Northwest Fisheries Science Center

National Marine Fisheries Service

Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

April 2012

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. Five divisions, Conservation Biology, Environmental Conservation, Fish Ecology, Resource Enhancement and Utilization Technologies, and Fishery Resource Analysis and Monitoring, conduct applied research to resolve problems that threaten marine resources or that deter their use. At the current time the Environmental Conservation and Resource Enhancement and Utilization Technologies Divisions are being restructured to form a single new division. 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 Kodiak, Alaska.

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 2011, FRAMD continued to: implement a West Coast observer program; conduct a coast wide survey program that includes West Coast groundfish acoustic and trawl surveys; develop new technologies for surveying fish populations, particularly in untrawlable areas; 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 Conservation Division (ECD) conducts nationwide research on the effects of chemical pollution and harmful algal blooms on habitat quality and fisheries resources. ECD is also a leader in NMFS' National Marine Mammal Health and Stranding Response Program's bio-monitoring and quality assurances projects.

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 Resource Enhancement and Utilization Technologies Division draws together multi-disciplinary groups to address existing and developing challenges of captive rearing of salmon and other marine fish, improved hatