes*) in Southern California**

Investigators: A.C. Hicks, J.H. Harms, J.A Benante and R.M. Barnhart

Fishery-independent surveys are an important source of information for stock assessment and management worldwide. Research surveys often use trawl gear to capture commercially valuable species and calculate indices of relative abundance or density. However, many species of interest do not occur in direct contact with the bottom, or occur in areas where high-relief habitat precludes trawl operation. This research was undertaken during a standardized hook and line survey for rockfish conducted by NOAA Fisheries' Northwest Fisheries Science Center (NWFSC) in the Southern California Bight. The survey uses fishing gear similar to that used in many recreational fisheries to sample approximately 121 locations covering a wide range of depths and habitats. The methods described in Harms et al. (2010) were applied to hook and line survey data for six important species of shelf rockfish to generate fishery-independent abundance indices, including the first unique indices for vermilion rockfish (*S. miniatus*) and its cryptic pair, sunset rockfish (*S. crocotulus*). This survey is the only annual tuning index for the adult portion of many structure-associated shelf rockfish species in the region, as historically-used recreational catch per unit effort indices have been compromised due to changes in bag limits and other management restrictions.

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**j) Recent developments: Southern California shelf rockfish hook and line survey**

Investigators: R.M. Barnhart, J.H. Harms and J.A. Benante

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 time series of catch-per-unit-effort data and associated biological data are 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 55% of survey sites in every year of the survey. Survey personnel are currently working with the NWFSC Genetics & Evolution Program to develop separate indices of abundance for vermilion and sunset rockfish by analyzing the finclips collected from each of the vermilion rockfish complex specimens collected during sampling.

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 survey has prioritized the collection of ovary specimens to support research aimed at estimating size at maturity for vermilion rockfish, sunset rockfish, greenspotted rockfish, cowcod, and bocaccio. Efforts to collect video habitat information via the deployment of an underwater camera sled continue to move forward. The survey is improved by its collaboration with the sportfishing industry and has strengthened the working relationship between NOAA Fisheries and stakeholders in the region.

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**k) Classification of benthic habitats in the Southern California Bight**

Investigators: A. Chappell, R.M. Barnhart, J.H. Harms, J.A. Benante and C.E. Whitmire.

The Southern California Shelf Rockfish Hook and Line Survey uses rod and reel gear to sample hard bottom habitats within the Southern California Bight (SCB) 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 spanning from Pt. Arguello (34.6° N) to the Mexican border (32.1° N) in 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 type 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. The primary objective is to compare the proportion of each habitat type within the survey's sampling frame relative to their composition in the SCB as a whole as determined by available habitat maps. To date, 73 sled dives have occurred producing informative footage during 43 dives representing 41 unique stations. Preliminary findings suggest some smaller hard-bottom habitat features may not be adequately resolved within available maps. If these features support significant abundances of fish and invertebrates, this may have implications for coastwide biomass estimates for these species. Longer 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.

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**l) Fishing Vessel-based Survey of Young-of-the-Year (YOY) Groundfishes along the Newport Hydrographic Line**

Investigators: W. Wakefield, M. Yergey and L. Ciannelli

The Northwest Fisheries Science Center (NWFSC) Fishery Resource Analysis and Monitoring Division conducts a comprehensive groundfish bottom trawl survey encompassing the U.S. west coast between the borders with Canada and Mexico and water depths of 55 – 1280 m. This survey does an excellent job of quantifying adult fishes in the study area, but was not designed to quantitatively sample the young-of-the-year (YOY) life history stage. Limited research has been conducted on YOY groundfishes off Oregon since the pioneering work during the late 1970s and early 1980s. A recent Oregon Sea Grant funded project on the effects hypoxia on pelagic larval and benthic juvenile groundfishes has allowed for sampling in nearshore waters (30 – 80 m) during the summer months, but there has been no systematic seasonal sampling across the entire continental shelf since the early 1980s. In 2012 a project was initiated to conduct a fishing vessel-based survey of YOY groundfishes along the NH-Line synoptically with a separate and ongoing plankton/physical oceanography sampling program.

A 2-m wide by 0.5-m high video beam trawl system, equipped with a high-definition video system and scaling lasers is being used to collect fish samples as well as video of fish habitat and behavior. On board, scientists work with the fishing crew to collect fish from the trawl, measuring and returning the large juveniles and adults (anything greater than 150 mm SL), and freezing the juvenile and YOY groundfish. These frozen fish are brought back to the lab, where they are classified to lowest possible taxonomic group possible (usually species), measured, and weighed. These fish are then preserved to allow for future research that may look at the diets or growth rates. The video that is collected on each deployment of the beam trawl is also analyzed back in the laboratory, where each fish in the video is classified to the lowest possible taxonomic group possible, and their behavior is quantified. This information is then used to better understand how the behavior of these YOY fishes changes with a changing environment. A total of 90 tows have been conducted as a part of this project, with 34 in 2012, 56 in 2013. The fish samples collected from the first full year (July 2012 – July 2013) have been fully processed with fishes identified to lowest taxonomic level (species in most cases), and cataloged into our database (Fisheries Oceanography Information System or FOIS).

Analysis of the data from the first complete year of sampling was recently presented at the 18th Western Groundfish Conference in Victoria, British Columbia in February 2014.

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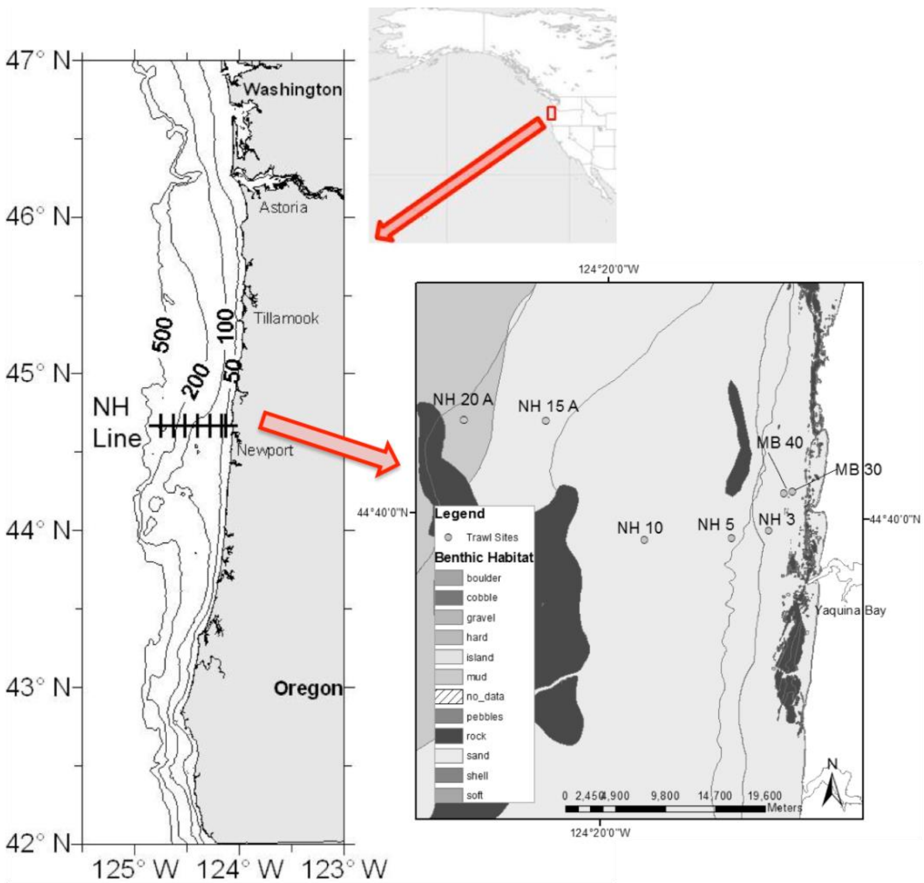


**Figure 1.** Hydrography/zooplankton/ichthyoplankton stations sampled along the Newport Hydrographic Line at biweekly intervals by the NWFSC Estuarine and Ocean Ecology Program (left). Detailed view of beam trawl stations off Moolack Beach and along the Newport Hydrographic Line.

**Figure 2.** NMFS and PSMFC researchers and the crew of the F/V Miss Yvonne look on during a deployment of the beam trawl system equipped with HD camera and scaling lasers. F/V Miss Yvonne, off Newport OR, July 30th 2012.

**m) Impact of light on catch rate of four demersal fish species during the 2009 - 2010 U.S. west coast groundfish bottom trawl survey**

Investigators: M. Bradburn and A.A. Keller

To determine the influence of light on catch of demersal fish, the relationship between near-bottom light levels, catch rates, and catch probability for four abundant groundfish species well represented in annual bottom trawl surveys on the U.S. west coast: arrowtooth flounder (*Atheresthes stomias*), greenstriped rockfish (*Sebastes elongatus*), longnose skate (*Raja rhina*), and Pacific hake (*Merluccius productus*) was examined. Relative downward irradiance was measured with net-mounted archival tags during annual trawl surveys along the U.S. west coast in 2009 and 2010. Near-bottom light levels were recorded for 818 hauls at depths less than 400 m. Significant linear relationships were observed between catch per unit effort (CPUE, kg $ha^{-1}$) and near-bottom light ($P < 0.05$). CPUE of arrowtooth flounder, longnose skate, and Pacific hake was negatively related to near-bottom light. For these species, CPUE decreased 16 - 22% per unit increase in log10 light (μE $m^{-2}$ $s^{-1}$). CPUE of greenstriped rockfish increased

39% per unit increase in log10 light. Light, depth, and latitude explained 15 - 47% of the variance in CPUE for the four species. Catch probability was significantly related to light, depth, latitude, and relative time of day ($P < 0.05$). For all species, catch probability varied inversely with light when depth was less than 200 m. At depths of 200 to 300 m, catch probability increased with light for arrowtooth flounder and greenstriped rockfish. Catch probability for Pacific hake decreased slightly at depths greater than 200 m while longnose skate was relatively unaffected by light at these depths. These relationships were used to explain the variability in catch rates for individual species within bottom trawl surveys. By influencing the density and distribution of these groundfish species, light can alter catch rates. Furthermore, possible herding of greenstriped rockfish, and trawl avoidance by arrowtooth flounder, Pacific hake, and longnose skate were suggested.

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**n) Distribution of demersal fishes along the U.S. west coast (Canada to Mexico) in relation to spatial fishing closures (2003 – 2011)**

Investigators: A.A. Keller, W.W. Wakefield, C.E. Whitmire, B.H. Horness, M.A. Bellman and K.L. Bosley

A temporally and spatially variable Rockfish Conservation Area (RCA) was established as a marine protected area along the U.S. west coast in 2002 to protect stocks of rockfishes (*Sebastes* spp.) by restricting commercial trawling in regions where depleted stocks were most abundant. Since the RCA falls within the region sampled annually by the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey (32º30′ – 48º10′ N Lat.), data collected from 2003 to 2011 were utilized to evaluate if establishment of the RCA influenced catch per unit effort (CPUE, kg $ha^{-1}$), species richness, and size distribution of demersal fishes. Catch and species richness were compared among three management areas (continuously closed, periodically closed, and open to commercial bottom trawling) using analysis of covariance models that account for variability due to area, year, and depth. The most appropriate models for catch (35 species treated individually and aggregated into six subgroups) and species richness were selected using Akaike's information criteria (AIC). All of the best fit models were highly significant ($P < 0.0001$), explaining 3 to 76% of the variation in catch and the majority (19 of 35) included both area and depth. For 27 species and five subgroups of demersal fishes, the mean CPUE (based on Tukey's multiple comparison test) was significantly greater within the area continuously closed to commercial bottom trawling relative to areas periodically closed or open. The most appropriate model for species richness included area and year and mean richness was greatest in the area continuously closed to commercial bottom trawling. Species-specific length composition distributions were calculated from subsampled individual lengths which were available for 31 species. Significant differences in length frequency distributions (Kolmogorov-Smirnov asymptotic test statistic, $P < 0.001$) were observed for these 31 demersal fish species, with a higher proportion of larger fish most often (~65%) present in areas continuously closed to commercial bottom trawling (20 of 31 species) relative to other areas. The data suggest that the RCA is an effective management tool for conserving not only rockfishes, but other demersal fish species. Although no increases in CPUE occurred over the time examined, both catch and species richness were greater in the closed portion of the RCA and a higher proportion of larger fish occurred within the RCA boundaries.

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**o) A review of essential fish habitat (EFH) for Pacific coast groundfishes**

A review of Essential Fish Habitat (EFH) for 91 species of Pacific coast groundfish was ongoing in 2013. The review of the key products developed for this study is now available to the public. Initial EFH designations were based on best available data developed from 2002 to 2005; NOAA's National Marine Fisheries Service (NMFS) implemented these designations in May 2006. Beginning in 2010, the Pacific Fisheries Management Council (PFMC), Northwest and Southwest Fisheries Science Centers, and the NMFS Regions initiated the next 5-year review for EFH provisions of the groundfish Fishery Management Plan. In Phase I of this process, new and relevant information were compiled and summarized for the review. Sources of information included published scientific literature and unpublished scientific reports, solicitation of data from interested parties, and the review of previously unavailable or inaccessible data sets. Coast-wide maps were updated for (1) bathymetry and interpreted groundfish habitat types, (2) the distribution and extent of commercial fishing effort (as potential impact to EFH), (3) the distribution and relative abundance of biogenic habitat (i.e., sponges and corals), and (4) spatial management boundaries (as potential mitigation of impacts). This complete body of information, in the form of a written report and supporting Internet data catalog, was presented to the PFMC, its advisory bodies and the public at the Council's September 2012 meeting (Phase I Report: http://www.pcouncil.org/2013/05/25450/rfp-gf-efh-may2013/; online data catalog: http://efh-catalog.coas.oregonstate.edu/overview/). NMFS conducted an analysis of the information in the Phase I Report, and delivered a Synthesis Report to the Council in April 2013 (http://www.pcouncil.org/2013/05/25450/rfp-gf-efh-may2013/). During Phase II of the process, the Council solicited proposals to modify EFH and Habitat Areas of Particular Concern (HAPC). The Council accepted the EFHRC Phase 2 report, thus formally ending the Phase 2 process. Towards the next step in Phase 3 the Council requested that the Northwest and Southwest Fisheries Science Centers investigate the question of essential fish habitat effectiveness, accuracy, and completeness, and present their findings at the September 2014 Council meeting. At the September meeting, the Council is tentatively scheduled to initiate a fishery management plan amendment, including alternatives for refining elements of groundfish EFH as warranted by new information, the Science Center evaluation, and proposals received. If the Council decides to amend EFH, Phase III of the process will begin and may require an amendment to the groundfish Fisheries Management Plan. This 5-year review represents a major update of the groundfish habitat assessment for the California Current and will have research and management applications well beyond satisfying the regulatory guidelines associated with EFH.

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**p) Evaluating sustainability of fisheries bycatch mortality for marine megafauna: a review of conservation reference points for data-limited populations**

Investigators: J.E. Moore, K.A. Curtis, R.L. Lewison, P.W. Dillingham, Jason M. Cope, S.V. Fordham, S.S. Heppell, S.A. Pardo, C.A. Simpfendorfer, G.N. Tuck and S. Zhou

Fisheries bycatch threatens populations of marine megafauna such as marine mammals, turtles, seabirds, sharks and rays, but fisheries impacts on nontarget populations are often difficult to assess due to factors such as data limitation, poorly defined management objectives and lack of quantitative bycatch reduction targets. Limit reference points can be used to address these issues and thereby facilitate adoption and implementation of mitigation efforts. Reference points based on catch data and life history analysis can identify sustainability limits for bycatch with respect to defined population goals even when data are quite limited. This can expedite assessments for large numbers of species and enable prioritization of management actions based on mitigation urgency and efficacy. This paper reviews limit reference point estimators for marine megafauna bycatch, with the aim of highlighting their utility in fisheries management and promoting best practices for use. Different estimators share a common basic structure that can be flexibly applied to different contexts depending on species life history and available data types. Information on demographic vital rates and abundance is required; of these, abundance is the most data-dependent and thus most limiting factor for application. There are different approaches for handling management risk stemming from uncertainty in reference point and bycatch estimates. Risk tolerance can be incorporated explicitly into the reference point estimator itself, or probability distributions may be used to describe uncertainties in bycatch and reference point estimates, and risk tolerance may guide how those are factored into the management process. Either approach requires simulation-based performance testing such as management strategy evaluation to ensure that management objectives can be achieved. Factoring potential sources of bias into such evaluations is critical. This paper reviews the technical, operational, and political challenges to widespread application of reference points for management of marine megafauna bycatch, while emphasizing the importance of developing assessment frameworks that can facilitate sustainable fishing practices.

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**q) Giants' shoulders 15 years later: lessons, challenges and guidelines in fisheries meta-analysis**

Investigators: J.T. Thorson, J.M. Cope, K.M. Kleisner, J.F. Samhouri, A.O. Shelton and E.J. Ward

Meta-analysis has been an integral tool for fisheries researchers since the late 1990s. However, there remain few guidelines for the design, implementation or interpretation of meta-analyses in the field of fisheries. Here, the authors provide the necessary background for readers, authors and reviewers, including a brief history of the use of meta-analysis in fisheries, an overview of common model types and distinctions, and examples of different goals that can be achieved using meta-analysis. The primary challenges in implementing meta-analyses are outlined, including difficulties in discriminating between alternative hypotheses that can explain the data with equal plausibility, the importance of validating results using multiple lines of evidence, the trade-off between complexity and sample size and problems associated with the use of model output. For each of these challenges, suggestions are also provided, such as the use of propensity scores for dealing with selection bias and the use of covariates to control for confounding effects. These challenges are then illustrated with examples from diverse subfields of fisheries, including (i) the analysis of the stock–recruit relationship, (ii) fisheries management, rebuilding and population viability, (iii) habitat-specific vital rates, (iv) life-history theory and (v) the evaluation of marine reserves. We conclude with our reasons for believing that meta-analysis will continue to grow in importance for these and many other research goals in fisheries science and argue that standards of practice are therefore essential.

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**r) Co-occurrence of bycatch and target species in the groundfish demersal trawl fishery of the U.S. west coast; with special consideration of rebuilding stocks**

Investigators: E. Heery and J.M. Cope

Bycatch and resultant discard mortality are issues of global concern. The groundfish demersal trawl fishery on the west coast of the United States is a multispecies fishery with significant catch of target and nontarget species. These catches are of particular concern in regard to species that have previously been declared overfished and are currently rebuilding biomass back to target levels. To understand these interactions better, data from the West Coast Groundfish Observer Program were used in a series of cluster analyses to evaluate 3 questions: 1) Are there identifiable associations between species caught in the bottom trawl fishery; 2) Do species that are undergoing population rebuilding toward target biomass levels (“rebuilding species”) cluster with targeted species in a consistent way; 3) Are the relationships between rebuilding bycatch species and target species more resolved at particular spatial scales or are relationships spatially consistent across the whole data set? Two strong species clusters emerged— a deepwater slope cluster and a shelf cluster—neither of which included rebuilding species. The likelihood of encountering rebuilding rockfish species is relatively low. To evaluate whether weak clustering of rebuilding rockfish was attributable to their low rate of occurrence, we specified null models of species occurrence. Results indicated that the ability to predict occurrence of rebuilding rockfish when target species were caught was low. Cluster analyses performed at a variety of spatial scales indicated that the most reliable clustering of rebuilding species was at the spatial scale of individual fishing ports. This finding underscores the value of spatially resolved data for fishery management.

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**s) Resolving the 10-year rebuilding dilemma for U.S. fish stocks**

Investigators: W.S. Patrick and J.M. Cope

Worldwide, a major goal of fisheries management is to maintain fish stocks at or above levels that produce maximum sustainable yields, and to rebuild overexploited stocks that can no longer support such yields. In the United States, rebuilding overexploited stocks is an especially contentious issue, where most stocks are mandated to rebuild in as short a time as possible, and in a time period not to exceed 10 years. Opponents of such mandates and related guidance, note that rebuilding requirements are arbitrary, and create discontinuities in the time and fishing effort allowed for stocks to rebuild due to differences in productivity. Proponents, however, highlight how these mandates and guidance were needed to curtail the continued overexploitation of these stocks by setting firm deadlines on rebuilding. Here the statements made by opponents and proponents of the 10-year rebuilding mandate were evaluate and related guidance provided to determine whether such points are technically accurate using a simple population dynamics model and a database of U.S. fish stocks to parameterize the model. Overall, the authors found several of the statements made about the rebuilding mandates and guidelines were not supported by the analyses (i.e., generation time of stocks correspond with productivity, guidelines are needed to prevent overfishing), while other statements were supported (i.e., most stocks can rebuild within five years, half of the U.S. stocks are susceptible to a 10-year moratorium, there is a discontinuity in rebuilding plans for short- and long-lived species, and the rebuilding framework increases transparency). Lastly, the authors offer a resolution to many of the issues surrounding this mandate and its implementation by recommending some constant fishing mortality (F) based frameworks, which meet the intent of 10-year rebuilding requirement while also providing more flexibility.

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**t) A Bayesian approach to estimation of length-weight relationships in fishes**

Investigators: R. Froese, J.T. Thorson and R.B. Reyes, Jr.

A Bayesian hierarchical approach is presented for the estimation of length-weight relationships (LWR) in fishes. In particular, estimates are provided for the LWR parameters, a and b, in general as well as by body shape. These priors and existing LWR studies were used to derive species-specific LWR parameters. In the case of data-poor species, the analysis includes LWR studies of closely related species with the same body shape. This approach yielded LWR parameter estimates with measures of uncertainty for practically all known 32,000 species of fishes. Provided is a large LWR data set extracted from www.fishbase.org, the source code of the respective analyses, and ready-to-use tools for practitioners. This is presented as an example of a self-learning online database where the addition of new studies improves the species-specific parameter estimates and where these parameter estimates inform the analysis of new data.

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### u) Rigorous meta-analysis of life history correlations by simultaneously analyzing multiple population dynamics models

Investigators: J.T. Thorson, I. Taylor, I.J. Stewart and A.E. Punt

Correlations among life history parameters have been discussed in the ecological literature for over 50 years, but are often estimated while treating model estimates of demographic rates such as natural mortality (M) or individual growth (k) as ‘‘data.’’ This approach fails to propagate uncertainty appropriately because it ignores correlations in estimation errors between parameters within a species and differences in estimation error among species. An improved alternative is multi-species mixed-effects modeling, which we approximate using multivariate likelihood profiles in an approach that synthesizes information from several population dynamics models. Simulation modeling demonstrates that this approach has minimal bias, and that precision improves with increased number of species. As a case study, the authors demonstrate this approach by estimating M/k for 11 groundfish species off the U.S. West Coast using the data and functional forms on which pre-existing, peer-reviewed, population dynamics models are based. M/k is estimated to be 1.26 for Pacific rockfishes (*Sebastes* spp.), with a coefficient of variation of 76% for M given k. This represents the first-ever estimate of correlations among life history parameters for marine fishes using several age-structured population dynamics models, and it serves as a standard for future life history correlation studies. This approach can be modified to provide robust estimates of other life history parameters and correlations, and requires few changes to existing population dynamics models and software input files for both marine and terrestrial species. Specific results for Pacific rockfishes can be used as a Bayesian prior for estimating natural mortality in future fisheries management efforts. We therefore recommend that fish population dynamics models be compiled in a global database that can be used to simultaneously analyze observation-level data for many species in life history meta-analyses.

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### v) Advice for estimating fishery management reference points given low frequency between-year environmental variability

Investigators: M.A. Haltuch, A.E. Punt and M.W. Dorn

There is strong evidence that low frequency between-year environmental variability, in addition to fishing, is able to affect fish population abundance via recruitment. However, scientific advice regarding catch limits is often based on control rules that depend on the estimation of biomass reference points which typically do not explicitly consider the effects of trends over time in reference points caused by environmental variability. Harvest rates based on commonly used biological reference points such as the level of un-fished spawning biomass (B0), the current size of the stock in relation to B0, and BMSY that are sustainable under current environmental conditions may be unsustainable under different environmental conditions. Although several methods exist for estimating biomass reference points, it is unclear which of these are most robust to the effects of long term, low frequency environmental variability. Therefore, simulation is used to evaluate alternative estimators, which differ in terms of how the stock–recruitment relationship is modeled, and whether explicit estimators or proxies are used for B0, the steepness of the stock–recruitment relationship, and current spawning biomass relative to B0. The simulations consider three life histories: a long-lived unproductive rockfish, a moderately long-lived and productive flatfish, and a moderately long-lived and productive hake with highly variable recruitment. Results indicate that in the presence of low frequency autocorrelated forcing of recruitment, biomass reference points should be based on average recruitment and/or dynamic B0 if catch and survey data are available for at least one full period of the environmental variable. In contrast, previous analysis suggests that in the absence of autocorrelated environmental forcing of recruitment, and if the available catch and survey data do not span at least, in this case, 50 years which is one full period of the environmental variable, biomass reference points should be based on the fit of the stock–recruitment relationship. Life history affects the estimability of biomass reference points, which are more difficult to estimate for species with more rapid dynamics such as hake. The method used to calculate the reference points given the results of a stock assessment has a larger effect on estimability than the configuration of the stock assessment method, for the three stock assessment model configurations investigated in this study.

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**w) Projecting U.S. west coast sablefish (*Anoplopoma fimbria*) recruitment under global climate change scenarios**

Investigators: M.A. Haltuch, N.A. Bond and M.J. Schirippa

U.S. west coast sablefish (*Anoplopoma fimbria*) recruitment has been correlated with changes in July sea surface height (SSH) measured at Crescent City, CA. This SSH index has been correlated with zooplankton abundance and previous research suggests that feeding conditions as indexed by zooplankton abundance and SSH are the mechanism driving sablefish recruitment. Given that the SSH-recruitment relationship has held up over time it was evaluated as a component of the 2011 sablefish stock assessment model. Assessment results found that the use of the environmental index did not have a large effect on model results due to the reasonably consistent signals from fishery and survey data sources regarding year-class strengths. This analysis focuses on using multi-decadal SSH forecasts to allow management to better respond to shifts in productivity before they occur, rather than refining our ‘hindsight’ further. Future environmental conditions, as manifested by changes in the timing, dynamics and productivity of the California current ecosystem, via climate change, or cycles similar to the historical period, are considered a significant source of uncertainty in the stock status projections. Therefore, this project investigates methods for scaling between the currently used local environmental covariate and larger scale measurements of SSH such as those produced by SODA for past conditions and IPCC-class climate models for future conditions. This project then produces long term projections of the sablefish population under alternative global climate change scenarios using the 2011 stock assessment to assess possible directional changes in sablefish recruitment on multi-decadal time scales.

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**x) A California current bomb radiocarbon reference chronology and petrale sole age validation**

Investigators: M.A. Haltuch, O.S. Hamel, K.R. Piner, P. McDonald, C.R. Kastelle and J.C. Field

As petrale sole (*Eopsetta jordani*) is a valuable groundfish harvested in the California Current, proper ageing is important for its assessment and management. This study presents the first bomb radiocarbon reference chronology for the California Current and petrale sole age validation. Break-and-burn and surface ages are negatively biased by approximately 1 year and 2–3 years, respectively. The reference and validation curves are more variable and show a lag in the rate of radiocarbon increase in comparison to most other time series of bomb radiocarbon in marine systems. Upwelling in the California Current produces a lagged rate of increase in radiocarbon levels owing to the introduction and mixing of radiocarbon-depleted deep waters with surface waters that interact with the atmosphere. The variable and lagged rate of radiocarbon increase in the petrale sole data may be due to their spending a substantial portion of their first year of life in areas subject to variable upwelling, illustrating the importance of using reference curves for age validation that are region and species specific when possible.

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**y) Improving ecosystem-based stock assessment and forecasting by using a hierarchical approach to link fish productivity to environmental drivers**

Investigators: Tim Essington, Trevor Branch (UW), Melissa Haltuch, Anne Hollowed, Paul Spencer, and Nate Mantua (NMFS).

We investigated the hypothesis that synchronous recruitment is due to a shared susceptibility to environmental processes using stock-recruitment residuals for 52 marine fish stocks within three Northeast Pacific large marine ecosystems: the Eastern Bering Sea and Aleutian Islands (BSAI), Gulf of Alaska, and California Current. There was moderate coherence in terms of exceptionally strong and weak year classes and significant distributions of across stock correlation. Based on evidence of synchrony from these analyses, we used Bayesian hierarchical models to relate recruitment to environmental covariates for groups of stocks with similar susceptibility to environmental processes. There were consistent relationships among stocks to the covariates, especially within the Gulf of Alaska and California Current. The best Gulf of Alaska model included Northeast Pacific sea surface height data as predictors of recruitment, and was particularly strong for stocks dependent on cross-shelf transport during the pelagic larval phase for recruitment. In the California Current the best-fit model included San Francisco coastal sea level data as predictors, with higher recruitment for many stocks corresponding to anomalously high sea level the year before spawning and low sea level the year of spawning. The best BSAI model included several environmental variables as covariates and there was some consistent response across stocks to these variables. Future research may be able to utilize these across stock environmental influences, in conjunction with an understanding of ecological processes important across early life history stages at appropriate temporal and spatial scales, to improve identification of environmental drivers of recruitment.

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**z) Fisheries management under climate and environmental uncertainty: control rules and performance simulation**

Investigators: A.E. Punt, T. A'Mar, N.A. Bond, D.S. Butterworth, C.L. de Moor, J.A.A. De Oliveira, M.A. Haltuch, A.B. Hollowed and C. Szuwalski.

The ability of management strategies to achieve fishery management goals are impacted by environmental variation and, therefore, also by global climate change. Management strategies can be modified to use environmental data using the "dynamic $B_0$" concept, and changing the set of years used to define biomass reference points. Two approaches have been developed to apply management strategy evaluation to examine the impact of environmental variation on the performance of management strategies. The "mechanistic approach" estimates the relationship between the environment and elements of the population dynamics of the fished species and makes predictions for population trends using the outputs from global climate models. In contrast, the "empirical approach" examines possible broad scenarios without explicitly identifying mechanisms. Many reviewed studies have found that modifying management strategies to include environmental factors does not improve the ability to achieve management goals much, if at all, and only if the manner in which these factors drive the system is well known. As such, until the skill of stock projection models improves, it seems more appropriate to consider the implications of plausible broad forecasts related to how biological parameters may change in the future as a way to assess the robustness of management strategies, rather than attempting specific predictions per se.

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## 2. Stock Assessment

### a) Stock assessment model development

Stock Synthesis (SS) is an assessment model in the class termed integrated analysis and is the basis for West Coast groundfish assessments and many other assessments around the world. SS is built with a population sub-model that simulates a stock's growth and mortality processes, an observation sub-model to estimate expected values for various types of data, and a statistical sub-model to characterize the data's goodness of fit and to obtain best-fitting parameters with associated variance. It includes a rich feature set including age- and size-based population dynamics and the ability to specify observational phenomena, such as ageing imprecision. Model parameters can vary over time or be specified as functions of environmental data. SS includes routines to estimate MSY and exploitation levels that correspond to various standard fishery management targets. It supports assessments spanning several geographic areas and can use tag-recapture data. A customizable harvest policy is used to conduct a forecast in the final phase of running the model. The model is coded in ADMB (www.admb-project.org). SS is included in the NOAA Fisheries Assessment Toolbox (http://nft.nefsc.noaa.gov/) incorporating a graphical user interface developed by Alan Seaver (NEFSC). It is now at version 3.24s as of July 2013).

*In 2013 Stock Synthesis was featured in the following publications as well as numerous publications reported below in section 10:*

Cope, J.M. 2013. Implementing a statistical catch-at-age model (Stock Synthesis) as a tool for deriving overfishing limits in data-limited situations. Fisheries Research. 142: 3-14.

Taylor, I.G., Gerseva, V., Methot, R.D., Maunder, M.N. 2013. A stock-recruitment relationship based on pre-recruit survival, illustrated with application to spiny dogfish shark. Fisheries Research. 42: 15-21.

MacCall, A.D. 2013. Use of the delta method to evaluate the precision of assessments that fix parameter values. Fisheries Research. 42: 56-60.

MacCall, A.D., Teo, S.L.H. 2013. A hybrid stock synthesis- Virtual population analysis model of Pacific bluefin tuna. Fisheries Research. 142: 22-26.

Maunder, M.N., Punt, A.E. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research. 42: 61-74.

Methot, R.D. Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research. 42: 86-99.

Punt, A.E., Maunder, M.N. 2013. Stock Synthesis: Advancing stock assessment application and research through the use of a general stock assessment computer program. Fisheries Research. 42: 1-2.

Stewart, I.J., Hicks, A.C., Taylor, I.G., Thorson, J.T., Wetzel, C., Kupschus, S. 2013. A comparison of stock assessment uncertainty estimates using maximum likelihood and Bayesian methods implemented with the same model framework. Fisheries Research. 42: 37-46.

Taylor, I.G., Methot, R.D. 2013. Hiding or dead? A computationally efficient model of selective fishing mortality. Fisheries Research. 42: 75-85.

Thorson, J.T., Stewart, I.J., Taylor, I.G., Punt, A.E. 2013. Using a recruitment-linked multispecies stock assessment model to estimate common trends in recruitment for US West Coast groundfishes. Marine Ecology Progress Series. 483: 245-256.

Wayte, S.E. 2013. Management implication of including a climate-induced recruitment shift in stock assessment for jackass morwong (*Nemadactylus macropterus*) in south-eastern Australia. Fisheries Research. 42: 47-55.

Whitten, A.R., Klaer, N.L., Tuck, G.N., Day, R.W. 2013. Accounting for cohort-specific variable growth in fisheries stock assessments: A case study from south-eastern Australia. Fisheries Research. 42: 27-36.

*Additional papers that featured Stock synthesis:*

Hurtado-Ferro, F., Punt, A.E., Hill, K.T. *in press*. Use of multiple selectivity patterns as a proxy for spatial structure. Fisheries Research.

Thorson, J.T., Taylor, I.G., Stewart, I., Punt, A.E. *in press*. Rigorous meta-analysis of life history correlation by simultaneously analyzing multiple population dynamics models. Ecological Applications.

Punt, A.E. Hurtado-Ferro, F., Whitten, A.R. *in press*. Model selection for selectivity in fisheries stock assessments. Fisheries Research.

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**b) Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management**

Investigators: R.D. Methot and C.R. Wetzel

Stock Synthesis (SS) is a statistical age-structured population modeling framework that has been applied in a wide variety of fish assessments globally. The framework is highly scalable from data-weak situations where it operates as an age-structured production model, to complex where it flexibly incorporates multiple data sources and accounts for biological and environmental processes. SS incorporates compensatory population dynamics through use of a function relating mean recruitment to spawner reproductive output. This function enhances its ability to operate in data-weak situations and enables SS to estimate fishery management quantities such as fishing rates that would provide for maximum sustainable yield and to employ these rates in forecasts of potential yield and future stock status. Complex model configurations such as multiple areas and multiple growth morphs are possible, tag-recapture data can be used to aid estimation of movement rates between areas, and most parameters can change over time in response to environmental and ecosystem factors. SS is coded using Auto-Differentiation Model

Builder, so inherits powerful capability to efficiently estimate hundreds of parameters using either maximum likelihood or Bayesian inference.

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**c) Hiding or dead? A computationally efficient model of selective fisheries mortality**

Investigators: I. Taylor and R.D. Methot

100 years after Rosa Lee (1912) showed that higher mortality on faster growing fish can alter length-at-age distributions in fish populations, a computationally-efficient and parsimonious method for modeling size-selective mortality within a commonly-used assessment model, Stock Synthesis, was developed. Stock Synthesis allows the normal distribution of length-at-age to be partitioned into three or five overlapping platoons with slow, medium, or fast growth trajectories. The platoons are tracked separately in the model, and experience different degrees of size-selective fishing pressure and mortality, but are assumed to be unobservable except through changes in the length distribution. Simulations are used to explore this phenomenon in conjunction with dome-shaped selectivity, an alternative explanation for observing fewer than expected large fish in sampled data, but with very different implications for population productivity. For data simulated both with and without platoons, misspecification of the assumptions about growth are found to bias model results, with selectivity often incorrectly identified as the cause of fewer observations of larger fish. Trends in dome-shaped selectivity were explored as a potential diagnostic of model misspecification.

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**d) A stock-recruitment relationship based on pre-recruit survival illustrated with application to spiny dogfish shark**

Investigators: I. Taylor, V. Gertseva, R.D. Methot, and M. Maunder

Understanding the relationship between abundance of spawners and subsequent recruitment is one of the central issues in fisheries stock assessment. A new, pre-recruit survival based stock–recruitment model was developed that enables explicit modeling of survival between embryos and age 0 recruits, and allows the description of a wide range of pre-recruit survival curves. The model is especially useful for low fecundity species that produce relatively few offspring per litter and exhibit a more direct connection between spawning output and recruitment than species generating millions of eggs. The proposed model provides additional flexibility in the stock–recruitment options that may be explored in any fishery stock assessment, and it is now available within the Stock Synthesis assessment platform. In this paper, the authors describe the mathematical formulation of the new stock–recruitment model, explain how this model can be specified within Stock Synthesis, and use it to model the stock–recruitment relationship of the spiny dogfish shark in the Northeast Pacific Ocean. The results of the application of this new stock–recruitment model were compared with those from traditional Beverton–Holt relationship, and illustrate why the new approach is more appropriate for this species.

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**e) Stock Synthesis Development Workshop, Seattle, WA, December 10-12 2013**

Investigator: R.D. Methot

A three day workshop was held to discuss Stock Synthesis. Topics ranging from: current available features including the R-SS interface and potential improvements, how best to use programmers for structured programming, steps to move towards an open source structure, wish list of features, and ease of use were discussed. Participants from research organizations and universities attended in person along with national and international participation through virtual attendance.

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**f) Implementing a statistical catch-at-age model (Stock Synthesis) as a tool for deriving overfishing limits in data-limited situations**

Investigator: J.M. Cope

Stock Synthesis (SS) is a likelihood-based statistical catch-at-age modeling environment allowing multiple data sources to be used to characterize population dynamics through time. While it is typically applied in data-rich circumstances, its suitability in data-limited situations is investigated in this work. Two "Simple Stock Synthesis" (SSS) approaches are outlined, each developed to mimic the Depletion-Based Stock Reduction Analysis (DB-SRA) estimation of overfishing limits (OFLs) currently applied to data-limited U.S. west coast groundfish species. SSS-MC uses Monte Carlo draws of natural mortality, steepness, and stock depletion and estimates initial recruitment, while SSS-MCMC estimates natural mortality, steepness, and initial recruitment while fitting to an artificial abundance survey representing stock depletion with an error distribution equivalent to the stock depletion prior used in DB-SRA. These approaches are applied to 45 species of unassessed groundfishes in the Pacific Fishery Management Council Groundfish Fishery Management Plan, and the OFL estimates are compared to corresponding DB-SRA estimates. Despite model structure and parameter specification differences, SSS led to results comparable to DB-SRA over a wide range of species and life histories. SSS models with sex-specific life history parameters and growth variability are also presented as examples of how the inherent flexibility of SS can be used to account for more uncertainty in derived quantities. SSS-MCMC, while exhibiting statistically undesirable traits due to the inclusion of the artificial survey, readily includes data-informed abundance surveys into an assessment framework consistent with more complex, data-informed assessments. Establishment of viable data-limited approaches in SS is a convenient first steps in "building-up" stock assessments towards fuller implementation in SS when additional data become available, while also providing a way to inform management in data-limited situations.

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**g) Applying catch-only (SSS) and catch-index (exSSS) methods in Stock Synthesis to northeast Pacific groundfishes**

Investigators: J.M. Cope, J.T. Thorson and C.R. Wetzel

Recent applications of Stock Synthesis have reduced the stock assessment information to catch-only (Simple Stock Synthesis [SSS]) and catch and index (extended Simple Stock synthesis [exSSS]) models to provide information on sustainable catch levels and status. To further understand the behavior of these applications, the authors stripped down several data-heavy stock assessments into SSS and exSSS versions and compared biomass and depletion trajectories. These comparisons seek to understand general patterns of these approaches, including the level of estimated uncertainty and systematic behavior of derived quantities. The authors also applied an updated prior on depletion to theoretically improve performance and compared those results to previous implementations that assume a similar depletion prior for all stocks.

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**h) Stock assessment and management in data-limited situations**

Investigator: J.M. Cope

A presentation given to an Indonesian delegation visiting the NWFSC highlighted the work being done in developing data-limited stock assessment methods and areas wherein collaboration could advance the development and application of this work.

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**i) The biology of fisheries stock assessments**

Investigator: J.M. Cope

Stock assessments provide a critical link between science and management. The integrated nature of stock assessments means many different data types are used to present the best available scientific information for management use. This overview presents not only the inter-relationships of disparate data types typically used in U.S. west coast groundfishes stock assessments, but also the “life cycle” of an assessment: from family planning/birth (stock prioritization), early development (data and parameters), adolescence (stock assessment review), maturity (assessment application), senility/death (expire assessments), and reincarnation (alternative stock assessment approaches).

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**j) The (d)evolution of U.S. west coast groundfish assessments: from data-poor to data-less poor and back**

Investigators: J.M. Cope, E.J. Dick and C.R. Wetzel

The 1982 groundfish fishery management plan (FMP), comprising 90+ species, ushered in the era of formal groundfish management for the Pacific Fishery Management Council. Early stock assessments were comprised of data summaries and stock reduction analysis. Synthetic approaches started being applied in the late 1980s and remain the predominant approach, though only about a third of managed stocks have ever applied such models. The reauthorization of the Magnuson-Stevens Act in 2006, requiring annual catch limits (ACLs), changes the emphasis from "data-rich" only to "data-poor" stock assessment development to include analyzing all species within an FMP. The authors present this "evolution" from full synthetic models back to deterministic modeling approaches. Two newer implementations of catch-only and catch-index methods were featured, Depletion-based- Stock Reduction Analysis (DB-SRA) and Simple Stock Synthesis (SSS) developed to meet these management needs, and applyied them to several groundfish stocks lacking current stock assessments. Simulation results also give insight into how each model performs under known conditions. The development of these models bridges scientific advice to management across different resource availability and management needs. It also highlights current deficiencies and the need for ongoing model development, including the use of approaches that do not need baseline information. While data-limited stock assessments, by definition, are inherently dealing with high parameter and data uncertainty, the results demonstrate such reasons are insufficient to disregard their utility. Management— and ultimately the resources and its users—can benefit from such applications.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

**k) A new role for effort dynamics in the theory of harvest populations and data-poor stock assessment**

Investigators: J.T. Thorson, Minto, Coilin, C. Minte-Vera, K. Kleisner and C. Longo

Research shows that population status can be predicted using catch data, but there is little justification for why these predictions work or how they account for changes in fisheries management. The authors demonstrate that biomass can be reconstructed from catch data whenever fishing mortality follows predictable dynamics over time (called "effort dynamics"), and develop a state-space catch only model (SSCOM) for this purpose. Theoretical arguments and simulation modeling were used to demonstrate that SSCOM can, in some cases, estimate population status from catch data. Next, the authors use meta-analysis to estimate effort dynamics for U.S. West Coast groundfishes before and after fisheries management changes in the mid-1990s. They apply the SSCOM using meta-analytic results to data for eight assessed species and compare results with stock assessment and data-poor methods. Results indicate general agreement among all three methods. The authors conclude that effort dynamics provides a theoretical basis for using catch data to reconstruct biomass and has potential for conducting data-poor assessments.

However, they still recommend that index and compositional data be collected to allow application of data-rich methods.

For more information, please contact James Thorson at James.Thorson@noaa.gov

**l) A comparison of parametric, semi-parametric, and non-parametric approaches to selectivity in age-structured assessment models**

Investigators: J.T. Thorson and I.G. Taylor

Integrated assessment models frequently track population abundance at age, and hence account for fishery removals using a function representing fishery selectivity at age. However, fishery selectivity may have an unusual shape that does not match any parametric function. For this reason, previous research has developed flexible 'non-parametric' models for selectivity that specify a penalty on changes in selectivity as a function of age. In this study, the authors describe an alternative 'semi-parametric' approach to selectivity, which specifies a penalty on differences between estimated selectivity at age and a pre-specified parametric model whose parameters are freely estimated, while also using cross-validation to select the magnitude of penalty in both semi- and non-parametric models. The authors then compare parametric, semi-parametric, and non-parametric models using simulated data and evaluate the bias and precision of estimated depletion and fishing intensity. Results show that semi- and non-parametric models result in little decrease in precision relative to the parametric model when the parametric model matches the true data-generating process, but that the semi- and non-parametric models have less bias and greater precision when the parametric function is misspecified. As expected, the semi-parametric model reverts to its pre-specified parametric form when age-composition sample size is low but performs similarly to the non-parametric model when sample size is high. Overall, results indicate few disadvantages to using the non-parametric model given the range of simulation scenarios explored, and that the semi-parametric model provides a selectivity specification that is intermediate between parametric and non-parametric forms.

For more information, please contact James Thorson at James.Thorson@noaa.gov

**m) A comparison of stock assessment uncertainty estimates using maximum likelihood and Bayesian methods implemented with the same model framework**

Investigators: I.J. Stewart, A.C. Hicks, I.G. Taylor, J.T. Thorson, C.R. Wetzel and S. Kupschus

Many fisheries stock assessment models are implemented specifically for likelihood-based estimation or for Bayesian inference (via full integration of the joint posterior distributions), but not all have appropriate structure for both statistical approaches. Bias correction of recruitment deviations, in particular, must be adjusted to achieve consistency in each case. Fisheries management often uses the two types of results similarly, setting future catch quotas based on expected values or posterior medians depending on which is available given time constraints. Using two recent examples from the U.S. west coast, Pacific hake and sablefish, both implemented in Stock Synthesis, the authors find that likelihood-based estimates of key management quantities, such as spawning biomass, corresponded well with posterior modes, but tend to be lower (on an absolute scale) than posterior median values and that the asymptotic approximation for uncertainty intervals based on the Hessian matrix tends to overestimate the likelihood of smaller stock sizes and underestimate that of larger stock sizes. This pattern may be caused by a basic asymmetry in most fisheries data-sets: the necessity of a minimum stock size to have generated the observed catch/time-series, but little information regarding the plausibility among much larger stock sizes. Where only one type of inference is available, this asymmetry may be important for management decision-making. Even if management takes explicit account of uncertainty, in some cases adding a precautionary buffer that scales with the relative uncertainty in point estimates, the differences in catch advice may turn out to be important and the relative reductions non-linear.

For more information, please contact James Thorson at Allan.Hicks@noaa.gov

**n) Using a recruitment-linked multispecies stock assessment model to estimate common trends in recruitment for U.S. West Coast groundfishes**

Investigators: J.T. Thorson, I.G. Taylor, I.J. Stewart and A.E. Punt

Recruitment is highly variable in marine fishes, and is often estimated using stock–recruit relationships that explain little of the observed variability in recruitment. Researchers have sought for decades to identify environmental indices that are associated with cohort strength, and often use stock assessment estimates of recruitment within secondary regressions to test hypothesized drivers of recruitment variability. This practice is statistically questionable because it fails to acknowledge differences in the precision of recruitment estimates among species and years, as well as covariance between recruitment estimates within a given species. We developed an alternative, statistically rigorous method to estimate an index of cohort strength that is shared among several species while accounting for each single-species stock–recruit relationship. This method simultaneously optimizes multiple stock assessment models with shared cohort strength parameters, while using observation-level fishery data for each species to propagate the precision and covariance of recruitment estimates. The method is demonstrated using data for 8 groundfish species off the U.S. West Coast for which recruitment is relatively well estimated: our model estimated high recruitment during 1990–1991 and 1999–2000, followed by anomalously low recruitment during 2002–2007. The impact of a shared index of cohort strength is demonstrated for 2 additional species with little information about recruitment, yelloweye *Sebastes ruberrimus* and blackgill *Sebastes melanostomus* rockfishes, where it decreases the coefficient of variation for recruitment estimates in the most recent modeled year by 40%. The method can be applied to other fishery management regions in the USA and elsewhere, and represents a rigorous method to estimate associations in cohort strength among species within a region.

**o) A method for calculating a meta-analytical prior for the natural mortality rate using multiple life-history correlates**

Investigator: O.S. Hamel

The natural mortality rate *M* is an extraordinarily difficult parameter to estimate for many fish species. The uncertainty associated with *M* translates into increased uncertainty in fishery stock assessments. Estimation of *M* within a stock assessment model is complicated by the confounding of this parameter with other life history and fishery parameters which are also uncertain and some of which are typically estimated within the model. Ageing error and variation in growth, which may not be fully modeled, can also affect estimation of *M*, as can assumptions, including the assumed form of the stock recruitment function (e.g., Beverton-Holt, Ricker) and the level of compensation (or steepness), which may be fixed (or limited by a prior) in the model. To avoid this difficulty, stock assessors often assume point estimates for M derived from meta-analytical relationships between *M* and more easily measured life history characteristics. However, these relationships depend upon estimates of *M* for a great number of species, and those estimates are also subject to errors and biases (as are, to a lesser extent, the other life history parameters). Therefore, at the very least, some measure of uncertainty should be calculated and used for evaluating uncertainty in stock assessments as well as in fishery management evaluations. Given error-free data on *M* and the covariate(s) for the meta-analysis, prediction intervals provide the appropriate measure of uncertainty in *M*. In contrast, if the relationship between the covariate(s) and *M* is exact and the only error is observation error in *M*, confidence intervals are appropriate. In this talk I will describe both types of intervals, develop priors based upon multiple published meta-analyses of various life history correlates using the prediction interval calculation, and discuss some caveats and considerations when deciding which meta-analyses to use in developing priors.

This research was presented at the World Conference on Stock Assessment Methods for Sustainable Fisheries in Boston, MA in July, 2013. A manuscript has been submitted to the ICES Journal of Marine Science.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov.

**p) Bootstrapping of sample sizes for length- or age-composition data used in stock assessments**

Investigators: I.J. Stewart and O.S. Hamel

Integrated stock assessment models derive estimates of management quantities by fitting to indices of abundance and length and age compositions. For composition data, where a multinomial likelihood is often applied, weights are determined by input sample sizes, which can be an important contributor to model results. The authors used a generic bootstrap method, verified through simulation, to calculate year-specific maximum realized sample sizes from the observation error inherent in fishery biological data. Applying this method to length-composition observations for 47 groundfish species collected during a standardized trawl survey, the authors found maximum realized sample size to be related to both the number of hauls and individual fish sampled from those hauls. Sampling in excess of 20 fish from each haul produced little increase in most cases, with maximum realized sample size ranging from approximately 2-4 per haul sampled. Utilizing these maximum realized sample sizes as input values for stock assessment (analogous to minimum variance estimates), appropriately incorporates interannual variability, and may reduce over-emphasis on composition data. Results from this method can also help determine sampling targets.

A manuscript on this subject has been accepted at the Canadian Journal of Fisheries and Aquatic Sciences.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov.

**q) Biology, fisheries, assessment and management of Pacific hake (*Merluccius productus*)**

Investigators: O. S. Hamel, P.H. Ressler, R. E. Thomas, D.A. Waldeck, A.C. Hicks, J.A. Holmes and G.W. Fleischer

Pacific hake (*Merluccius productus*), also known as Pacific whiting, is the most abundant commercial fish species in the California Current Large Marine Ecosystem (CCLME) and is an important part of the ecosystem as both predator and prey. A large migratory population occurs off California, Oregon, and Washington in United States waters and off British Columbia in Canadian waters. Smaller distinct non-migratory populations of Pacific hake occur in major inlets of the northeast Pacific Ocean, including the Strait of Georgia and Puget Sound. The coastal Pacific hake population has supported a fishery averaging 222 thousand tonnes per year since 1966. Coastal Pacific hake migrate to northern feeding areas in the summer and southern spawning areas in the winter. The extent of the northern migration and the distribution along the coast are related to the population age and size composition and to varying ocean-climatic conditions, which also influence growth and location of spawning aggregations. Pacific hake have a lifespan of around 20 years, reach maturity around age 4, and achieve an average asymptotic size of 53 cm.

Coastal Pacific hake are managed under the auspices of a treaty between the United States and Canada, and the two countries jointly conduct acoustic surveys of the resource, stock assessments, stock assessment reviews and management meetings. Prior to the treaty there were independent and competing stock assessments from the United States and Canada. The Hake Treaty established a default harvest policy, a fixed harvest allocation for each country, and a Joint Management Committee that determines the annual coastwide Total Allowable Catch based on the best available science, the treaty's default harvest policy, and input from industry advisors. Regulation and management of the individual fisheries continues to rest within each country.

The fishery is executed by four sectors in the United States: vessels that deliver to shore-based processors, vessels that deliver to at-sea processors (motherships), vessels that both catch and process at-sea (catcher-processors), and a tribal fishery. The Canadian fishery is prosecuted by vessels that deliver to shore-based processors, with a joint-venture mothership sector in some years. The Pacific hake fishery in the United States and Canada is jointly certified by the Marine Stewardship Council as a sustainable fishery. Pacific hake must be frozen or processed soon after harvest to achieve a marketable product. Currently, most Pacific hake is marketed as fillets or headed and gutted products, although previously a large portion of the harvest was turned into surimi. While none of these products demand a high price, the total revenue to the industry is in the tens of millions of U.S. dollars.

A chapter on this subject has been accepted at for publication in a new book Hakes: biology and exploitation.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov.

**r) Estimating process error in the assessment for Pacific hake and its effect on management decisions**

Investigators: A.C. Hicks, N.G. Taylor, S.Cox, I.G. Taylor and C. Grandin

Pacific hake or whiting (*Merluccius productus*) is the largest groundfish fishery off of the West Coast of the United States and Canada with recent annual catches ranging from 177,000 to 363,000 metric tons. Large variability in recruitment characterizes this stock with strong year-classes often supporting the fishery for many years. The stock is jointly assessed and managed by the U.S and Canada under an international agreement, and the countries conduct a stock assessment annually to provide up-to-date estimates of the highly variable population. However, data are typically not available for age-1 hake resulting in a large amount of uncertainty in the prediction of incoming year classes and can be the cause of considerable angst when setting quotas for a fishery that begins catching significant numbers of age-2 hake. Recently, there has been concern that estimates of large year-classes are biased high when the cohort is young and there are few years of data to inform the strength of the cohort. Through simulation, we investigated the estimates of recruitment for strong, average, and weak cohorts under the current paradigm of data collection and assessment modeling. Under the ideal situations assumed in the simulations, recruitment estimates show a small bias which is reduced as the cohort ages and multiple observations are available. However, we attempt to explain why recent retrospective patterns in estimated recruitment from the actual stock assessment have occurred and if this is a pattern that we can expect to see in the future.

A poster of this research was presented at the World Conference on Stock Assessment Methods for Sustainable Fisheries in Boston, MA on July 17, 2013.

For more information, please contact Allan Hicks at Allan.Hicks@noaa.gov.

**s) Random effect estimation of time-varying factors in Stock Synthesis**

Investigators: J. T. Thorson, A.C. Hicks and R.D. Methot

Biological processes such as fishery selectivity, natural mortality, and somatic growth can vary over time, but it is challenging to estimate the magnitude of time-variation of demographic parameters in population dynamics models, particularly when using penalized likelihood estimation approaches. Random-effect approaches can estimate the variance, but are computationally infeasible or not implemented for many models and software packages. The authors show that existing models and software based on penalized-likelihood can be used to calculate the Laplace approximation to the marginal likelihood of parameters representing variability over time, and specifically demonstrate this approach via application to Stock Synthesis. Using North Sea cod and Pacific hake models as case studies, the authors show that this method has little bias in estimating variances for simulated data. It also provides a similar estimate of variability in hake recruitment (log-SD = 1.43) to that obtained from Markov chain Monte Carlo (MCMC) methods (log-SD = 1.68), and the method estimates a non-trivial magnitude (log-SD = 0.07) of variation in growth for North Sea cod. The authors conclude by discussing the generality of the proposed method and by recommending future research regarding its performance relative to MCMC, particularly when estimating multiple variances simultaneously.

Published in ICES Journal of Marine Science, January 9, 2014.

For more information, please contact James Thorson at James.Thorson@noaa.gov

## C. By Species, by Agency

The PFMC currently operates under a biennial schedule for the development of stock assessments and management guidance. For all groundfish species except Pacific hake, stock assessments are scheduled for review only during odd-numbered years. A schedule for Stock Assessment Review (STAR) panels for full assessments of species conducted in 2013, along with the 2013 and 2014 Hake Scientific Review Group meetings, is shown in Table 1.

**Table 1.** Review Schedule for Full Groundfish Assessments.

| STAR PANEL | STOCK | AUTHOR(S) | REVIEW PANEL DATES | STAR PANEL LOCATION |
|---|---|---|---|---|
| Hake SRG* Panel | Pacific hake/ whiting | Allan Hicks<br>Nathan Taylor<br>Chris Grandin<br>Ian Taylor<br>Sean Cox | February 19-22, 2013 | Vancouver, British Columbia Canada |
| Hake SRG* Panel | Pacific hake/ whiting | Allan Hicks<br>Nathan Taylor<br>Chris Grandin<br>Ian Taylor<br>Sean Cox | February 18-21, 2014 | Seattle, WA, USA |
| 1 | Data Moderate: Brown, China, Copper, Sharpchin, Stripetail**, Vermilion***, Yellowtail rockfish; Rex and English sole | Jason Cope<br>E.J. Dick | April 22-26, 2013 | Santa Cruz, CA |
| 2 | Petrale Sole<br>Darkblotched rockfish | Melissa Haltuch<br>Vlada Gertseva | May 13-17, 2013 | Seattle, WA |
| Updates<br>Data Reports | Bocaccio rockfish<br>Canary rockfish<br>Pacific ocean perch<br>Yelloweye rockfish | John Field<br>John Wallace<br>Owen Hamel<br>Ian Taylor | June 18, 2013 | Garden Grove, CA |
| 3 | Rougheye rockfish<br>Aurora rockfish | Allan Hicks<br>Owen Hamel | July 8 – 12, 2013 | Seattle, WA |
| 4 | Shortspine thornyhead<br>Longspine thornyhead | Ian Taylor<br>Andi Stephens | July 22 -26, 2013 | Seattle, WA |
| 5 | Cowcod<br>Pacific sanddab** | E.J. Dick<br>Xi He | August 8-12, 2013 | Santa Cruz, CA |

***Scientific Review Group – for international review of Pacific hake under treaty with Canada
**Accepted for status determination but not for management (scale of population not accepted)
*** Not accepted for management or status determination at the STAR panel

## 1. Shelf Rockfish - West Coast

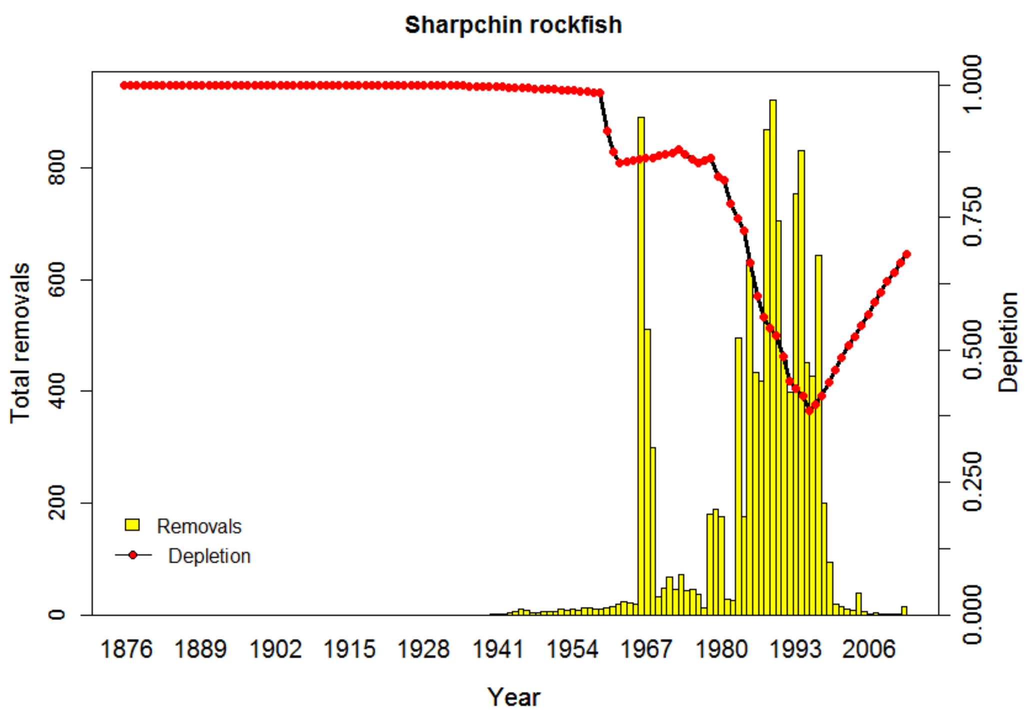
### a) Stock Assessments

Full assessments of cowcod and data moderate rockfish species brown, china, copper, sharpchin, stripetail, and yellowtail were conducted in 2013. An update of the 2009 assessment of bocaccio and data reports on canary and yelloweye rockfish and Pacific ocean perch were also conducted in 2013.

**Bocaccio:** An update of the 2009 bocaccio assessment was conducted in 2013 by the SWFSC. The complete version of: Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas as evaluated for 2013 can be viewed online at:
http://www.pcouncil.org/wp-content/uploads/Bocaccio_2013_Assessment_Update..pdf
For more information on the bocaccio assessment, contact John Field at John.Field@noaa.gov

**Brown, China, Copper, Sharpchin, Stripetail and Yellowtail rockfishes:** Catch and index only assessments ("data-moderate" assessments) were performed for 5 groundfish species. Four of the five had sufficient information in the index data to advise catch levels and status determination (see Figure 3a and 3b below for assessment summaries for sharpchin and yellowtail rockfish). Stripetail rockfish had too much uncertainty in the scale of the population to inform catches, but could inform stock status enough to indicate the population was well above the target stock status.

**A.**



**B.**

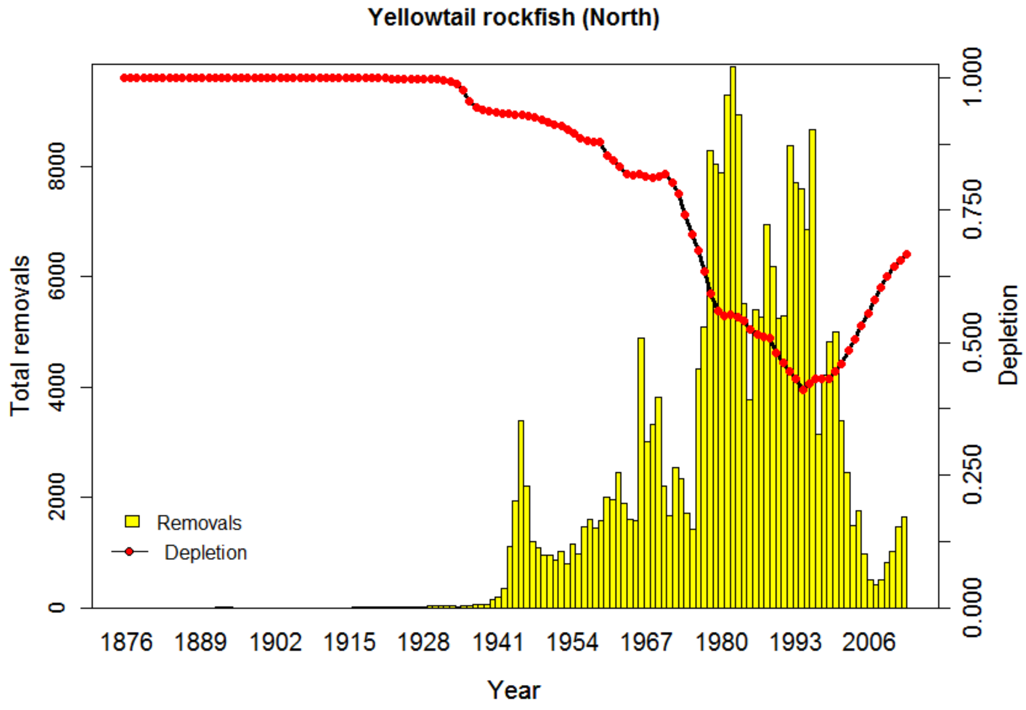



**Figure 3.** Time series of total removals (mt; bars) and estimated depletion (line) for A) sharpchin and B) yellowtail rockfish.

The data moderate assessment document for the brown, china, copper, sharpchin, stripetail (status only), and yellowtail rockfish can be found at: http://www.pcouncil.org/groundfish/stock-assessments/by-year/gf2013/.

For more information on the 2013 data-moderate rockfish assessments, contact Jason Cope at Jason.Cope@noaa.gov or E. J. Dick at Edward.Dick@noaa.gov.

**Cowcod:** The complete version of the 2013 stock assessment of cowcod, *Sebastes levis*, can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/cowcod/
For more information on the cowcod assessment, contact E. J. Dick at Edward.Dick@noaa.gov

**Canary rockfish:** A data report showing that overfishing has not been occurring was conducted for canary rockfish in 2013. For more information on the canary rockfish data report, contact John Wallace at John.Wallace@noaa.gov

**Yelloweye rockfish:** A data report showing that overfishing has not been occurring was conducted for yelloweye rockfish in 2013. For more information on the yelloweye rockfish data report, contact John Wallace at John.Wallace@noaa.gov

## 2. Slope Rockfish

### a) Stock assessments

Full assessments of aurora, darkblotched, and rougheye and blackspotted rockfish (the latter two as a complex), and a data report on Pacific ocean perch were conducted in 2013.

**Aurora rockfish**: This first full age-structured assessment for aurora rockfish (*Sebastes aurora*) reports the status of the species off the west coast of the United States. Aurora rockfish are a long-lived member of the rockfish family, with a life-span over 100 years while reaching lengths only in the mid-30 cm range. Aurora rockfish occur from the Queen Charlotte Islands (British Columbia, Canada) south to mid-Baja California (Mexico), but are most common in U.S. waters from northern Oregon to southern California. They are deep-dwelling, occurring from 200 to 700 meters, with the median depth increasing to the south. They are most abundant from 350 to 550 m in the north and 400 to 600 m in the south. While there are intermittent areas of greater and lesser abundance, the population appears continuous over the entire coast and there is no clear point for stock delineation. For the purposes of this assessment, the population of Aurora rockfish was treated as a single stock from the U.S.-Mexico border to the U.S.-Canada border.

Previous estimates of sustainable aurora rockfish removals (via catch-only methods) compared to actual removals indicated possibly elevated overfishing risks. The aurora base-case model provides an improved basis for evaluating the stock's exploitation history. Even so, the assessment relies upon a number of parameters estimated outside of the model. The natural mortality rate in the model is set equal to the median of the prior distribution based upon Hoenig's method relating natural mortality to longevity (Hoenig, 1983). The steepness of the Beverton-holt stock-recruitment relationship is set equal to the median of the meta-analytical prior used for the 2013 stock assessments.

The current model estimates that exploitation of aurora rockfish has been relatively low, with total catch estimated to have exceeded the current management harvest-rate limits in only 2 years, during the early peak in trawl catch (1990 and 1992). Recent levels of removals have remained moderate. There is very low risk that current removals are causing overfishing. Unfished spawning biomass (acting as a proxy for productions of eggs or larva) is estimated to be 2626 mt (95% CI: 1165-4087; CV = 28.4%) with spawning biomass at the beginning of 2013 estimated to be 1050 mt (95% CI: 466-1635; CV = 40.4%). The stock's status is estimated to be at 64% of the unfished level in 2013. Both scale and status are very sensitive to assumed natural mortality rates, though all plausible values of this parameter result in estimated current status above the biomass target ($B_{40\%}$).

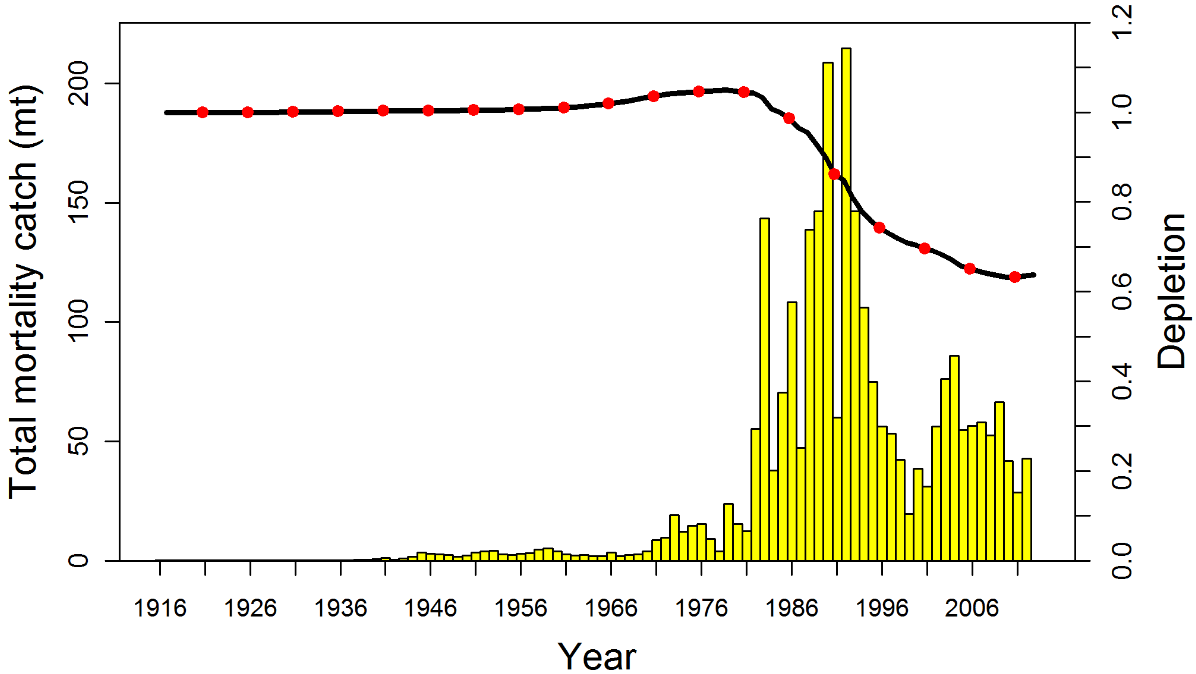



**Figure 4**. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for aurora rockfish, 1936-2013.

The complete version of "Stock assessment of aurora rockfish in 2013" can be found online at: http://www.pcouncil.org/wp-content/uploads/AURORA_Assessment_2013_Final.pdf

For more information on the aurora rockfish assessment, contact Owen Hamel at Owen.Hamel@noaa.gov

**Darkblotched rockfish:** Darkblotched rockfish (*Sebastes crameri*) in the Northeast Pacific Ocean occur from the southeastern Bering Sea and Aleutian Islands to near Santa Catalina Island in southern California. This species is most abundant from off British Columbia to Central California. Commercially important concentrations are found from the Canadian border through Northern California. This assessment focuses on the portion of the population that occurs in coastal waters of the western United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The population within this area is treated as a single coastwide stock, due to the lack of biological and genetic data supporting the presence of multiple stocks.

Darkblotched rockfish has always been caught primarily with commercial trawl gear, as part of a complex of slope rockfish, which includes Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*). Catches taken with non-trawl gear over the years comprised less than 2% of the total coastwide domestic catch. This species has not been taken recreationally.

Catch of darkblotched rockfish first became significant in the mid-1940s when balloon trawl nets (efficient in taking rockfish) were introduced, and demand for rockfish increased due to World War II. The largest removals of the species occurred in the 1960s, when foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria and East Germany came to the Northeast Pacific Ocean to target large aggregations of Pacific ocean perch, a species that co-occurs with darkblotched rockfish. In 1966 the removals of darkblotched rockfish reached 4,220 metric tons. By the late-1960s, the foreign fleet had almost abandoned the fishery. Domestic landings of darkblotched rockfish rose again between the late-1970s and the late-1980s, peaking in 1987 with landings of 2,415 metric tons. Since the mid-1970s, a small amount of darkblotched rockfish has been also taken as bycatch in the at-sea Pacific hake fishery, with a maximum annual removal of 49 metric tons that occurred in 1995. In 2000, the species was declared overfished, and landings substantially decreased due to management regulations. This species is currently in under rebuilding. During the last decade the average landings of darkblotched rockfish made by the domestic trawl fishery was around 120 metric tons.

The first stock assessment of darkblotched rockfish was done in 1993 and stock assessments have been conducted frequently since then. This current assessment, conducted in 2013, shows that the stock of darkblotched rockfish off the continental U.S. Pacific Coast is currently at 36% of its unexploited level. This is above the overfished threshold of 25% of unexploited stock ($SB_{25\%}$), but below the management target of 40% of unfished spawning output ($SB_{40\%}$). Historically, the spawning output of darkblotched rockfish dropped below the $SB_{40\%}$ target for the first time in 1987, as a result of intense fishing by foreign and domestic fleets. It continued to decline and reached the level of 13% of its unfished output in 1999. Since 2000, when the stock was declared overfished, the spawning output was slowly increasing primarily due to management regulations instituted for the species.

The time series of total mortality catch (landings plus discards) and estimated depletion for darkblotched rockfish are presented in Figure 5.

The assessment model captures some uncertainty in estimated size and status of the stock through asymptotic confidence intervals estimated within the model. To further explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed. A major source of uncertainty in the assessment is related to natural mortality, which was found to have a relatively large influence on the perception of current stock size. Female natural mortality in the assessment is fixed at the value estimated outside the model, based on other life history characteristics of the species, while male natural mortality is estimated within the model. Uncertainty from natural mortality is reported via alternate states of nature in the decision table, bracketing the base model results.

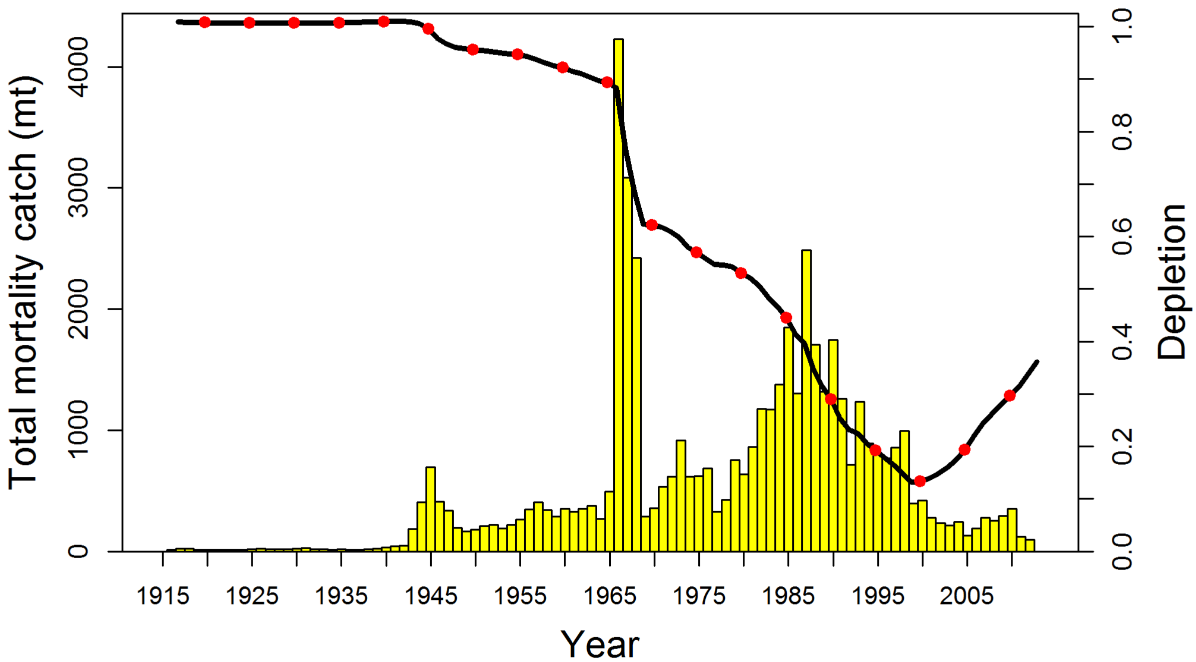



**Figure 5.** The time series of total mortality catch (bars) and estimated depletion (line) for darkblotched rockfish.

The complete version of "Status of the Darkblotched Rockfish Resource off the Continental U.S. Pacific Coast in 2013" can be found online at: http://www.pcouncil.org/wp-content/uploads/Darkblotched_2013_Assessment.pdf

For more information on the darkblotched rockfish assessment, contact Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

**Pacific ocean perch:** A data report showing that overfishing has not been occurring was conducted for Pacific ocean perch in 2013. For more information on the Pacific ocean perch data report, contact John Wallace at John.Wallace@noaa.gov

**Rougheye and blackspotted rockfishes:** This is an assessment of rougheye rockfish (*Sebastes aleutianus*) that reside in the waters off California, Oregon, and Washington from the U.S.-Canada border in the north to the U.S.-Mexico border in the south. Rougheye rockfish are more common north of the California-Oregon border and are also harvested in waters off British Columbia and the Gulf of Alaska. Although catches north of the U.S.-Canada border were not included in this assessment, it is not certain if those populations contribute to the biomass of rougheye rockfish off of the U.S. West Coast possibly through adult migration and/or larval dispersion.

The depth and geographic distribution of blackspotted rockfish (*S. melanostictus*) overlaps with rougheye rockfish and it is very difficult to visually distinguish between the two species. It has only been from recent genetic studies in the early 2000's that two separate species have been identified and described. Consequently, the vast majority of data that are available include pooled contributions from both rougheye rockfish and blackspotted rockfish. Due to the difficulty in distinguishing these two species and the lack of historical separation of the species in all of the data, this assessment combines any data for blackspotted rockfish with rougheye rockfish and provides management advice for the two species combined. In this assessment, the term "rougheye rockfish" refers to rougheye and blackspotted rockfishes unless specified.

Rougheye rockfish are landed as part of the minor slope rockfish species complex. Because landings from the complex need not be sorted into component species for purposes of fish-ticket reporting, species composition sampling of this 'market' category is required to determine the amount of landed catch. The uncertainty in species composition is greater in past years, thus landings of rougheye rockfish are not well known further back in history.

This assessment was the first formal assessment model for rougheye rockfish on the U.S. West Coast and was conducted using the length- and age-structured model called Stock Synthesis (version 3.24o, pers. comm. Richard Methot, NMFS). The data used in the assessment model consisted of survey abundance indices, length compositions, discard data, and ages. Model-based biomass indices and length compositions were determined from three different surveys. Length data were also available from the fisheries in recent years. Discard data for the trawl and hook & line fisheries were available for 2002–2011 in the form of discarded biomass, length compositions, and average weights. No data were available to inform discarding practices of rougheye rockfish prior to 2002, although anecdotal information suggests little discarding occurred before trip limits were implemented in the 1990's.

Although there are many types of recent data available for rougheye rockfish, which were used in this assessment, there is little information about steepness, natural mortality, and historical recruitment. Estimates of steepness are uncertain partly because the stock has not been fished to low levels. Uncertainty in natural mortality is common in many fish stock assessments and because length and age data are available only for recent years, there is little information to accurately estimate natural mortality, thus estimated spawning biomass is also uncertain. Finally, there is little information about the levels of historical recruitment mostly due to a lack of historical length or age data. This uncertainty was included in the predictions from this assessment.

The predicted spawning biomass from the base model generally showed a slight decline over the entire time series with a period of steeper decline during the 1980's and 1990's. Since 2000, the spawning biomass has stabilized and possibly increased because of reduced catches and above average recruitment in 1999. The 2013 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass and there is a small probability that the stock has dropped below the 40% of unfished spawning biomass threshold in the last decade. Uncertainty in the estimated spawning biomass is high.

Exploitation rates on rougheye rockfish have exceeded *MSY* proxy target harvest rates during the 1980's and 1990's, and only slightly in the mid-2000's. Exploitation rates decreased in the late 1990's due to management restrictions, and have increased in recent years. Rougheye rockfish are managed as part of the minor slope rockfish complex, and there were species specific contributions to the OFL catch levels set for the complex in 2011 and 2012. However, catch is measured on the complex as a whole and rougheye landings exceeded the rougheye contributions to the ABC's for the complex in 2011 and 2012. In retrospect, recent landings are predicted to have been only slightly above proxy harvest target levels. Recent catch and levels of depletion are presented in Figure 6.

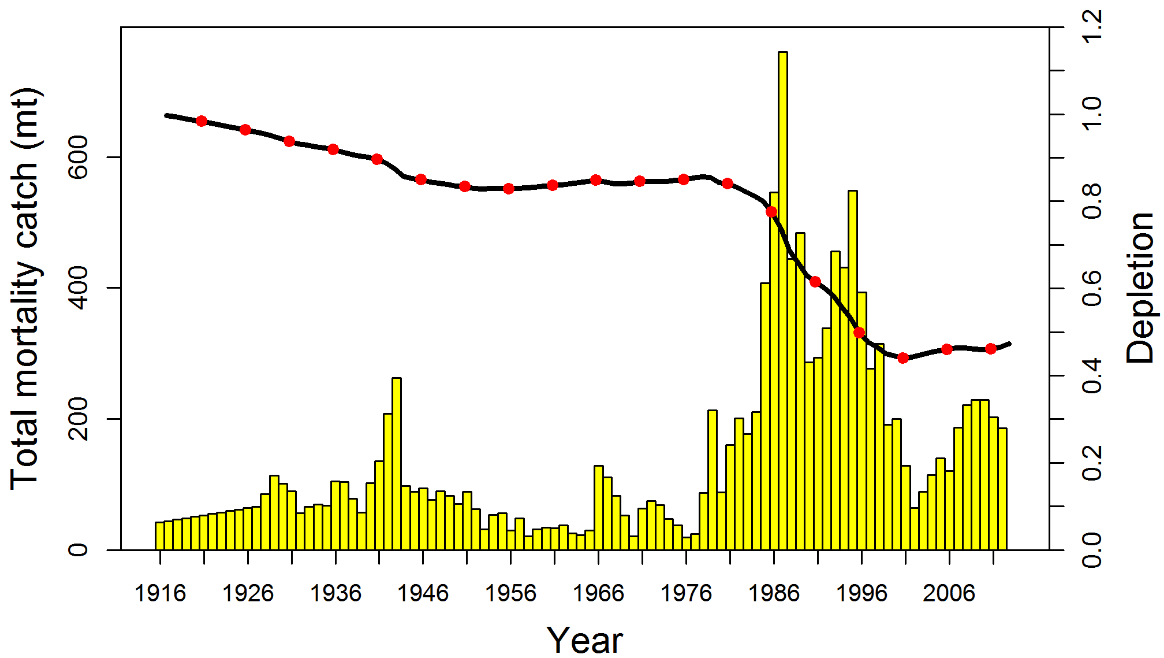



**Figure 6.** Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for rougheye/blackspotted rockfish, 1916-2013.

The complete assessment, "The status of Rougheye Rockfish (*Sebastes aleutianus*) and Blackspotted Rockfish (*S. melanostictus*)" by Allan Hicks, Chantel, Wetzel, and John Harms can be found online at:
http://www.pcouncil.org/wp-content/uploads/Rougheye_and_Blackspotted_2013_Assessment.pdf

For more information on the rougheye and blackspotted rockfish assessment, contact Allan Hicks at Allan.Hicks@noaa.gov

### 3. Thornyheads

#### a) Stock Assessments

Full assessments of both shortspine and longspine thonyhead were conducted in 2013.

**Longspine thornyhead**: This assessment pertains to the longspine thornyhead (*Sebastolobus altivelis*) population located off the west coast of the continental USA, from the U.S.-Canada border in the north to the southern end of the Conception INPFC area (32.5° latitude). Longspine thornyheads have been reported from 200 meters (m) to as deep as 1,755 m, however survey and fishery data are only available down to 1,280 m. This resource is modeled as a single stock because genetic analyses do not indicate significant stock structure within this range. This is the same stock assumption made in the most recent assessment of longspine thornyhead in 2005 (Fay, 2005).

Landings of longspine were modeled as a single coast-wide fishery. Very small amounts of longspine thornyhead are caught using gears other than trawl; this catch was combined with the trawl catch. Recreational fishery landings of thornyheads were negligible, so only commercial landings were included in the model. No age information is available for longspine thornyhead, so none was included in this model. Fixed parameters used in this assessment included a natural mortality rate (M) of 0.11, and Beverton-Holt steepness (h) of 0.6. Fishery and survey selectivities were estimated as asymptotic, with the exception of the AFSC slope survey, which is dome shaped.

Total and spawning biomass of longspine thornyhead declined from the beginning of the modeled period, in 1964, until the late 1990s, with the rate of this decline being highest from the late 1980s until the mid to late-1990s due to peak catches during that period. Total biomass reached a low of 48,200 mt (compared to an unexploited level of 91,049 mt) in 1998, and spawning biomass reached a low of 18,184 mt (a depletion level of 46% of the unfished equilibrium level of 39,134). The stock, is currently only lightly exploited, and the current spawning biomass is estimated to be over 29,400 mt (a depletion of 75%), with a 95% confidence interval of 12,500 – 46,400 mt. Recent catch and depletion levels are presented in Figure 7.

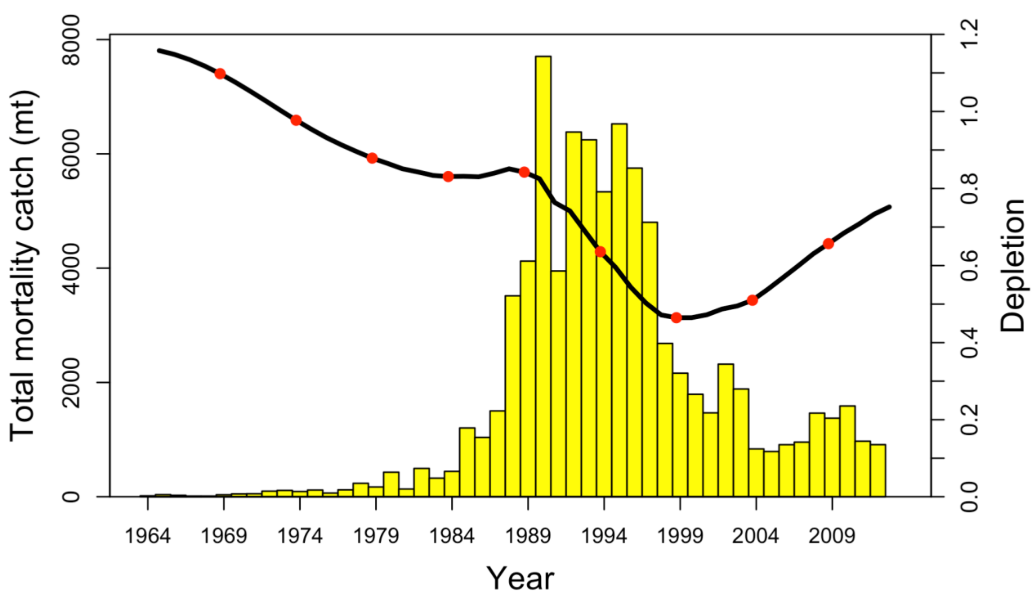



**Figure 7.** Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for longspine thornyhead, 1964-2012.

The complete document, “Stock Assessment and Status of Longspine Thornyhead (*Sebastolobus altivelis*) off California, Oregon and Washington in 2013” can be viewed online at: [www.pcouncil.org/wp-content/uploads/Longspine_Assessment_2013.pdf](www.pcouncil.org/wp-content/uploads/Longspine_Assessment_2013.pdf)

For more information on the longspine thornyhead assessment, please contact Andi Stephens: [Andi.Stephens@noaa.gov](mailto:Andi.Stephens@noaa.gov).

**Shortspine Thornyhead:** This assessment applies to shortspine thornyhead (*Sebastolobus alascanus*) off of the west coast of the United States from the U.S.-Canada border in the north to the U.S.-Mexico border in the south. Shortspine thornyheads have been reported as deep as 1,524 m, and this assessment applies to their full depth range although survey and fishery data are only available down to 1,280 m. This resource is modeled as a single stock because genetic analyses do not indicate significant stock structure within this range. This is the same stock assumption made in the most recent assessment of shortspine thornyhead in 2005 (Hamel, 2005).

Unfished equilibrium spawning biomass ($B_0$) is estimated to be 189,765 mt, with a 95% confidence interval of 57,435 – 322,095 mt. The $B_0$ estimate represents an increase from the 130,646 mt estimate for $B_0$ in the previous assessment although this previous estimate falls well within the uncertainty interval around the current estimate. Spawning biomass is estimated to have remained stable until the mid-1970s and then declined from the 1970s to about 80% in the 1990s, followed by a slower decline under the lower catch levels in the 2000s. The estimated spawning biomass in 2013 is 140,753 mt, which represents a stock status or “depletion” (represented as spawning biomass in 2013, $B_{2013}$, divided by $B_0$) of 74.2%. The depletion estimated for 2005 is 76.4%, which is higher than the 62.9% estimated for 2005 in the previous assessment. The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.45$, which is less than the 0.72 default minimum used in *p** adjustments to OFL values for Category 2 stock assessments.

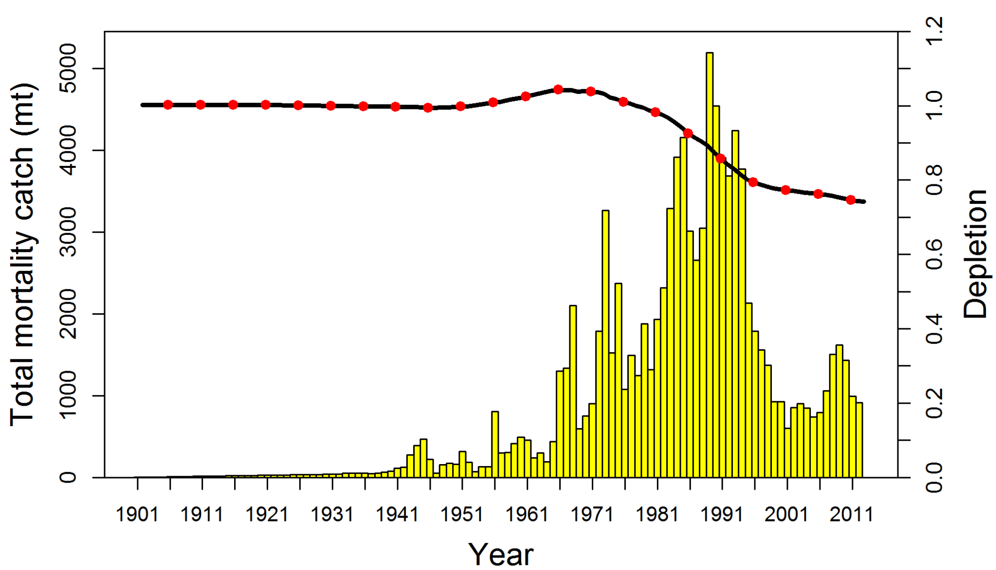



**Figure 8.** Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for shortspine thornyhead, 1901–2012.

The complete document: "Stock Assessment of Shortspine Thornyhead in 2013" can be viewed online at: http://www.pcouncil.org/wp-content/uploads/Shortspine_2013_Assessment.pdf

For more information on the shortspine thornyhead assessment, please contact Ian Taylor at Ian.Taylor@noaa.gov.

## 4. Sablefish

### a) Stock Assessments

No sablefish assessment was conducted in 2013. The complete version of: Status of the U.S. sablefish resource in 2011 can be viewed online at:
http://www.pcouncil.org/wp-content/uploads/Sablefish_2011_Assessment.pdf

For more information on sablefish, contact James Thorson at James.Thorson@noaa.gov.

## 5. Flatfish

### a) Stock Assessments

Full assessments of Pacific sanddab (accepted for status determination only) and petrale sole and data moderate assessments for English and rex soles were conducted in 2013.

**Pacific sanddab**: The 2013 assessment of Pacific sanddab can be found online at: http://www.pcouncil.org/wp-content/uploads/Sanddab_2013_Assessment.pdf

For more information on the Pacific sanddab assessment, contact Xi He at Xi.He@noaa.gov.

**Petrale sole:** This assessment reports the status of the petrale sole (*Eopsetta jordani*) resource off the coast of California, Oregon, and Washington using data through 2012. While petrale sole are modeled as a single stock, the spatial aspects of the coast-wide population are addressed through geographic separation of data sources/fleets where possible and consideration of residual patterns that may be a result of inherent stock structure. There is currently no genetic evidence suggesting distinct biological stocks of petrale sole off the U.S. coast. The limited tagging data available to describe adult movement suggests that petrale sole may have some homing ability for deepwater spawning sites but also have the ability to move long distances between spawning sites and seasonally.

The earliest catches of petrale sole are reported in 1876 in California and 1884 in Oregon. Recent annual catches during 1981–2012 range between about 700-3,000 mt (Figure 9). Petrale sole are almost exclusively caught by trawl fleets. Non-trawl gears contribute less than 2% of the catches. Based on the 2005 assessment, subsequent ACLs were reduced to 2499 mt. Following the 2009 assessment /ACLs were further reduced to 976 mt for 2011. Following the 2011 assessment ACLs were set at 1,160 and 2,592 for 2012 and 2013, respectively. From the inception of the fishery through the war years, the vast majority of catches occurred between March and October (the summer fishery), when the stock is dispersed over the continental shelf. The post-World War II period witnessed a steady decline in the amount and proportion of annual catches occurring during the summer months (March-October). Conversely, petrale catch during the winter season (November–February), when the fishery targets spawning aggregations, has exhibited a steadily increasing trend since the 1940's. Since the mid-1980s, catches during the winter months have been roughly equivalent to or exceeded catches throughout the remainder of the year. In 2009 catches of petrale sole began to be restricted due to declining stock size. However, stock increases observed during the 2011 assessment lead to less restricted catches during recent years.

Petrale sole were lightly exploited during the early 1900s but by the 1950s the fishery was well developed and showing clear signs of depletion and declines in catches and biomass (Figure 9). The rate of decline in spawning biomass accelerated through the 1930s–1970s reaching minimums generally around or below 10% of the unexploited levels during the 1980s and 1990s (Figure 9). The petrale sole spawning stock biomass is estimated to have increased slightly from the late 1990s, peaking in 2005, in response to above average recruitment (Figure 9). However, this increasing trend reversed between 2005 and 2010 and the stock has been declining, most likely due to strong year classes having passed through the fishery. Since 2010 the total biomass of the stock has increased slightly as a large 2007 recruitment appears to be moving into the population. While this increase was slight during 2011 because these fish were not yet fully mature the 2013 stock assessment has observed increases in spawning biomass as these fish have aged. The estimated relative depletion level in 2013 is 22% (~95% asymptotic interval: 15%-30%, ~ 75% interval based on the range of states of nature: 18-28%), corresponding to 7,233 mt (~95% asymptotic interval: 5,668–8,796 mt, states of nature interval: 6,800-7,846 mt) of female spawning biomass in the base model. The base model indicates that the spawning biomass has been below 25% of the unfished level since the mid-1950s.

Unfished spawning stock biomass was estimated to be 32,426 mt in the base case model. The target stock size ($SB_{25\%}$) is therefore 8,107 mt which gives a catch of 2,750 mt. Model estimates of spawning biomass at MSY and MSY yield are similar to those specified under the current harvest control rule. Maximum sustained yield (MSY) applying recent fishery selectivity and allocations was estimated in the assessment model at 2,732 mt, occurring at a spawning stock biomass of 8,739 mt (SPR = 0.25). Pacific coast flatfish, including Petrale sole, are considered overfished when the stock falls below 12.5% of unfished spawning biomass and rebuilt when it reaches 25% of unfished spawning biomass.

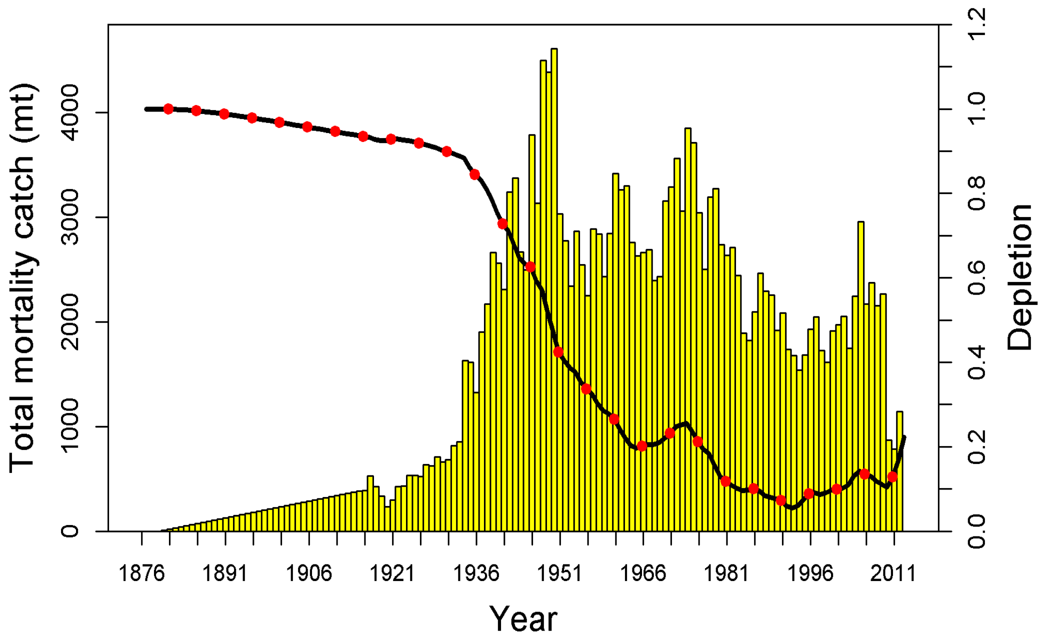


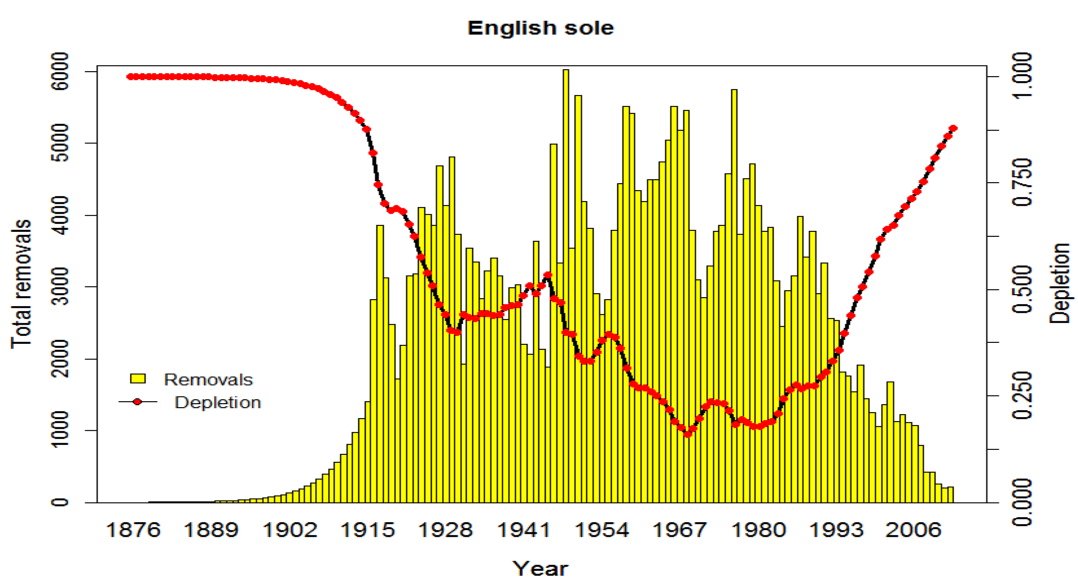

**Figure 9.** Time series of catch (mt; bars) and estimated depletion (line) for petrale sole.

The complete version of: Status of the U.S. petrale sole resource in 2012 can be viewed online at: http://www.pcouncil.org/groundfish/gfstocks.html

For more information on the petrale sole assessment, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

**English and Rex Soles:** Catch and index only assessments ("data-moderate" assessments) were performed for English sole and rex sole (see Figure 10a and 10b below for assessment summaries).

**A.**



**B.**

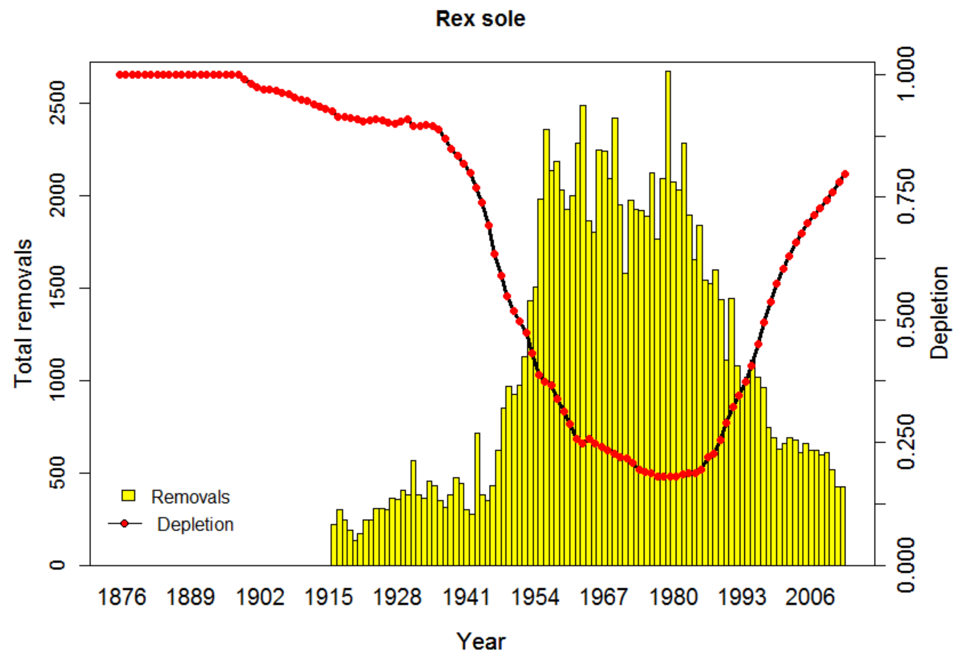



**Figure 10.** Time series of removals (mt; bars) and estimated depletion level (line) for catch for A) English sole and B) rex sole.

The data moderate assessment document for English and rex soles can be found at: http://www.pcouncil.org/groundfish/stock-assessments/by-year/gf2013/

For more information on the 2013 data-moderate assessments, contact Jason Cope at Jason.Cope@noaa.gov

## 6. Pacific Hake:

This stock assessment reported the collaborative efforts of the official U.S. and Canadian JTC members in accordance with the Agreement between the government of the United States and the government of Canada on Pacific hake/whiting. The assessment reported the status of the coastal Pacific Hake (or Pacific whiting, *Merluccius productus*) resource off the west coast of the United States and Canada. Coast-wide fishery landings of Pacific Hake averaged 222 thousand mt from 1966 to 2012, with a low of 90 thousand mt in 1980 and a peak of 363 thousand mt in 2005. Prior to 1966 the total removals were negligible relative to the modern fishery. Recent coast-wide landings from 2008–2012 have been above the long term average, at 243 thousand mt. Landings between 2001 and 2008 were predominantly comprised of fish from the very large 1999 year class, with the cumulative removal from that cohort exceeding 1.2 million mt. In 2012, U.S. fisheries caught mostly 2- and 4-year old fish from the 2008 and 2010 year classes, while the Canadian fisheries encountered older fish from the 2005 and 2006, and 2008 year classes. The Agreement between the United States and Canada establishes U.S. and Canadian shares of the coast-wide TAC at 73.88% and 26.12%.

Data were updated for the 2013 assessment with the addition of new ages into the 2011 age distribution, the addition of a new age distribution from the 2012 fishery and acoustic survey, and addition of the 2012 acoustic survey biomass estimate to the abundance index. The assessment used Bayesian methods to incorporate prior information on two key parameters (natural mortality, *M*, and steepness of the stock-recruit relationship, *h*) and integrated over parameter uncertainty to provide results that can be probabilistically interpreted. The exploration of uncertainty was not limited to parameter uncertainty as structural uncertainty was investigated through sensitivity analyses. Pacific hake displays the highest degree of recruitment variability of any west coast groundfish stock, resulting in large and rapid changes in stock biomass. This volatility, coupled with a dynamic fishery, which potentially targets strong cohorts resulting in time-varying selectivity, and little data to inform incoming recruitment until the cohort is age 2 or greater, will, in most circumstances, continue to result in highly uncertain estimates of current stock status and even less-certain projections of future stock trajectory. Uncertainty in this assessment is largely a function of the potentially large 2010 year class being observed once in the acoustic survey and twice in the fishery, although with low and uncertain selectivity. The supplemental acoustic survey performed in 2012 helped reduce the uncertainty of the strength of this year class, which is an expected result of increasing the survey frequency. However, with recruitment being a main source of uncertainty in the projections and the survey not quantifying hake until they are 2 years old, short term forecasts are very uncertain.

The base-case stock assessment model indicates that Pacific Hake female spawning biomass was below the unfished equilibrium in the 1960s and 1970s. The stock is estimated to have increased rapidly after two or more large recruitments in the early 1980s, and then declined steadily after a peak in the mid- to late-1980s to a low in 2000. This long period of decline was followed by a brief increase to a peak in 2003 (a median female spawning biomass estimate of 1.34 million mt in the SS model) as the large 1999 year class matured. The stock is then estimated to have declined with the aging 1999 year class to a female spawning biomass time-series low of 0.42 million mt in 2009. This recent decline is similar to that estimated in the 2012 assessment, but at a slightly greater absolute value. The current (2013) median posterior spawning biomass is estimated to be 72.3% of the estimated unfished equilibrium level (*SB0*) with 95% posterior credibility intervals ranging from 34.7% to 159.7%. The estimate of 2013 female spawning biomass is 1.50 million mt, which is more than double the projected spawning biomass from the 2012 assessment (0.64 million mt). The difference in projected biomass is largely driven by increases in the estimated size of the 2008 and 2010 year classes.

Estimates of historical Pacific hake recruitment indicate very large year classes in 1980, 1984, 1999, and 2010. The U.S. fishery and acoustic age compositions both show the 2010 year class comprised a very large proportion of the observations in 2012. Uncertainty in estimated recruitments is substantial, especially for 2010, as indicated by the broad posterior intervals. The fishing intensity on the Pacific hake stock is estimated to have been below the $F_{40\%}$ target until 2007 and was substantially below the $F_{40\%}$ target in 2012. Although the official catch targets adopted by the U.S. and Canada have been exceeded only once in the last decade (2002), in retrospect the fishing intensity is estimated to have exceeded the target rate in three of the last five years. Recent catch and levels of depletion are presented in Figure 11.

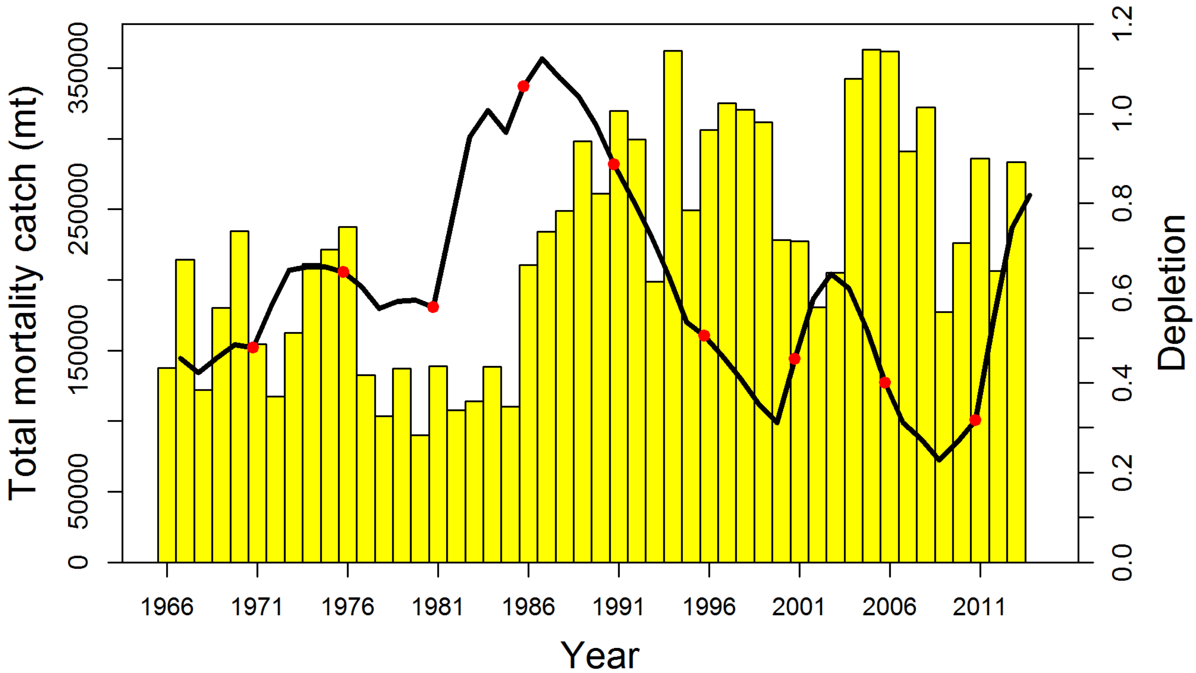



**Figure 11.** Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Pacific hake, 1966-2013.

The complete document: "Status of the Pacific hake (Whiting) stock in U.S. and Canadian Waters in 2013" can be viewed online at:
http://www.pcouncil.org/wp-content/uploads/Hake_2013_Assessment.pdf

For more information on the Pacific hake assessment, please contact Allan Hicks at Allan.Hicks@noaa.gov

### 7. Other species

No species in the 'other' category were assessed in 2013.

## D. Other Related Studies

### 1. The PaCOOS, West Coast habitat data portal

The PaCOOS West Coast Habitat Data Portal and associated server were conceived in 2005 as a Local Data Access Center (LDAC) of the Integrated Ocean Observing System (IOOS). Funding for its development was provided by the NOAA IOOS Program through the FRAM Division of the Northwest Fisheries Science Center. The database and GIS system had its origin the data collected together for the West Coast Essential Fish Habitat Environmental Impact Statement, which was completed in 2005/2006. Maintained jointly by FRAM and Oregon State University, College of Oceanic and Atmospheric Sciences Seafloor Mapping Laboratory and in collaboration with PSMFC, the portal provides access to data (search, connection, and download), a visualization environment, and integrated navigation tools. The data portal houses an ever expanding array of information including but not limited to geological and geophysical data, benthic habitat maps, fisheries survey datasets, and ocean climatologies. Data access, which includes data searching and metadata harvesting, is provided through IOOS Data Management and Communications (DMAC) compliant pathways such as OPeNDAP, OGC WMS, and ESRI ArcIMS map services. The portal's centerpiece is its unique map viewer environment (http://pacoos.coas.oregonstate.edu/), an online application that provides a map interface to data holdings with custom tools for data downloads and queries. There is a growing user base that includes local, state, and federal agencies within the California Current Large Marine Ecosystem.

The functionality of the PaCOOS data portal is continually being improved and new data sets are being added. During the latter part of 2011 and continuing into 2013, the Active Tectonics and Seafloor Mapping Lab started to transition the PaCOOS server from ESRI ArcIMS Internet Map Server software to the current ESRI ArcGIS Server software, and upgrade the application underlying the West Coast Habitat server. Datasets and metadata developed as part of the current Pacific coast groundfish EFH 5-year review will be placed on the PaCOOS West Coast Habitat Server. During the transition period, all new information and updates will be placed on the "Consolidated GIS Data Catalog and Online Registry for the 5-Year Review of Pacific Coast Groundfish EFH (or EFH Catalog for short) at http://efh-catalog.coas.oregonstate.edu/overview/).

For more information, contact Waldo Wakefield at waldo.wakefield@noaa.gov, Chris Goldfinger at gold@coas.oregonstate.edu or Chris Romsos at cromsos@coas.oregonstate.edu

## 2. Bycatch Reduction Research

*Recent Conservation Engineering Work in U.S. West Coast Groundfish Fisheries*

Beginning in 2004, the NOAA Fisheries Northwest Fisheries Science Center (NWFSC) initiated a fisheries conservation engineering program within its Fisheries Resource Analysis and Monitoring Division. Through key regional collaborations with the Pacific States Marine Fisheries Commission, Oregon Department of Fish and Wildlife, Alaska Fisheries Science Center, and the fishing industry, the NWFSC has been able to pursue a wide-ranging array of conservation engineering projects relevant to reducing bycatch in the west coast groundfish and ocean shrimp trawl fisheries. In the past several years, these projects included: 1) Reducing Chinook salmon, eulachon, rockfish, and Pacific halibut bycatch in midwater and bottom trawl fisheries using BRDs, 2) Providing loaner video camera systems to the fishing industry, and 3) Examining selectivity characteristics of codends that differ in mesh size and configuration in the bottom trawl fishery. Much of our current work has been in response to the fishing industries concerns over catches of overfished rockfishes and Pacific halibut IBQ (Individual Bycatch Quota) allocated in the Pacific coast Groundfish Trawl Rationalization Catch Share Program. The trawl rationalization program, starting in January 2011, established formal Annual Catch Limits (ACLs) and individual catch share quotas. In addition to ACLs, fishing opportunities may also be limited by hard caps or IBQs for non-groundfish species (e.g., Chinook salmon, and Pacific halibut). Bycatch of overfished and prohibited species in the west coast groundfish trawl fishery has the potential to constrain the fishery such that a substantial portion of available harvest may be left in the ocean.

**a) Reducing and Rockfish Bycatch in the Pacific Hake Fishery**

In 2011, the U.S. Pacific hake fishery began management under a catch share program (PFMC and NMFS, 2010). This program establishes annual catch limits (ACLs) and individual fishing quotas (IFQs) along with individual bycatch quotas for prohibited species. For many Pacific hake fishermen participating in this program, bycatch of rockfishes (i.e. darkblotched rockfish [*S. crameri*], widow rockfish [*S. entomelas*], canary rockfish [*S. pinniger*]) is a major concern because limited quota is available due to low spawning stock biomass for these species relative to the more abundant and productive Pacific hake stock. Individual fishermen could reach their quota for one of these "lower-quota" species before reaching their catch share quota of Pacific hake, thereby ending their fishing season with allowable harvest still left in the ocean unless additional quota can be leased or purchased from another quota share/permit holder. Acquiring additional quota, however, can be costly and/or difficult to obtain given certain circumstances (i.e. species needing quota coverage, amount of extra quota needed, time of year). This scenario occurred in 2011, 2012, and 2013. Developing techniques that reduce rockfish bycatch while retaining a high proportion of the targeted species in the U.S. Pacific hake fishery are increasingly important.

The Pacific States Marine Fisheries Commission (PSMFC), NOAA Fisheries Northwest Fisheries Science Center-Marine Habitat and Ecology group, and fishing industry conducted a collaborative workshop to develop a rockfish excluder for testing in the Pacific hake fishery during 2012. After an exchange of information and considerable discussion, the group came to a consensus that a flexible sorting grid excluder showed merit for reducing rockfish bycatch. Implementing recommendations made at the workshop, a pilot study was conducted in 2012 examining two (design-A and B) flexible sorting grid rockfish excluders. Results were relatively successful with one design (design-B) retaining a relatively high proportion of Pacific hake (>93% by weight) while reducing rockfish bycatch by 70%. Design-B, however, was only effective under slow-to-moderate fish volumes. Under moderate-to-high fish volumes this design tended to clog. Although design-B was ineffective under increased fish volumes, gear researchers and fishermen believed that the gear could be modified to improve its performance under higher catch levels and be effective at reducing rockfish bycatch while limiting Pacific hake loss. In 2013, we undertook a study to build on our recent findings and further examine flexible sorting grid excluders designed to reduce rockfish bycatch and evaluate its efficacy in the U.S. Pacific hake fishery.

The concept for the flexible sorting grid excluder tested is that fish smaller than the grid openings (i.e. Pacific hake) will pass through and move aft towards the codend, whereas fish larger than the grid openings (i.e. rockfishes) will be excluded. The excluder was constructed within a four-seam tube of netting that was 200 meshes deep (fore to aft) and 168 meshes in circumference, excluding meshes in each selvedge. The device was designed to be inserted between the intermediate section of the trawl and the packer/stuffing tube forward of the codend. The design utilizes two vertical panels (grids) of 7.62 x 8.89 cm (H x L) rectangular slot openings to crowd fish and direct large fish towards an upward-angled exit ramp. The vertical panels stand approximately 1.2 m in height and extend longitudinally down the tube of netting 175 meshes deep before connecting to the exit ramp. Over this distance the two panels gradually angle inward then straighten to create a narrow "hallway" that extends aft (Fig. 1). Within the "hallway" section of the excluder ropes with chaffing material wedged through them were installed to stimulate fish to interact with the vertical panels by creating a partial obstruction to fish moving aft. These ropes were positioned vertically (attached to the bottom and top panel of the tube of netting) and placed approximately every 15 meshes deep within the "hallway" section of the excluder. To reduce the potential of clogging under high fish volumes, three large rectangular sections 0.91 x 1.52 (H x L), referred to as "flex panels", along each vertical sorting panel were created that were designed to swing open (such as a door would) to allow fish to move directly aft towards the codend if clogging was occurring. Strands of shock cord were placed vertically over the outside of the rectangular sections to keep them closed under slow-to-moderate fish volumes. These rectangular sections occurred every 1.52 m apart within the "hallway" section of the excluder. Escapement of Pacific hake and bycatch was quantified using a recapture net. The excluder and recapture net used in this study was manufactured by Foulweather Trawl, LLC.

Tests occurred off Oregon during 2013 aboard a commercial trawler. During this study, widow rockfish (*S. entomelas*) was the primary rockfish species caught. Their bycatch was reduced 26.2% by weight. The retention of Pacific hake was 92.7% by weight. Widow rockfish caught in the recapture net were statistically larger than widow rockfish retained in the trawl. Mean lengths of Pacific hake caught between the trawl and recapture net did not differ significantly. Estimated single haul catches of Pacific hake ranged from 40 to 100 mt. Catches producing over 90 mt of Pacific hake in haul durations less than 2.5 hours were made. However, under heavier fish volumes (when over 90 mt of Pacific hake were being caught in less than 45 minutes of towing) the excluder tended to clog. While further refinement of the excluder is needed for the gear to function under heavy fish volumes, this project has developed a bycatch reduction device that can assist Pacific hake fishermen reduce rockfish bycatch when fishing conditions are moderate-to-high.

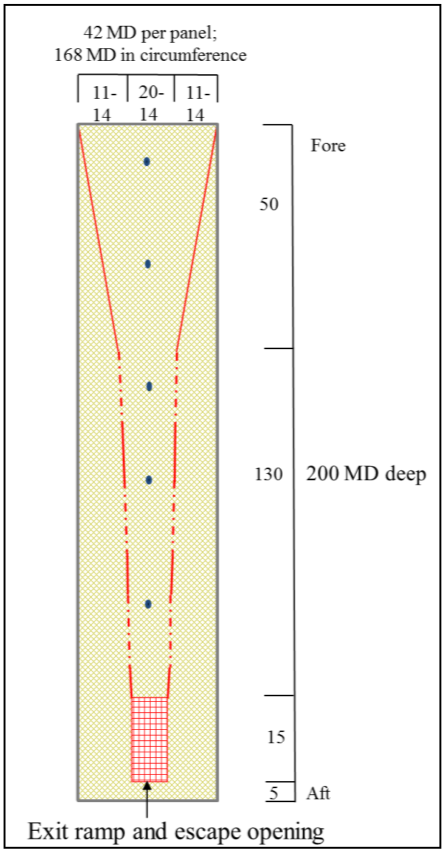



**Figure 12.** Top view diagram depicting the flexible sorting grid excluder tested. Solid red lines represent the vertical sorting panels; red dashed-dot-dash lines represent the "flex panels; the red grids represent the exit ramp and escape opening; the blue oval shapes represent the ropes with chaffing gear wedged through them; MD = diamond mesh. Note: this diagram is not drawn to scale.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov or Mark Lomeli at MLomeli@psmfc.org or visit http://www.nwfsc.noaa.gov/research/divisions/fram/habitat.cfm

**b) Reducing Pacific halibut bycatch in bottom trawl fisheries**

In 2011, the west coast LE groundfish trawl fishery started to be managed under a catch share program (PFMC and NMFS, 2010). This program established annual catch limits (ACLs) and individual fishing quotas (allocated by weight) along with individual bycatch quotas (IBQs) for prohibited species. For many fishermen participating in the bottom trawl component of this fishery, a major bycatch species of concern is Pacific halibut (*Hippoglossus stenolepis*), because limited IBQ is available. Individual fishermen could reach their Pacific halibut IBQ before reaching their groundfish catch share quotas, thereby ending their fishing season with allowable harvest still left in the ocean unless additional Pacific halibut bycatch quota can be leased or purchased from another quota share/permit holder. Acquiring additional quota, however, can be costly and/or difficult to obtain given certain circumstances (i.e. amount of quota needed, time of year). This scenario did occur both in 2011 and 2012. Reducing Pacific halibut bycatch would allow fishermen to more effectively utilize their catch share quotas and increase their net economic benefits. Under mandate of the International Pacific Halibut Commission (IPHC) trawl-caught Pacific halibut must be discarded at sea. Prior to the catch share program fishermen were not held individually accountable for discarding Pacific halibut. The implementation of a catch share program has created increased demand among fishermen to reduce bycatch and improve trawl selectivity. Since 2011, many fishermen have begun using BRDs to improve trawl selectivity; however, limited scientific evaluation of the devices being used is available to industry or management.

In 2013, we tested an industry-designed flexible sorting grid bycatch reduction device (BRD) that many fishermen felt showed promise in reducing Pacific halibut bycatch, while maintaining catch levels for several target species (Figure 13). Fish retention and escapement was quantified using a recapture net. Pacific halibut bycatch was reduced 83.7% by weight and 74.3% by numbers. Exclusion was highest for Pacific halibut longer than 80 cm. Retention of marketable-sized arrowtooth flounder, Dover sole, and petrale sole was 93.3%, 99.0%, and 96.9%, respectively. The percentage retained of marketable-sized shortspine thornyhead, and sablefish was 96.9% and 90.0%, respectively. Sablefish longer than 79 cm were caught in the recapture net in a higher proportion than in the trawl and accounted for nearly 50% of the 10.0% loss observed. Results demonstrated the capability of a flexible sorting grid BRD to reduce Pacific halibut bycatch, while maintaining catch levels for several target species. The scientific evaluation of this BRD will provide valuable information to the fishing industry and management.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov or Mark Lomeli at MLomeli@psmfc.org or visit http://www.nwfsc.noaa.gov/research/divisions/fram/habitat.cfm

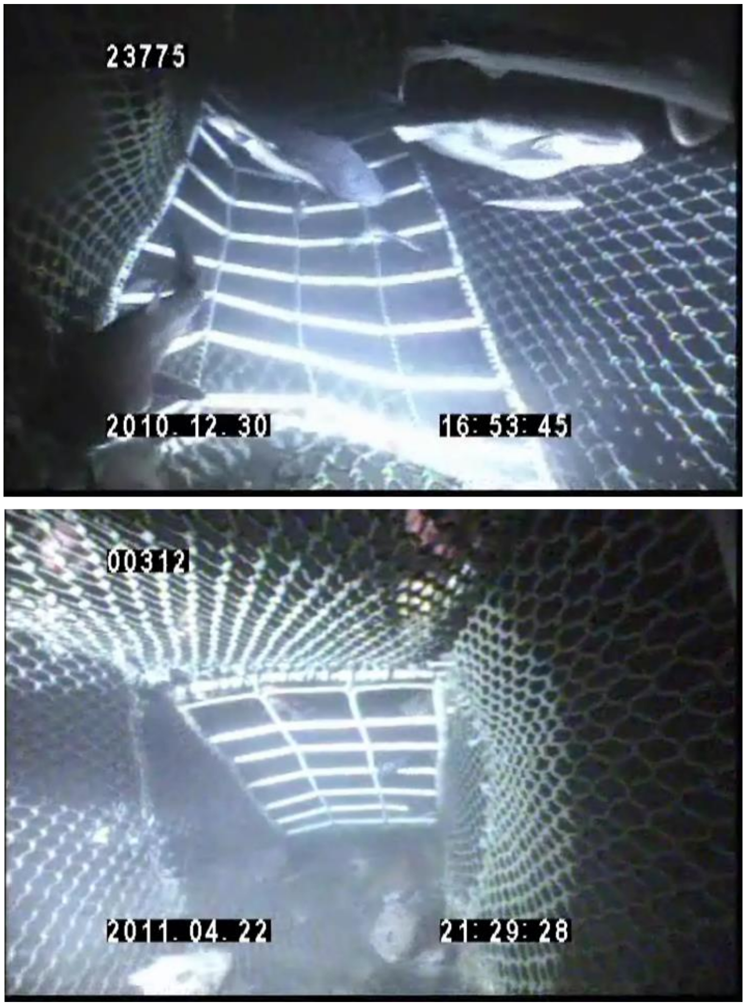



**Figure 13.** Video frame grabs showing flexible sorting grates developed by the fishing industry to reduce Pacific halibut bycatch in the groundfish bottom trawl fishery. Information gained from the videos was used to improve the performance of the grates.

**c) Providing direct observation video camera systems to fishermen for use in evaluating industry-designed approaches to reducing bycatch and impacts to benthic habitats**

Since 2010, the NWFSC, working in collaboration with PSMFC, has operated an underwater video camera loaner to make systems available to commercial fishers and other sectors of the industry for their use in evaluating industry-designed bycatch reduction devices. In 2011, the NWFSC added two additional video systems to the pool (Figure 14). These camera systems have been used extensively across the Pacific hake midwater trawl fishery, groundfish bottom trawl fishery, and the pink shrimp trawl fishery.


**Figure 14.** One of four autonomous direct observation video camera systems developed at the NWFSC.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov or Mark Lomeli at MLomeli@psmfc.org or visit http://www.nwfsc.noaa.gov/research/divisions/fram/habitat.cfm

## 3. Cooperative Ageing Unit

The Cooperative Ageing Project (CAP) operates under a grant from the Northwest Fisheries Science Center to Pacific States Marine Fisheries Commission, and provides direct support for U.S. West Coast groundfish stock assessments by providing fish ages derived primarily from otoliths. In 2013, CAP aged more than 28,000 otoliths. About 15,500 were aged in the first half of the year, for inclusion in the 2013 assessments for petrale sole, darkblotched rockfish, aurora rockfish and rougheye rockfish. Throughout 2013, 8,700 hake otoliths were aged for use in the 2014 joint hake assessment with Canada. CAP also completed over 1,800 training age reads during the year. CAP continued the practice of recording otolith weights prior to breaking and burning, in support of research into alternative methods of age determination. They are also collaborating with a NW Center engineer in Seattle to explore alternative light-based means of counting annuli.

For more information, please contact Jim Hastie at Jim.Hastie@noaa.gov

## 4. Resource Surveys

### a) U.S. West Coast Groundfish Bottom Trawl Survey

The NWFSC conducted its sixteenth annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2013 survey was to provide information on the distribution and relative abundance of demersal species within this region at depths from 30 to 700 fathoms. Other biological information necessary to assess the status of groundfish stocks (e.g. length, weight, sex and age structures) was collected throughout the survey period. The 2013 survey was reduced to a 3-vessel survey in 2013 because of insufficient funds to conduct a full 4-vessel survey. The survey was further reduced by the government shutdown (Oct. 1 – 17) which caused an early end to the survey on Sept. 30. We lost 18 sampling days and about 72 stations all south of Monterey Bay, CA due to the unanticipated furlough. The complete loss of one of the four vessels used to conduct the survey in 2013, due to budget cuts, created problems with the 2013 data that were exacerbated by the complete loss of the final portion of the survey in southern CA. In addition to having less data, the latitudinal terminus of the data for the second pass of the survey is in the middle of statistical areas (depth x latitude) used for analysis across years. Our assessment scientists have indicated this will complicate and reduce the usefulness of even the data that were collected during the second pass.

The NWFSC chartered commercial fishing vessels to conduct independent, replicate surveys using standardized trawl gear. Fishing vessels *Last straw, Noah's Ark* and *Excalibur* were contracted to survey the area from Cape Flattery, WA to the Mexico border in Southern California, beginning in the later part of May and continuing through October. Each charter was for a period of 11-12 weeks with the *Last Straw* and *Noah's Ark* surveying the coast during the initial survey period from May to July. The *Excalibur* planned to survey the coast during a second pass from mid-August to late October. However since the survey ended on Sept. 30$^{th}$ the period of the charter was shortened by several weeks. The survey area was partitioned into ~12,000 adjacent cells of equal area (1.5 nm long. by 2.0 nm lat., Albers Equal Area projection) with each vessel assigned a primary subset of 188 randomly selected cells to sample. An Aberdeen-style net with a small mesh (1 1/2" stretch) liner in the codend was used for sampling. The survey followed a stratified random sampling scheme with 15-minute tows within 2 geographic strata (80% N of Pt. Conception, CA and 20% S) and 3 depth strata. The depth strata were: shallow (30-100 fms), middle (100-300 fms), and deep (300-700 fms). The sample design for a 3-vessel survey consisted of 564 sampling locations.

In 2013, we also continued to utilize the FSCS data collection system with updated software applications, and wireless networking. Established NOAA national bottom trawl protocols were used throughout the survey. As in prior years, a series of special research projects were undertaken in cooperation with other NOAA groups and various Universities.

Additional data were collected during the trawl survey for collaborative research projects with several NMFS/academic colleagues: 1) Echinoderm adaptations to hypoxia across the Southern California continental margin - Scripps Institution of Oceanography, UC San Diego; 2) Maturity investigations for blackgill rockfish (*Sebastes melanostomus*) – Southwest Fisheries Science Center; 3) *Chionoecetes* spp. mitogenome comparative research - AFSC; 4) A study on the life history of the pygmy rockfish, *Sebastes wilsoni* - Marine Science Institute, University of California, Santa Barbara; 5) Record all sightings of basking sharks – Moss Landing Marine Laboratories; 6) Collections of eastern North Pacific softnose skates, Genus *Bathyraja* – Moss Landing Marine Laboratories; 7) Collection of any Pacific black dogfish, *Centroscyllium nigrum* – Moss Landing Marine Laboratories; 8) Collection of all unusual or unidentifiable skates, deepsea skate, *Bathyraja abyssicola*, Pacific white skate, *Bathyraja spinossisima*, fine-spined skate, *Bathyraja microtrachys*, Aleutian skate, *Bathyraja aleutica*, and broad skate, *Amblyraja badia* – Moss Landing Marine Laboratories; 9) Collection of all unusual or unidentifiable sharks including small sleeper sharks, *Somniosus pacificus* and velvet dog shark (*Zameus squamulosus*) – Moss Landing Marine Laboratories; 10) Collection of any chimaera that is not *Hydrolagus colliei*, including: *Harriotta raleighana*, *Hydrolagus* spp. and *Hydrolagus trolli* – Moss Landing Marine Laboratories; 11) Collection of voucher specimens for multiple fish species – Northwest Fisheries Science Center; 12) Collection of vouncher specimens for multiple fish species – Oregon State University; 13) collection of squid species: *Octopoteuthis deletron*, *Chiroteuthis calyx*, *Galiteuthis phyllura*, *Taonius borealis*, *Vampyroteuthis infernalis*, *Japetella diaphana*, *Abraliopsis felis*, *Histioteuthis heteropsis*, *Histioteuthis dofleini*, and *Cranchia scabra* – Montery Bay Aquarium Research Institute.

Several other research initiatives were undertaken by the Survey Team including: 1) Use of stable isotopes and feeding habits to examine the feeding ecology of rockfish (genus *Sebastes*); 2) Fin clip collection for various shelf rockfish species; 3) Collection of stomachs for various rockfish species; 4) Collection and identification of cold water corals; 5) Fish distribution in relation to bottom dissolved oxygen concentration in the oxygen minimum zone; 6) Composition and abundance of benthic marine debris collected during the 2013 West Coast Groundfish Trawl Survey; and 8) Collection of ovaries from Pacific ocean perch, Pacific hake, aurora rockfish, lingcod, sablefish, shortspine thornyheads, Dover sole and canary rockfish to assess maturity; 9) maturity of tanner crabs.

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**b) Southern California shelf rockfish hook-and-line survey**

In early Fall 2013, FRAM personnel conducted the 10th hook and line survey for shelf rockfish in the Southern California Bight (SCB). This project is a cooperative effort with Pacific States Marine Fisheries Commission (PSMFC) and the southern California sportfishing industry aimed at developing an annual index of relative abundance and time series of other biological information for structure-associated species of rockfish (genus *Sebastes*) such as bocaccio (*S. paucispinis*), greenspotted rockfish (*S. chlorostictus*), cowcod (*S. levis*), and the vermilion rockfish complex (e.g., *S. miniatus* and *S. crocotulus*) within the SCB.

The F/V *Aggressor* (Newport Beach, CA), F/V *Mirage* (Port Hueneme, CA), and F/V *Toronado* (Long Beach, CA) were each chartered for 9 days of at-sea research, with 13 biologists participating during the course of the survey. The three vessels sampled a total of 121 sites ranging from Point Arguello in the north to 9 Mile Bank and the U.S.-Mexico EEZ boundary in the south. Normally conducted aboard two chartered vessels, the addition of a third survey boat in 2013 was a response to internal and external peer reviews recommending additional research into the role the vessel platform plays in abundance modeling.

Approximately 3,471 sexed lengths and weights, 3,386 fin clips, and 3,280 otolith pairs were taken during the course of the entire survey representing 33 different species of fish and 1 invertebrate species. Several ancillary projects were also conducted during the course of the survey. Approximately 640 ovaries were collected from 11 different species to support the development of maturity curves. Several dozen individual fish were retained for use in species identification training for west coast groundfish observers and for a genetic voucher program conducted by the University of Washington. Researchers also deployed an underwater video sled to capture visual observations for habitat analysis, species composition, and fish behavior studies.

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**c) 2013 joint U.S.-Canada integrated acoustic and trawl survey of Pacific hake and Pacific sardine**

The joint U.S.–Canada integrated acoustic and trawl survey was conducted in U.S. and Canadian waters by two U.S. teams (NWFSC/FRAM and SWFSC/FRD) on the NOAA ship *Bell M. Shimada* from 9 June 2013 to 27 August 2013, and by a Canadian team (DFO/Pacific region) on the CCGS *W.E. Ricker* from 22 August 2013 to 11 September 2013. The data collected during the survey were processed to provide an estimate of the abundance and spatial distribution of the coastal Pacific hake stock shared by both countries. The survey covered the slope and shelf of the U.S. and Canada West Coast from roughly 32.8°N (off San Diego) to 54.7°N (Dixon Entrance) with acoustic transects spaced 10 nm apart. Acoustic data were collected on the *Shimada* with an EK60 echosounder operating at frequencies of 18, 38, 70, 120, and 200 kHz, and on the *Ricker* with an EK60 echosounder operating at frequencies of 18, 38, and 120 kHz. The survey resulted in 134 transects with 5,536 nautical miles of acoustical transect that were used for the hake biomass estimate. Nine transects of 212 nautical miles in the Southern California Bight were used just for the sardine biomass estimate. Aggregations of adult (age 2+) Pacific hake were detected on 101 transects from just south of Morro Bay (35.3°N), north along the U.S. and Canadian coast, in the Queen Charlotte Sound and Hecate Strait, and at the southwest tip of Haida Gwaii (known formerly as the Queen Charlotte Islands). Highest concentrations of Pacific hake were observed off the San Francisco Bay area, north of Cape Mendocino to Crescent City, and off the central Oregon coast. Hake sign was relatively light off the Washington coast and Vancouver Island. North of Vancouver Island, hake were quite sparse or absent, except for one aggregation in Hecate Strait near Banks Island. Midwater trawls equipped with a camera system were conducted to verify species composition of observed backscatter layers and to obtain biological information (i.e., size distribution, age composition, sexual maturity). A total of 93 successful trawls (76 by the *Shimada* and 17 by the *Ricker*) resulted in a total hake catch of 19,249 kg (15,048 kg from the *Shimada* and 4,201 kg from the *Ricker*). The estimated total biomass of adult Pacific hake in 2013 was 2.423 million metric tons of which over 95% was from U.S. waters. The 2013 estimate represented an increase of over one million metric tons (75%) over the biomass estimate from 2012. Age-3 hake were dominant, amounting to 70% of the total survey-wide observed biomass and over 76% of observed numbers. The 2010 cohort was roughly seven times larger than the 2008 cohort.

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## 5. NOAA Program: Fisheries And The Environment (FATE)

### a) Modeling Pacific hake (*Merluccius productus*) summer distribution

Investigators: M. Haltuch, C. Holt, E.C. Clarke and A.E. Punt

Funding obtained via the NOAA Fisheries and the Environment (FATE) Program as well as funding via the Department of Fisheries and Oceans (DFO) Canada, International Governance Strategy Funds during 2010-2011 led to a joint project between the Northwest Fisheries Science Center (NWFSC) and DFO, Nanaimo focusing on building a model to describe hake distribution during the summer migratory season, with the long term goal of being able to both hind-cast and forecast hake distribution. The motivation for this work is that Pacific hake exhibits strong environmentally-driven inter-annual variation during the stock's annual summer northerly migration that impact monitoring, assessment, and management of hake. Being able to describe and forecast hake distribution could impact management via optimized survey design and planning, resulting in improved estimates of hake distribution and density. Specifically, survey effort could be distributed to minimize (expected) variance given the ability to predict hake distribution and density prior to a survey, resulting in more precise estimates of abundance that form the basis for stock assessment and management advice. Hind-casting hake distribution could also be useful for investigating hake selectivity and availability in the stock assessment model. Essentially, the ability to model hake selectivity as a function of a covariate(s) would reduce the number of parameters in the stock assessment model. Finally, understanding and forecasting of hake distribution during migration is important for both short-term management decisions and long-term planning under future climate scenarios.

This project is using the depth aggregated hake acoustics survey data (1992-2007) to investigate space (latitude and longitude), population age composition, and environmental drivers of the north-south and cross-shelf distribution of hake along the west coast of North America. A set of hypotheses have been proposed to investigate potential mechanisms underlying the hake summertime distribution. The null hypothesis is that the north-south summertime distribution of hake is determined by latitude and the population age structure; and that the cross-shelf distribution of hake is determined by bathymetry. Three hypotheses have been developed that address possible climate mechanisms forcing hake summer distribution. Hypothesis 1 proposes that the intensity and location of the poleward undercurrent impacts the period of active migration, with stronger poleward flow leading to the population moving farther north. Hypothesis 2 suggests that formation and distribution of mesoscale structure in the CCE, e.g. eddies, is different between warm and cool years, impacting the distribution of hake's main prey resource, euphausiids. The hake distribution then tracks the changes in the distribution of euphausiids. Hypothesis 3 concerns the timing of the spring transition and in turn the intensification of upwelling, which impacts the timing and distribution of euphausiid availability and therefore hake distribution. A suite of environmental data from both satellite data on surface ocean conditions (e.g. SST) and regional ocean model (ROMS) outputs (e.g. poleward flow) are being used to test these hypotheses.

A delta general additive modeling (GAM) approach is used to predict hake backscatter. This is a two-step hurdle model consisting of a presence-absence model and a positive data model (all zeroes excluded) and is often used for zero-inflated data. GAMs are extensions of generalized linear models that apply semi-parametric smoothing functions to each independent variable and additively calculate the component response. Zero-inflation is often found in ecological data and needs to be accounted for when modeling abundance data. The hurdle model also has the advantage that it is possible to model different variables for the binary and the positive abundance response, as they can be driven by different processes. In the first step a binomial GAM is used to model the occurrence (presence-absence) of hake backscatter. In the second step lognormal GAMs and variable coefficient GAMs are fit to the positive backscatter (presence data). The variable coefficient GAM allows for the testing of a variable spatial effect of the covariates on hake distribution in the California Current. The two models are merged by multiplying the predictions from both steps, resulting in the final model. Model fits are evaluated using residual plots, deviance explained by the model, and AIC is used for model selection. A runs test for randomness is used to test for problems with autocorrelation in model residuals, to avoid inflating the statistical significance of model results and to decrease the likelihood of type 1 errors (false positives).

The null model is explored by examining the spatial pattern of hake biomass-at-age composition data by applying two spatial indicators, center of gravity (spatial mean location) and the associated inertia (spatial variance). The population age structure is clearly contributing to both within and between year differences in hake distribution. The centers of gravity for young ages were found at more southerly locations than those of older ages. In warm years and years when there are proportionally more old fish in the population (e.g. 1998) the population is distributed further north. In cold years and years when there are proportionally fewer old fish in the population (e.g. 2001) the population is distributed further south. Based on the exploration of the hake biomass-at-age-and-latitude data and information on hake maturity, the hake age data are classified into juvenile (age 3) and adult categories (age 3+) for further modeling.

Each hake acoustic line transect is treated as the sampling unit for the GAM modeling described above, yielding a model that has hake backscatter summed for each transect and an average spatial scale of 50 to 100 kilometers. GAM model results show that the population age structure, satellite SST and ROMS temperature at depth and pole-ward velocity are drivers of hake distribution, supporting both the null and alternative hypotheses. Model fits are generally good, explaining between 35%-40% of the variability in the data, and runs tests indicate a lack of autocorrelation in the model residuals. Comparisons between the observed and predicted also indicate that the model fits the data well but generally under predicts the level of backscatter observed. Forecasts, in which one year of data are removed from the model and a forecast is made without those data, are reasonable. The final sets of alterative models are being finalized and a peer review publication is in preparation.

The funding for this project ended during September 2011 and alternative funds have not been identified to support further investigations at this time.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov.

**b) Incorporating climate driven growth variability into stock assessment models: a simulation-based decision table approach**

Investigators: J. T. Thorson, A.E. Punt and V.V. Gertseva

Funding for this collaborative project between the Northwest Fisheries Science Center (NWFSC) and University of Washington is obtained from the NOAA Fisheries and the Environment (FATE) Program, for the period between 2013 and 2015. The motivation for this work is that biological characteristics of managed fishes are likely to vary with time due to environmental variability. Growth of splitnose and yelloweye rockfishes has been previously found to be highly correlated with several productivity indicators in the California Current Ecosystem, and time-series of climate-growth indices have been developed for these two species, using otolith band reading techniques. These indices, however, have not been used to inform stock assessments, due to a lack of guidance for when and how to incorporate indices of time-varying individual growth into an assessment model. This project will use a generic decision table approach to evaluate the effects of incorporating climate-driven time-varying growth into stock assessment models. Values in the decision table will represent management outcomes (i.e. lost yield and the probability of overfishing) and will be generated using simulation modeling, while existing data for splitnose and yelloweye rockfishes will be used to estimate the prior probability of time-varying growth. This simulation-based decision table approach will provide guidance on whether and how to include the environmental indices in future splitnose and yelloweye rockfish assessments. It could also be used generically to help evaluate the utility of including environmental data in stock assessment models. Funding for this project will support a Master's student.

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## 6. Ecosystem Studies

### a) Integrated ecosystem assessment of the California Current

Investigators: P.S. Levin and B.K. Wells, eds.; numerous contributors from the NWFSC, SWFSC and partner institutions

An integrated ecosystem assessment (IEA) is a science support element for ecosystem-based management (EBM); the IEA process involves synthesizing and analyzing information through steps that include scoping, indicator development, risk analysis, and evaluating management strategies. The primary goal of the California Current IEA is to inform the implementation of EBM by melding diverse ecosystem components into a single, dynamic fabric that allows for coordinated evaluations of the status of the California Current ecosystem. We also aim to involve and inform a wide variety of stakeholders and agencies that rely on science support for EBM, and to integrate information collected by NOAA and other federal agencies, states, non-governmental organizations, and academic institutions. The essence of IEAs is to inform the management of diverse, potentially conflicting ocean-use sectors. As such, a successful California Current IEA must encompass a variety of management objectives, consider a wide-range of natural drivers and human activities, and forecast the delivery of ecosystem goods and services under a multiplicity of scenarios. This massive undertaking will evolve over time.

The Phase II iteration of the California Current IEA, which covers up to 2012, focused on 4 ecosystem components (ecosystem integrity, fisheries of groundfish and coastal pelagics, protected species, and vibrant coastal communities) and 11 drivers and pressures of those components; drivers and pressures were broadly binned (e.g., shipping, coastal development, fishing, aquaculture, climate change). The Phase II report is divided into sections that describe: (1) engagement with managers; (2) status and trends of drivers and pressures; (3) status and trends of key ecosystem components; (4) risk assessments for focal indicators to key pressures; and (5) scenario-based evaluation of management strategies, along with a series of visuals and detailed appendices. Groundfish-related analyses include: a risk assessment for groundfish to fisheries and non-fisheries threats; status and trends of ecosystem integrity, which features groundfish populations as key indicators; the potential effects of emerging fisheries on several groundfish species; overlap between groundfish fisheries and cetaceans; and the system-wide effects of the trawl fishery rationalization. The Phase II report of the California Current IEA is now available as a web document with downloadable chapters.

For more information, please contact Phil Levin at Phil.Levin@noaa.gov, or go to http://www.noaa.gov/iea/CCIEA-Report/index.html

**b) Spatial, semi-parametric models improve estimates of species abundance and distribution**

Investigators: A.O. Shelton, J.T. Thorson, E.J. Ward and B.E. Feist

Accurate estimates of abundance are imperative for successful conservation and management. Classical, stratified abundance estimators provide unbiased estimates of abundance but such estimators may be imprecise and impede assessment of population status and trend when the distribution of individuals is highly variable in space. Model-based procedures that account for important environmental covariates can improve overall precision, but frequently there is uncertainty about the contribution of particular environmental variables and a lack of information about variables that are important determinants of abundance. The authors develop a general semi-parametric mixture model that incorporates measured habitat variables and a non-parametric smoothing term to account for unmeasured variables. They contrast this spatial-habitat approach with two stratified abundance estimators and compare the three models using an intensively managed marine fish, darkblotched rockfish (*Sebastes crameri*). The authors show that the spatial habitat model yields more precise, biologically reasonable, and interpretable estimates of abundance than the classical methods. Results suggest that while design-based estimators are unbiased, they may exaggerate temporal variability of populations and strongly influence inference about population trend. Furthermore, when such estimates are used in broader meta-analyses such imprecision may affect the broader biological inference (e.g. the causes and consequences of the variability of populations).

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**c) Predicting regional and coast-wide impacts of future fisheries development in the California Current**

Investigators: K.N. Marshall, I.C. Kaplan and P.S. Levin

Growing human populations put increasing demands on marine ecosystems. Studies have demonstrated the importance of large biomass forage groups in model food webs, but small biomass contributors are often overlooked. Here, the authors predict the ecosystem effects of three potential future fisheries targeting functional groups that make up only a small proportion of total ecosystem biomass using the California Current Atlantis Model: deep demersal fish such as grenadier (*Albatrossia pectoralis* and *Coryphaenoides acrolepis*), nearshore fish such as white croaker (*Genyonemus lineatus*), and shortbelly rockfish (*Sebastes jordani*). Using a spatially explicit ecosystem model, fishing scenarios for these groups were explored that resulted in abundance levels of 75, 40, 25, and 0 percent of the status quo fishing scenario. The authors evaluated the effects on coast-wide biomass and describe variation in affected groups by region. Results indicate that developing fisheries on the proposed targets would have low coast-wide effects on other species. However, effects varied significantly within the ecosystem, with higher impacts concentrated in the central California region of the model. This work provides a framework for evaluating effects of new fisheries and suggests that regional effects should be evaluated within a larger management context.

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**d) Cumulative impacts of fisheries in the California Current**

Investigators: I.C. Kaplan, I.A. Gray and P.S. Levin

Ecosystem-based fisheries management calls for the consideration of the indirect and cumulative effects of fishing, in addition to estimating direct fishing mortality. Here, the authors quantify such effects of fishing fleets, and their interactions, using a spatially explicit Atlantis simulation model of the food web and fisheries in the California Current. Simulations testing the effects of single fleets suggested that bottom trawl, fixed gear, and hake (*Merluccius productus*) trawl primarily have direct impacts on their target and bycatch species. Few indirect effects from these three fleets extended through predator–prey links to other parts of the food web. In contrast, effects of the purse seine fleet extended beyond the three groups it harvested, strongly altering the abundance of predators, planktonic prey, and benthos. In terms of nine ecosystem attributes, the experiments involving single fleets identified six fleets that caused the bulk of negative impacts. Specific fleets impacted different aspects of the ecosystem, for instance, with groundfish gears causing reductions in piscivore abundance, and hake trawl and purse seine increasing krill through reducing abundance of planktivores. In terms of interactions among fleets' effects, the vast majority of effects were simply additive – the combined effect of two fleets was simply the sum of the individual fleets' effects. The analyses offer one way to sharpen the focus of ecosystem-based fisheries management in the California Current, emphasizing impacts and interactions of particular stressors.

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**e) Non-fisheries pressures on groundfish essential fish habitat**

Investigators: K.S. Andrews

There are numerous non-fisheries related pressures acting upon groundfish essential fish habitat (EFH) along the West Coast of the United States. The author presents an example of how some non-fisheries pressures can be analyzed in order to be incorporated into the management framework for West Coast groundfish EFH, and a synthesis of readily available information about threats in these marine areas. First, the author takes advantage of 16 spatially-explicit data layers available from Halpern et al. (2009) to quantify the intensity of non-fisheries pressures among various regions, depth strata, habitat substrate types, and spatial management boundaries related to West Coast groundfish EFH. From the 16 non-fisheries related pressures, the author identified seven that were most relevant to West Coast groundfish EFH and which had enough data to be useful for a coastwide analysis. Initially, these pressures along with two climate change pressures are individually reported. In order to summarize the distribution of non-fisheries pressures, all 16 non-fisheries pressures were into a "combined" pressures data layer.

Non-fisheries pressures were greatest in the Salish Sea sub-region, which is entirely in shelf habitat and is consequently highly exposed to numerous land-derived pressures. Among other sub-regions, offshore pressures were more intense in the north, while nearshore pressures were more intense in the south. For example, lower slope habitat was exposed to higher pressure intensity values in the northern sub-region, while shelf and upper slope habitat was exposed to higher pressure intensity values in the southern sub-region. There was little variation in the mean intensity of non-fisheries pressures across EFH conservation areas compared to other spatial management regions. This was likely because EFH conservation areas were located offshore and relatively unexposed to land-based pressures. Habitat areas of particular concern (HAPCs) were proportionately more exposed to high non-fisheries pressures than other spatial management areas, and this is generally true across other individual pressures.

Andrews, K.S. 2013. Non-fisheries pressures. Appendix 3.2 in National Marine Fisheries Service. Groundfish essential fish habitat synthesis: a report to the Pacific Fishery Management Council. NOAA NMFS Northwest Fisheries Science Center, Seattle, WA, April 2013. 107p.

For more information, please contact Kelly Andrews at Kelly.Andrews@noaa.gov.

**f) Potential overlap between cetaceans and commercial groundfish fleets operating in the California Current large marine ecosystem**

Investigators: B.E. Feist, M.A. Bellman, E.A. Becker, K.A. Forney, M.J. Ford and P.S. Levin

Many cetacean populations are confronted by many anthropogenic threats, including commercial whaling, anthropogenic noise, vessel collisions, gear entanglement, resource competition, habitat disturbance and global climate change. There is evidence that commercial fishing activities can have both direct (e.g., gear entanglement and bycatch) and indirect effects (e.g., prey reduction, noise) on cetaceans. However, few studies have addressed the potential vulnerability of a given cetacean species to an entire fishing fleet operating over a large marine ecosystem. In this study, the authors overlaid spatially explicit multi-year mean predicted densities of 11 cetacean species and one species guild within the California Current Large Marine Ecosystem with West Coast Groundfish Fishery commercial fishing effort data for fixed-gear, at-sea hake midwater trawl, and bottom trawl fleets. The authors quantified the exposure of each species to each fleet type by multiplying the predicted mean cetacean density by the measured fishing fleet effort.

They found that there was large interspecific and interfleet variability in the overlap between cetaceans and fishing fleets. While many of the species had relatively low overlap rates, others had substantial exposure to some of the fishing fleets, particularly those species with more nearshore distributions. While direct mortality from these fleets has been documented to be low, results suggest there is opportunity for fisheries interactions with some cetacean species, particularly in the fixed gear fleets. These analyses are an important first step in generating formal risk assessments for quantifying the population impacts of various fishing fleets on cetacean species that occur in the California Current Large Marine Ecosystem.

For more information, please contact Blake Feist at Blake.Feist@noaa.gov

**g) The legacy of a crowded ocean: indicators, status, and trends of anthropogenic pressures in the California Current ecosystem**

Investigators: K.S. Andrews, G.D. Williams, J.F. Samhouri, K.N. Marshall, V. Gertseva and P.S. Levin

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, there is a need to understand the links between pressures and ecosystem components, and those linkages cannot be drawn unless there is information on how pressures have been changing over time. The authors 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 2000's 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.

For more information, please contact Kelly Andrews at Kelly.Andrews@noaa.gov.

**h) Ecosystem-level consequences of movement: the predatory impact of spiny dogfish in Puget Sound.**

Investigators: K.S. Andrews and C.J. Harvey

Spatio-temporal patterns of species abundance influence the strength of trophic interactions, while movement of individuals helps determine those patterns of abundance. Thus, understanding movement is a basis for quantifying interactions within a food web. In Puget Sound, Washington, USA, the North Pacific spiny dogfish *Squalus suckleyi* is an abundant top predator with a diverse, generalist diet. Coastal dogfish populations make seasonal north−south migrations, but populations in inland waters are thought to be more resident. In this study, the authors combined acoustic telemetry and bioenergetics modeling to determine patterns of movement and to quantify seasonal variation in the predatory impact of dogfish in Puget Sound. All tagged dogfish migrated out of Puget Sound in the winter and were absent until the following summer. Individuals that returned to Puget Sound in subsequent years showed consistent timing and duration of residence across years, but these metrics varied across individuals. Incorporating movement data into the bioenergetics model resulted in a 70% decrease in the predatory impact of dogfish in the winter and a 30% decrease in the summer, compared to a year-round resident Puget Sound population. Incorporating metrics of movement into food web or ecosystem models will increase understanding of species interactions and will improve the ability to predict changes in food web dynamics under various environmental and management scenarios.

For more information, please contact Kelly Andrews at Kelly.Andrews@noaa.gov

**i) Spatial and seasonal variation in $\delta^{15}N$ and $\delta^{13}C$ values in a mesopredator shark, *Squalus suckleyi*, revealed through multi-tissue analyses.**

Investigators: J.C.P. Reum and T.E. Essington

The authors used variance decomposition to explore the importance of body size, sex, location, and sampling period as predictors of intrapopulation variation in $\delta^{15}N$ and $\delta^{13}C$ values in spiny dogfish *Squalus suckleyi* from the Puget Sound–Strait of Georgia basin. Isotopes in two tissues with long (dorsal white muscle) and short (liver) isotopic turnover rates (~1 year and ~3–4 months, respectively) were sampled to evaluate whether the relative importance of each variable differed depending on the time span over which diet information was integrated. Significant spatial variation was observed in both muscle and liver isotopic composition, whereby location uniquely explained 25 and 17 % of the total variance, respectively. The remaining variables explained considerably less variation in both tissue types. Furthermore, evidence of seasonal isotopic shifts in $\delta^{15}N$ and $\delta^{13}C$ values was apparent, but differed widely in direction and magnitude among groups. These findings suggest that members of spiny dogfish schools may share a common feeding history, possibly by spending extended time periods (weeks to months) foraging in a spatially fixed region. Another explanation is that individuals may move and feed in aggregations that exist for extended periods. These complex group-level patterns suggest that even for large-bodied, motile predators such as sharks, population-level diet estimates derived from averaging isotope ratios of individuals collected from only a few locations may poorly reflect the true population mean.

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**j) Comparing the movements of spiny dogfish *Squalus suckleyi* in the north Pacific with satellite and acoustic tracking technology**

Investigators: C. Tribuzio and K.S. Andrews

Spiny dogfish (*Squalus suckleyi*) are a small species of shark, common in coastal waters of the eastern North Pacific Ocean. Previous tagging studies have shown that they have the potential to undertake large scale migration and that there are seasonal patterns to their movement. This study investigates movement on an even finer scale. The miniaturization of pop-off satellite archival tags (PSATs) has enabled smaller species to be tagged. Since 2009, 184 PSATs were deployed on spiny dogfish at locations across the Gulf of Alaska, British Columbia (Canada) and Puget Sound (Washington, USA) waters. To date, 145 tags have been recovered, with 31 still outstanding and the remainder failed to report. As well, 6 spiny dogfish were double tagged with acoustic tags and deployed in Puget Sound. Preliminary results such as pop-off location are already elucidating surprising movement patterns. While most spiny dogfish were tagged in the Gulf of Alaska, many fish moved as far south as southern California. Further, the fish that undertook the large scale migrations, tended to have a different daily movement pattern from those that remained. A great deal of analysis remains on this project, but early results are intriguing and suggest that spiny dogfish are more highly mobile than previously believed.

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**k) Conceptual models and indicator selection process for Washington State's marine spatial planning process**

Investigators: K.S. Andrews, C.J. Harvey and P.S. Levin

In March 2010, the Washington State legislature enacted a new state law on marine spatial planning (MSP; Substitute Senate Bill 6350). One of the primary objectives of this law was to develop a comprehensive marine management plan for the state's marine waters. The law stipulated that the "plan must include an ecosystem assessment that analyzes the health and status of Washington marine waters including key social, economic, and ecological characteristics. This assessment should seek to identify key threats to plan goals, analyze risk and management scenarios, and develop key ecosystem indicators." In support of Washington State's MSP process, this report develops a conceptual model and begins to develop corresponding ecosystem indicators that describe the important ecological components, oceanographic drivers, and human pressures in Washington State waters. The conceptual model serves as the basic framework for the development of ecosystem indicators and assessing the status and trends of key components of the ecosystem in Washington marine waters. In this report, we focused on non-human ecological components, oceanographic drivers and human pressures. Future research will focus on integrating social, economic and cultural characteristics into the conceptual model. The authors organized the conceptual model of Washington State waters according to major types of habitat found along and off the coast: rocky intertidal shores, sandy beaches, kelp forests, seafloor, and the pelagic zone. Key components of each habitat (e.g., focal species, predator-prey interactions, oceanographic drivers, and human pressures) were linked within each conceptual model based on reviews of the literature and expert opinions of how the ecological systems worked. The authors then used an evaluation framework to select and evaluate potential indicators that could be tracked for each of the key components of each habitat's conceptual model. This research will continue until a suite of indicators have been chosen that will characterize the status and trends of key components related to the socio-ecological conditions of Washington's marine waters.

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**l) How does the definition of 'home range' affect predictions of the efficacy of marine reserves?**

Investigators: N. Tolimieri, K.S. Andrews and P.S. Levin.

Understanding how animals use space is fundamental to the employment of spatial management tools like marine protected areas (MPAs). A commonly used metric of space use is home range—defined as the area in which an individual spends 95% of its time and often calculated as 95% of the utilization distribution (UD), which is a probabilistic map describing space use. Since home range represents only 95% of an animal's time, it is important to understand whether the other 5% matters to the design of MPAs. The authors developed an MPA-population model for lingcod *Ophiodon elongatus* that examined the population recovery under six characterizations of space use ranging from one mean home range to nine real lingcod UDs. Mean home range and similar estimates (based on the area in which a fish spent 95% of its time) predicted higher biomass and numbers relative to the more complete analysis of space use like the UD (which represented 99.99% of a fish's time) and underestimated the size of reserves necessary to achieve the same level of recovery of biomass. Results suggest failing to account for the full extent of a fish's time overestimates the effectiveness of marine reserves.

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**m) Linking changes in mean trophic level of groundfishes to ecosystem structure and function on the U.S. west coast**

Investigators: N. Tolimieri, J.F. Samhouri, V. Simon, B.E. Feist and P.S. Levin

Mean trophic level (MTL) is one of the most widely used indicators of marine ecosystem health. It usually represents the relative abundance of fished species across a spectrum of TLs. The reality, ubiquity, and causes of a general decline in the MTL of fisheries catch through time, and whether fisheries catch tracks ecosystem level changes, have engendered much attention. However, the consequences of such patterns for broader ecosystem structure and function remain virtually unexplored. Along the Pacific U.S. Coast, previous work has documented fluctuations and a slow increase in ecosystem MTL from 1977 to 2004. Here, the authors document a decline in the ecosystem MTL of groundfishes in the same ecosystem from 2003 to 2011, the proximate cause of which was a decrease in the biomass of higher TL groundfishes. Using a food web model, they illustrate how these shifts in ecosystem structure may have resulted in short term, positive responses by many lower TL species in the broader ecosystem. In the longer term, the model predicts that initial patterns of prey release may be tempered in part by lagged responses of other higher TL species, such as salmon and seabirds. Although ecosystem functions related to specific groups like piscivores (excluding high-TL groundfishes) changed, aggregate ecosystem functions altered little following the initial reorganization of biomass, probably due to functional redundancy within the predator guild. Efforts to manage and conserve marine ecosystems will benefit from a fuller consideration of the information content contained within, and implied by, fisheries-independent TL indicators.

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**n) Beta diversity of demersal fish assemblages in the north-eastern Pacific: interactions of latitude and depth.**

Investigators: M.J. Anderson, N. Tolimieri and R. Millar.

Knowledge of broad-scale global patterns in beta diversity (i.e., variation or turnover in identities of species) for marine systems is in its infancy. The authors analyzed the beta diversity of groundfish communities along the North American Pacific coast, from trawl data spanning 32.57°N to 48.52°N and 51 m to 1341 m depth. Analyses were based on both the Jaccard measure and the probabilistic Raup-Crick measure, which accounts for variation in alpha diversity. Overall, beta diversity decreased with depth, and this effect was strongest at lower latitudes. Superimposed on this trend were peaks in beta diversity at around 400-600 m and also around 1000-1200 m, which may indicate high turnover around the edges of the oxygen minimum zone. Beta diversity was also observed to decrease with latitude, but this effect was only observed in shallower waters (<200 m); latitudinal turnover began to disappear at depths >800 m. At shallower depths (<200 m), peaks in latitudinal turnover were observed at ~43°N, 39°N, 35°N and 31°N, which corresponded well with several classically observed oceanographic boundaries. Turnover with depth was stronger than latitudinal turnover, and is likely to reflect strong environmental filtering over relatively short distances. Patterns in beta diversity, including latitude-by-depth interactions, should be integrated with other biodiversity measures in ecosystem-based management and conservation of groundfish communities.

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**o) Economic impacts of ocean acidification on California Current fisheries**

Investigators: B. Wippel, K.N. Marshall, and I.C. Kaplan

Ocean acidification may restructure marine food webs by causing declines in calcifying species and the predators that feed on them. Here, the authors quantify economic effects of reduced catches of predators in the California Current stemming from erosion of their calcifying prey groups. Diet data were synthesized from the published literature to describe the vulnerability of commercially important species (Dungeness crab, Dover sole, Pacific whiting, and sablefish) to potential declines in echinoderms and mollusks. The authors then predicted potential losses of fisheries revenues due to loss of these prey species. They predict Dover sole is highly vulnerable because calcifiers comprise 40% of its diet. Ocean acidification could cost $690,000 - 2.76 million in lost fisheries. Costs would be disproportionately higher in Oregon, where most Dover sole are landed. This simple analysis is a first step in predicting economic costs of indirect effects of ocean acidification for fisheries along the West Coast.

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**p) Larval rockfish survival decreases in an elevated $CO_2$ environment**

Investigators: S. Norberg, D.S. Busch and P. McElhany

Information regarding the effects of high-$CO_2$ environments on fish is limited. In vertebrates, high levels of environmental $pCO_2$ can lead to lethal hypercapnia-induced acidification of intracellular body fluids. Fish can tolerate brief exposures to high $pCO_2$ because of their ability to accumulate buffering ions from the water through transport across cell membranes. Larval fish, which must meet the large daily energy requirements for growth and development, may not be able to contend with the extra energetic expense of increased ion transport. The authors explored the impacts of $CO_2$ on growth, development, and survival of China rockfish (*Sebastes nebulosa*) larvae. Larvae were reared in three different pH treatments: 7.70, 8.05, and 8.10. These conditions approximate past (280 ppm), present (400 ppm), and future (1000 ppm) global average atmospheric $pCO_2$ levels. Larvae exposed to high $pCO_2$ had significantly lower survival over a 20-day period (21%) than larvae exposed to moderate $pCO_2$ (70%). After two weeks of exposure to treatment conditions, larvae that survived in high $pCO_2$ were shorter than larvae in moderate and low $pCO_2$, though they had greater body depth than larvae in moderate $pCO_2$. At the end of the experiment, larval size and shape was similar in all treatments. However, otolith diameter relative to body size in larvae reared in moderate $pCO_2$ treatments was significantly larger than those reared in high and low $pCO_2$. From these results, we conclude that high $pCO_2$ conditions negatively impacted the growth, development and survival of larval China rockfish.

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**q) Variability in rockfish (*Sebastes* spp.) fecundity: species contrasts, maternal size effects, and spatial differences**

Investigators: S.G. Beyer, S.M. Sogard, C.J. Harvey and J.C. Field

Over 60 species of rockfish (*Sebastes* spp.) reside off the coast of California, many of which are economically important to both recreational and commercial fisheries. Rockfish are live-bearers with a diverse array of reproductive strategies. Understanding the reproductive potential of an exploited stock is critical to assessing the health and status of a fishery. The authors investigated the reproductive ecology of four rockfish species to examine species contrasts and to determine spatial and maternal-size effects on reproductive potential. Females were sampled during the winter parturition season (November through March) of 2009 through 2012. Maternal length and somatic weight were positively correlated with relative fecundity (larvae per g somatic weight) in all four species, indicating a disproportionately greater reproductive output by larger, older females. Fecundity estimates in chilipepper, *S. goodei*, and yellowtail rockfish, *S. flavidus*, varied regionally, but did not significantly differ over time within the years sampled (sample sizes for speckled, *S. ovalis*, and blackgill rockfish, *S. melanostomus*, were too small to allow spatiotemporal comparisons). Two reproductive strategies were evident as yellowtail and blackgill rockfish produced a relatively highly fecund, single brood of smaller-sized larvae annually, in contrast to chilipepper and speckled rockfish, which produced larger-sized larvae with lower fecundity. In some regions multiple broods were common, complicating estimates of annual fecundity for these two species. There was some evidence that egg production was positively correlated with female condition, indicating that environmental variability in oceanographic conditions and productivity may drive changes in fecundity and reproductive strategy (i.e., single versus multiple broods).

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**r) Anthropogenic drivers and pressures in the California Current integrated ecosystem assessment**

Investigators: K.S. Andrews, G.D. Williams and V.V. Gertseva

This work is a part of the California Current Integrated Ecosystem Assessment (IEA). One of the goals of the IAE is to fully understand the web of interactions that links drivers and pressures to ecosystem-based management (EBM) components and to forecast how changing environmental conditions and management actions affect the status of EBM components.

As human population size and demand for seafood increases globally and within the California Current, numerous human activities in the ocean (e.g., fishing and shipping activity) and on land (e.g., pollutants and runoff from agricultural activities) need to be recognized and incorporated into management of marine resources. Because these pressures originate from human activities, there is a need to assess current and historic levels, as well as predict future levels of the pressure. Establishing specific target levels of a pressure (e.g., fisheries landings quotas or concentration of nitrogen in coastal waters) will allow managers to determine whether the current status and trend of the pressure is moving in the right direction or whether alternative management strategies may be needed. The authors identified and described primary groups of fisheries and non-fisheries related anthropogenic pressures that affect various components of the CCLME. They also evaluated various indicators that are best suited to capture the trends and variability of these pressures and provided time series data describing the status and trends of each pressure.

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### 7. Acoustic Modeling and Research

**a) Calibration of a broadband acoustic system in nearfield** (ASTWG funded research)

Conventional calibrations of narrowband systems involving one or more standard targets are normally conducted in the farfields of both the transducer and the calibration sphere. However, for a multibeam system that spans a wide angular range or a broadband system that spans a wide frequency range, the farfield requirement may not be satisfied easily. The effect and influence of the nearfield application have been discussed and analyzed by various investigators. To improve our ability to conduct calibration in the nearfield, researchers have accomplished a number of tasks related to this project:

- Built a laboratory pulse-echo system.

  The dimensions of the tank are 60 cm x 38 cm x 30 cm (shown in Fig. 15). The precision of the 3D positioning system is 0.01mm. The bandwidth of Pulser/Receiver system, manufactured by Panametrics, Inc, is more than 30 MHz, with output energy selectable from 12.5 μJ to 100 μJ. A digital oscilloscope (LaCroy Wave Runner) can provide 100 MHz maximum sampling rate.

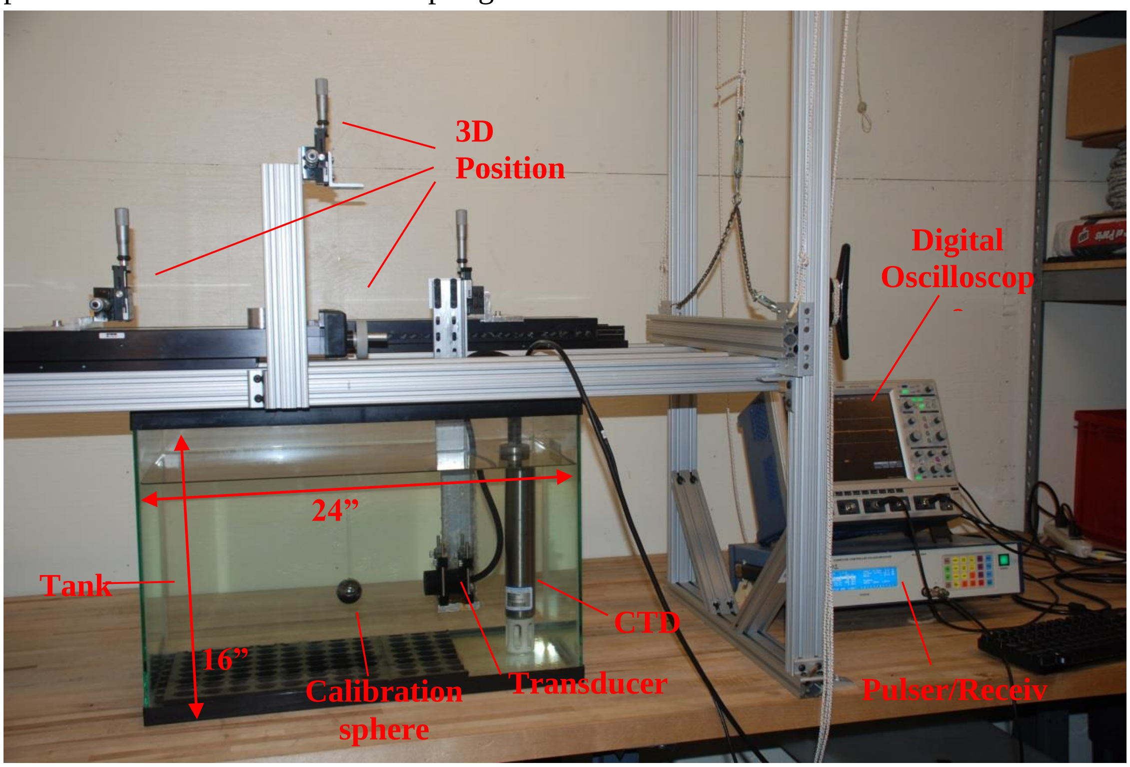


**Figure 15.** Photograph of the experiment tank, position system, and the pulse-echo system.

- Determination of the material properties of calibration spheres.

  The previous pre- and post- survey calibrations were all based on the TS of spheres calculated with the nominal material properties: density, and compressional and shear wave speeds. Using the built pulse-echo system, these parameters were measured and determined for all 38.1 mm WC spheres and the 25 mm WC sphere #1, including the one used in the hake acoustic survey in 2013 (WC38.1 #2, NWFSC) (Table 2). The authors also helped to measure the material properties for two spheres (20 mm and 22 mm) from our colleagues at the Institute of Marine Research (IMR), Norway. Utilizing the determination methods, one of the spheres was an unknown, but was determined to be stainless steel.

In addition to these targets, nearfield measurements were made on the 1st 64 mm Cu sphere at a separation of 10 cm. The compressional speed was hardly changed from its nominal value and the shear wave speed was also only slightly different from its nominal value showing only about 0.10% variation from the mean.

**Table 2.** Experimentally determined material properties of the calibration spheres.

| Sphere | Density ($g\ cm^{-3}$) | Compressional wave speed ($m\ s^{-1}$) | Shear wave speed ($m\ s^{-1}$) |
|---|---|---|---|
| WC25 #1, NWFSC | 14.23 ± 0.02 | 6765.05 ± 4.06 | 3964.70 ± 5.37 |
| WC38.1 #1, NWFSC | 14.96 ± 0.01 | 6804.19 ± 4.90 | 4182.59 ± 6.69 |
| WC38.1 #2, NWFSC | 14.46 ± 0.01 | 6802.93 ± 4.74 | 4083.74 ± 2.53 |
| WC38.1 #3, NWFSC | 14.92 ± 0.01 | 6802.48 ± 4.66 | 4191.15 ± 4.17 |
| WC20, IMR | 14.96 ± 0.01 | 6800.63 ± 0.92 | 4187.71 ± 1.25 |
| SS20, IMR | 7.96 ± 0.01 | 5669.94 ± 21.71 | 2987.69 ± 2.24 |
| Cu64 #1, NWFSC | 8.93 ± 0.004 | 4760.01 ± 0.24 | 2282.02 ± 2.37 |

- Development of the theory, algorithms, and experimental protocols of near-field calibration for high frequency broadband transducers.
  The theory is based on the exact integral representations of acoustic radiation/reception by a circular disk (piston), and the exact backscattering by a solid elastic sphere with a spherical incident wave. The solutions are exact for both far-field and near-field applications, which allows a variety of better controlled acoustic scattering measurements to be conducted in the laboratory to determine the acoustic characteristics of marine species. The results from such scattering characteristics provide very useful information for spectral classification of marine animals. The data processing algorithms for broadband transducer calibration have been developed, including numerical evaluations of integral representation of the exact solution, spherical wave representation of the backscattering by a solid elastic sphere, and spectral processing and analysis of broadband signals. In addition, the protocols of conducting near-field calibration in a small aquarium have been developed, i.e. a

capability of calibrating a broadband transducer with much less efforts and less time consuming.

- Determination of the calibration curves as a function of frequency.
  Total of five transducers have been calibrated, including four from the NWFSC and one out of three broadband transducers from Dr. Kelly Benoid-Bird (OSU). These five transducers have a frequency band covering several hundreds of kHz, all with center frequency around 500 kHz. The nominal bandwidths (manufacturer's specification sheet) are only less than 200 kHz, but with near-field calibration, a much wider usable bandwidth can be achieved since a higher signal-to-noise ratio (SNR) can be obtained in near-field. A representative calibration curve of the Transducer #1 from NWFSC as a function of frequency is shown in Fig. 16. The comparison of the theoretical predictions with the calibrated backscattering data using a WC25 sphere at different distances is provided in Fig. 17.

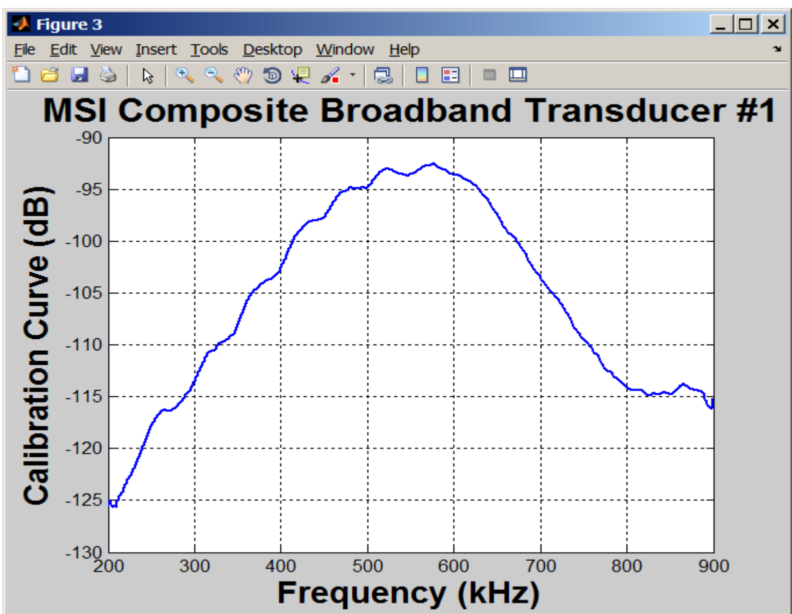


**Figure 16.** Calibration curve of the NWFSC Transducer #1 (MSI) as a function of frequency. The useable bandwidth is seen to be approximately from 300 kHz to 800 kHz.

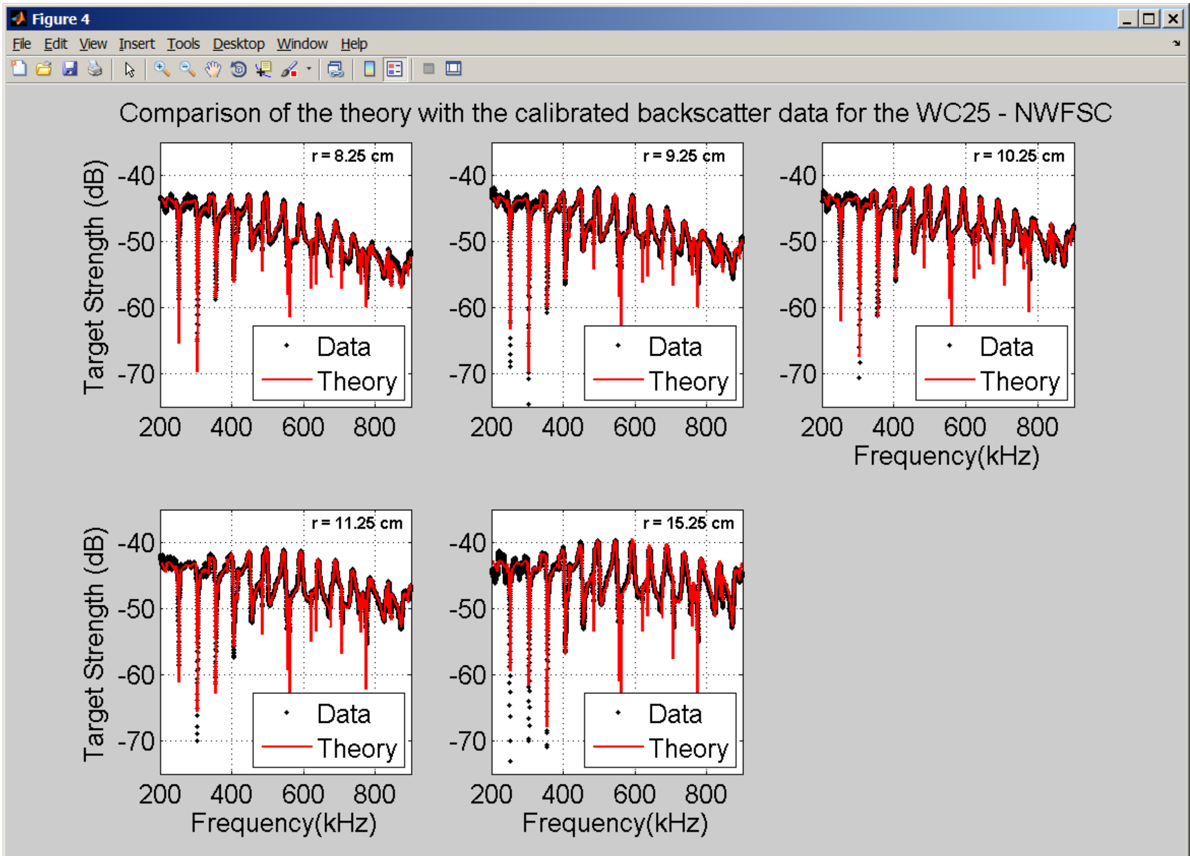


**Figure 17.** Comparison of the theoretical predictions with the calibrated backscattering data using a WC25 sphere at five different distances, 8.25 cm, 9.25 cm, 10.25 cm, 11.25 cm, and 15.25 cm, respectively.

For more information, please contact Larry Hufnagle at lawrence.c.hufnagle@noaa.gov.

## 8. Advance Technologies

### a) Pilot study utilizing a Wave Glider towed echo-sounder system for fisheries acoustic surveys (ASTWG funded research)

The primary goal of the project is to accelerate the transition of NOAA National Marine Fishery Service (NMFS) fishery acoustic assessments from their current operational dependence on manned survey vessels to a more strategic mix of ships and Autonomous Lagrangian Platforms and Sensors (ALPS). The Liquid Robotics Incorporated (LRI) SV3 Wave Glider (WG) is probably the most suitable ALPS system currently available for fulfilling NMFS's scientific and operational needs in this area. During 2013, the authors conducted two case studies to test feasibility of using the vehicle and towbody equipped with 38- and 120-kHz transducers for acoustic surveys.

I. Case Study I: The first case was to test the upgraded WG-TES system in Monterey Bay, CA in July 2013 (Fig. 18).

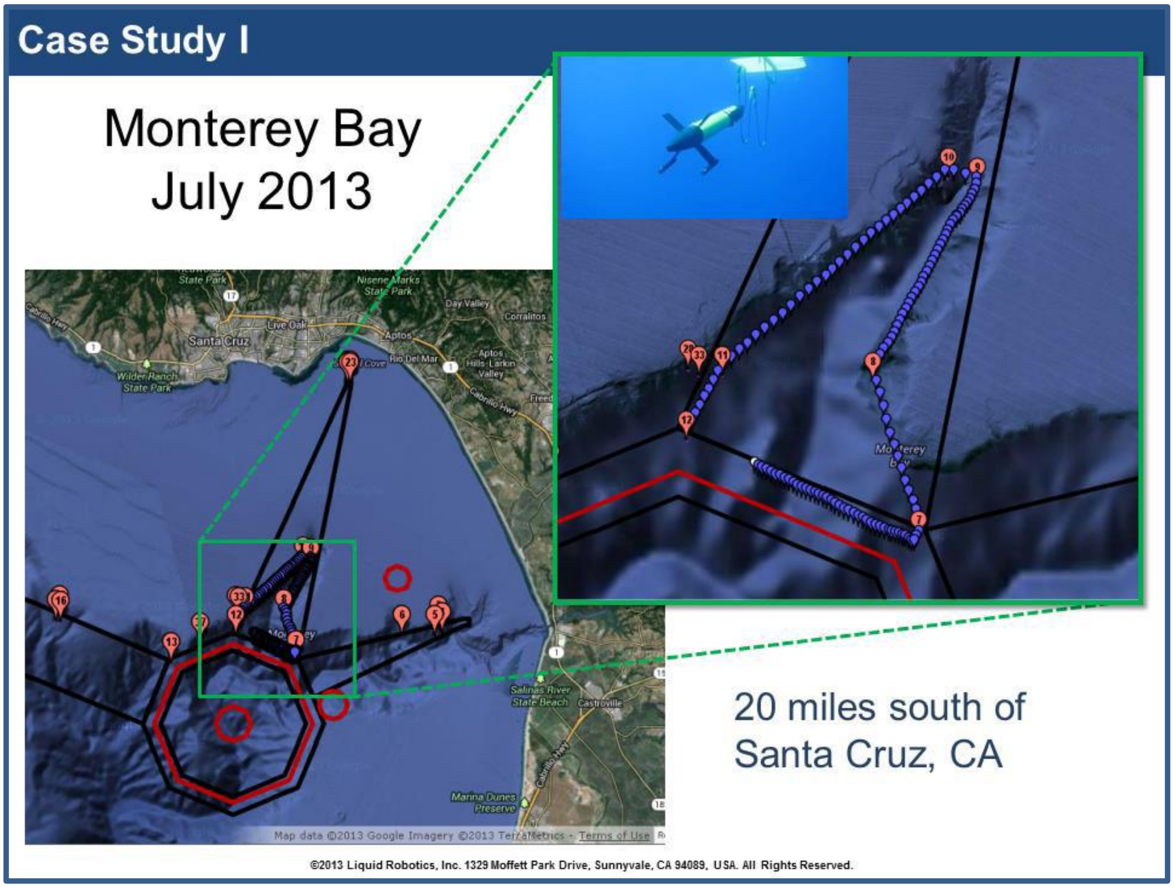


**Figure 18.** Test area for case I showing the tracks for the WG-TES system on day 2 of the deployment (courtesy of Liquid Robotics, Inc.).

This was a two-day mission with the following tests completed:

- WG upgrades
  - new impedance matched cables.
- Power Consumption
  - Reduced the power consumption by about 10%.
- Communication
  - Transferred the snippets (low-resolution echo integration report and status report) via satellite in real time.
- Reliability Test
  - Power on/off reliability (hardware)
  - Platform stability
  - WGMS interface/control
- Sonar Data Validation
  - Same sonar configuration as the real deployment in July-Aug., 2013

– Acoustic signal validation
– Noise floor validation

The collected low-resolution and high resolution data are shown in Fig. 19. Clearly the two aggregations, one is a fish aggregation (most likely myctophids with air-filled swimbladders), and the other is fluid-like zooplankton (most likely euphausiids).

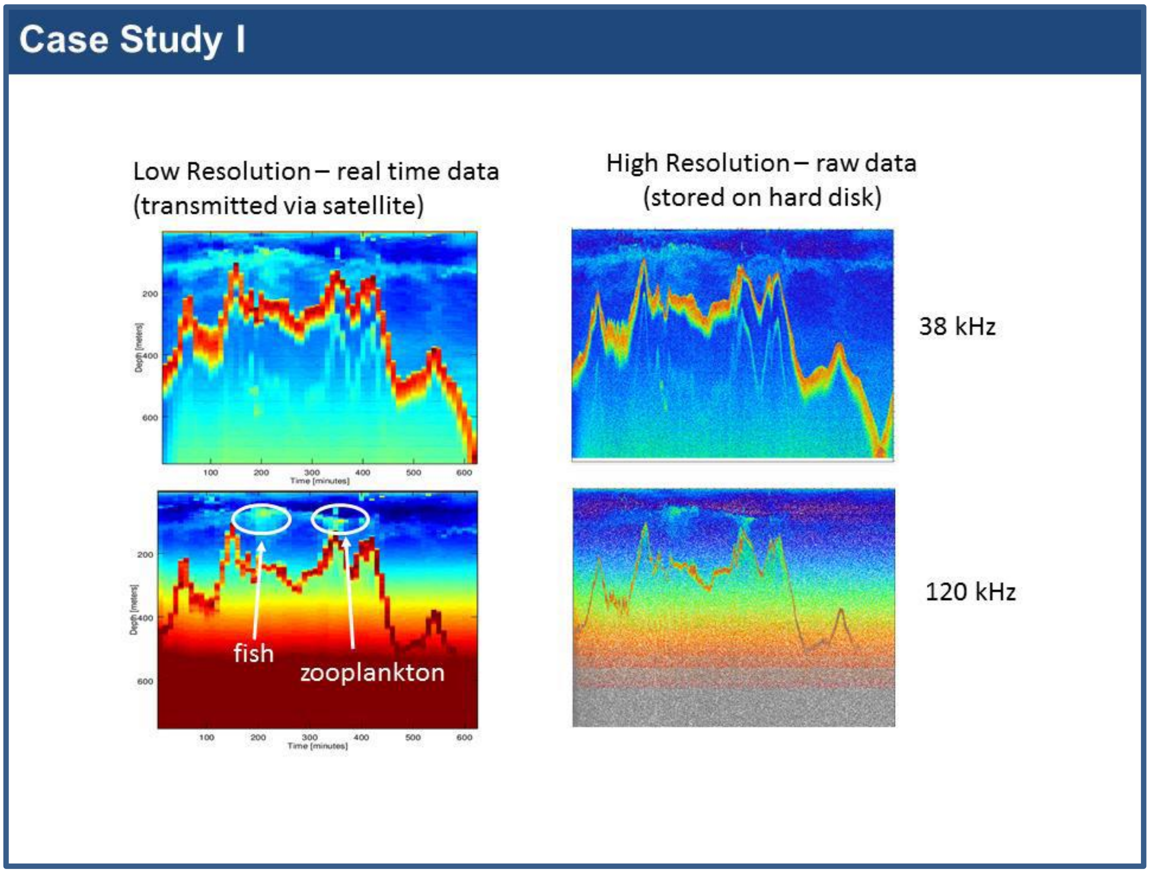


**Figure 19.** Low and high resolution acoustic data collected in case study I, where fish and zooplankton (euphausiids) could be identified based on their frequency responses.

II. Case Study II: For this case study, the WG-TES system was successfully deployed off the NOAA Ship FSV *Bell Shimada* once and other smaller vessels off the Oregon and Washington coasts (Fig. 20).

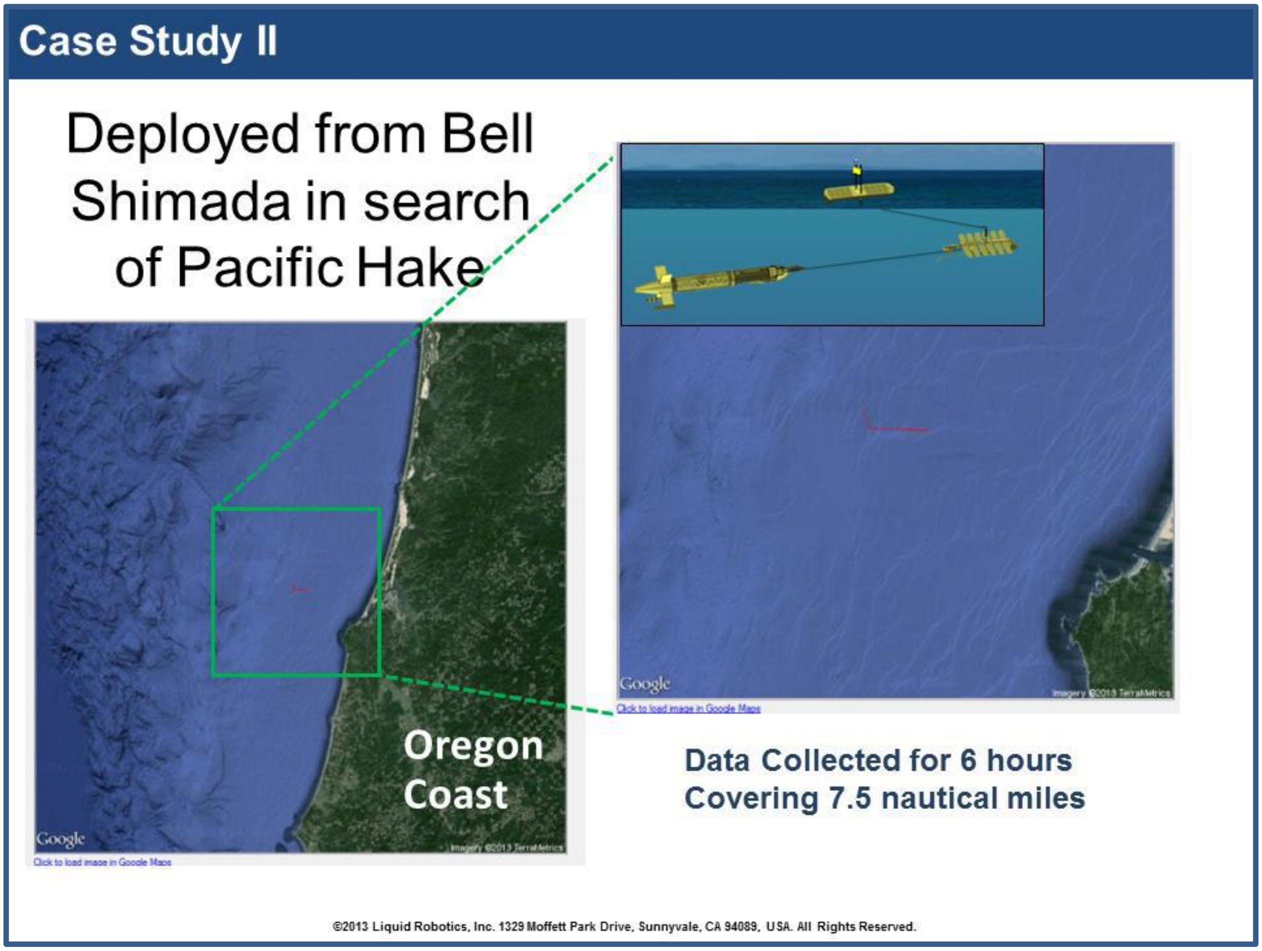


**Figure 20.** Study area for case II where the WG-TES system was successfully deployed in a region surveyed during the 2013 Joint sardine and Pacific hake acoustic survey. The rectangular box shows the region for the first deployment on July 27, 2013 off the FSV *Bell Shimada* (courtesy of Liquid Robotics, Inc.).

The two deployments, off the FSV *Bell Shimada* and a smaller OSU research vessel were successful but communication between the WG and the towfish failed under rougher sea conditions. After modifications of the electronics, the third deployment was near La Push, Washington on Aug. 31, 2014. The system worked well for more than a week until the towfish was lost on Sept. 7, 2014. The exact reason why it was lost could not be determined but there were some indications that the towfish might have been caught up for a short time and then the tow cable broke. Despite the loss of the towfish, acoustic raw data was collected from the second deployment off Coos Bay, OR shown in Figure 21. Multiple aggregations shown on 120 kHz echograms are clearly identifiable on both low-resolution and high resolution data and are most likely due to echoes from fluid-like zooplankton (euphausiids).

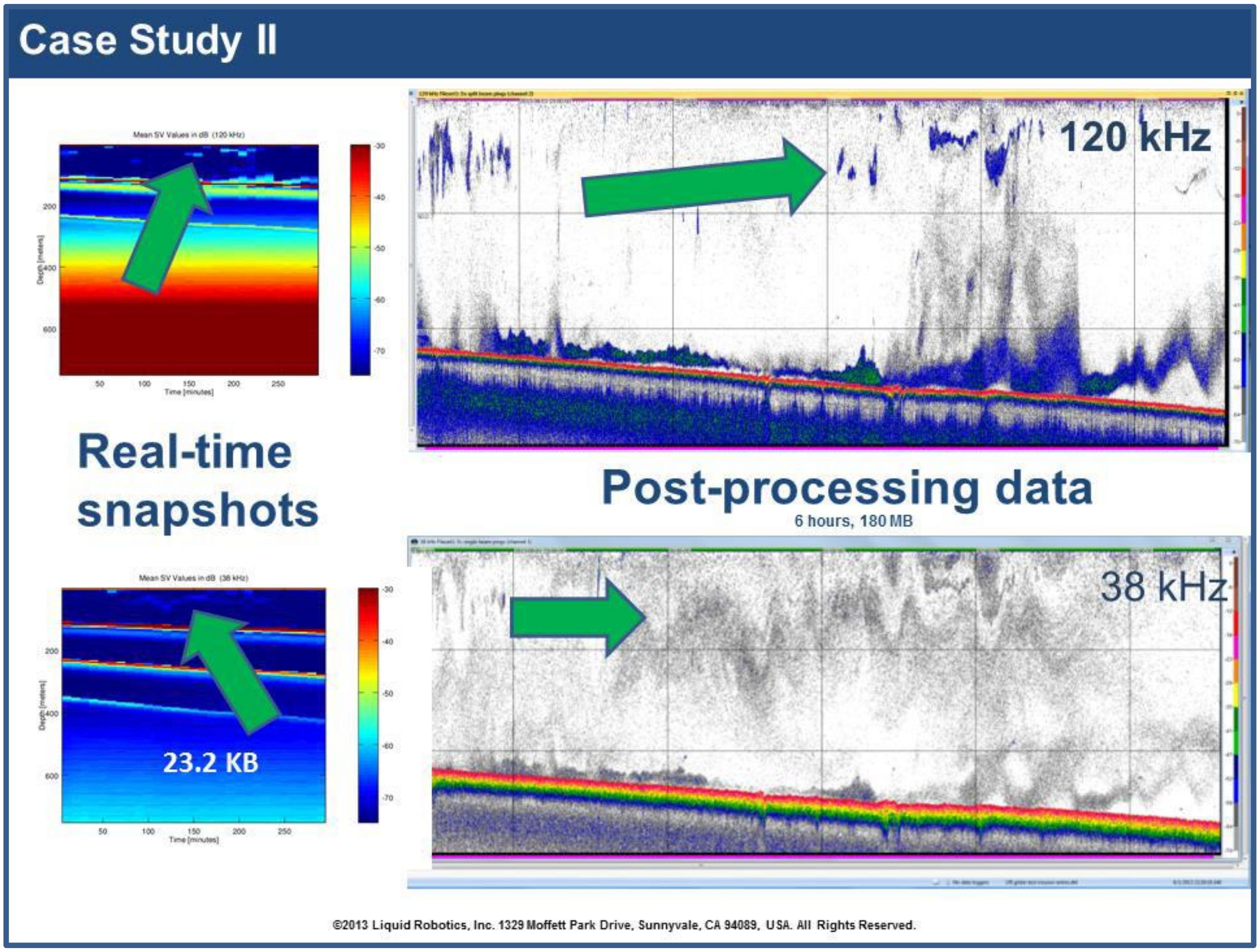


**Figure 21.** Low and high resolution echograms from 38- and 120-kHz echosounders collected during case study II, showing multiple zooplankton aggregations in the water column as well as near the bottom. The left column shows the low-resolution (raw) data while the right column provides the high-resolution acoustic echograms (courtesy of Liquid Robotics, Inc.).

Although the mission was not completely successful, it provided important guidance for future development: (a) the WG-TES system can be successfully deployed from both the small vessels and NOAA FSVs like *Bell Shimada*; (b) revisions are needed to avoid the loss of the towbody; and (c) more reduction in power consumption is desirable to conduct a more efficient survey.

Based on work completed during the past two years, the integrated WG-TES system is capable of collecting high quality multi-frequency acoustic data and transmitting snippets of low-resolution echo-integration data in real-time. We have submitted a proposal to NOAA-NOS-IOOS for the FY2014 Marine Sensor and Other Advanced Observing Technologies Transition Project. The title of our proposal is “Coastal Ocean Wave Glider Investigations for Rapid Low-Cost Surveys to Monitor, Assess, and Map Marine Fishery Resources and Ecosystems of the US Exclusive Economic Zone”. It is a 3-year proposal collaborative proposal led by Dr. Greene (Cornell University) involving scientists from

NOAA fisheries NWFSC and SWFSC, and PMEL, MBARI. We have been invited to submit a full proposal.

For more information, please contact Larry Hufnagle at lawrence.c.hufnagle@noaa.gov.

**b) The implications of spatially varying catchability on bottom trawl surveys of fish abundance: a proposed solution involving underwater vehicles**

Investigators: J. Thorson, M.E Clarke, I.J. Stewart, and A.E. Punt

Bottom trawl sampling is used to estimate trends in stock abundance for groundfishes worldwide, including Pacific rockfishes (*Sebastes* spp.). However, trawl sampling efficiency varies spatially and the distribution of groundfish populations may change among easy- and difficult-to-survey areas over time. These concerns have prompted interest in using underwater vehicles (UVs), for which catchability is likely to decrease less in rocky habitats. In this study, the authors use simulation modeling to evaluate the abundance trends arising from bottom trawl sampling given density-dependent habitat selection and spatially varying catchability. The authors first demonstrate that relative abundance indices in this case will generally be biased measures of changes in population abundance. They also propose and evaluate a sampling design that combines data from bottom trawl and UV gears. Combined sampling has greater precision than UV sampling, lower bias than bottom trawl sampling, and is robust to moderately violated assumptions regarding sampling strata or spatial catchability. In conclusion, the authors recommend future research that could test the assumptions under which combined sampling is a feasible solution to spatially varying catchability.

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**9. Observer Data Collection and Analysis**

The FRAM West Coast Groundfish Observer Program (WCGOP) continued collecting fishery-dependent data during 2013 on groundfish fleets along the entire U.S. west coast. The groundfish fishery is broken down into two main categories: the catch share fisheries and the non-catch share fisheries. The catch share fisheries require 100% observer and shore side monitoring. The non-catch share fisheries require observer coverage upon request and coverage is randomly assigned by fishery and port group.

**Table 3.** Number of observers that were deployed by the WCGOP in 2013

| 2013 | |
|---|---|
| Number of catch share observers | 87 |
| Number of non-catch share observers | 22 |
| Number of ASHOP Observers | 35 |

## a) Catch Shares

There are three sectors in the catch share program: shorebased, motherships (includes motherships and mothership catcher-vessels), and catcher-processors. All vessels participating in the shorebased sector or acting as mothership catcher-vessels (MSCV's) must carry one observer on all trips. Motherships and catcher-processors carry two observers each trip. The shorebased sector is managed through Individual Fishing Quotas (IFQ's) and includes all vessels that land catch at shoreside processors. Catch shares regulations allow the shorebased sector to use trawl, longline, or pots to harvest IFQ species. The mothership and catcher-processor sectors target Pacific hake using trawl gear and process it entirely at-sea. Motherships and catcher-processors have formed cooperatives to ensure sectors can attain Pacific hake quota without exceeding bycatch caps for overfished species or salmon. Table 4 below provides information on observer activities in the catch share fishery.

Catch Share observers are deployed in the following catch share fisheries:

- All vessels participating in the shore-based Individual Fishing Quota (IFQ) program including hake and non-hake groundfish trawl and fixed gear vessels
- All motherships participating in the at-sea hake fishery
- All mothership catcher-vessels participating in the at-sea hake fishery
- All catcher-processors participating in the at-sea hake fishery

**Table 4**. Summary of observer coverage and sea days in the catch share fisheries

| DESCRIPTION | SS IFQ Trawl | SS IFQ Fixed Gear | SS Hake | MSCV | A-SHOP |
|---|---|---|---|---|---|
| Number of vessels | 69 | 18 | 25 | 18 | 14 |
| Number of trips* | 1,227 | 122 | 943 | 46 | 72 |
| Number of Sea days* | 4,857 | | 2,082 | 627 | 1,424** |
| Number of Observers | 87 | | | | 35 |

*Includes trips and/or sea days where no fishing activity occurred.
**Includes both Lead and Second observers
Note: Totals as of 2/14/2014. Since data have not been finalized, these could change in the future.

**SS IFQ trawl**: vessels targeting non-hake groundfish with trawl gear and landing at shorebased processors.
**SS IFQ Fixed Gear**: vessels targeting non-hake groundfish using longlines or pots and landing at shorebased processors.
**SS Hake:** vessels targeting hake using trawl gear and landing at shorebased processors.
**MSCV**: mothership catcher-vessel targeting hake with trawl gear
**A-SHOP**: motherships and catcher-processors targeting hake using trawl gear

**b) Non-catch shares**

The observer program collects data in other west coast fisheries that are not part of the catch share program. The program had 1,450 sea days in the non-catch share fisheries in 2013 aboard vessels ranging in size from skiffs to larger fixed gear vessels and depths ranging from less than 20 fm to more than 300 fm.

**Table 5.** Non-Catch Share sea day summary by fisheries/sectors:

| NCS Sea Days | |
|---|---|
| **FISHERY DESCRIPTION** | SEA DAYS* |
| CA Yellowtail EFP | 6 |
| CA Halibut | 33 |
| CA Nearshore | 174 |
| CA Pink Shrimp | 42 |
| Limited Entry Sablefish | 222 |
| Limited Entry Zero Tier | 145 |
| OR Blue/Black Rockfish | 55 |
| OR Blue/Black Rockfish Nearshore | 170 |
| OR Pink Shrimp | 417 |
| WA Pink Shrimp | 124 |
| WC Open Access Fixed Gear | 62 |

*Includes sea days where no fishing activity occurred.

Due to its unique data collection circumstances in both the catch shares and non-catch shares fisheries, the program continues to stress safety and data quality.

**c) Data and analytical reports**

The data collected by observers is used to improve total catch estimates, primarily for fish discarded at-sea. The data are used in assessing a variety of groundfish species, by fisheries managers, and by other fishery, protected resource, and other scientists.

Summaries of data collected on observed trips are routinely published on the NWFSC web site.

All WCGOP reports can be obtained at:
http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/index.cfm.

For more information, please contact Jon McVeigh at Jon.McVeigh@noaa.gov

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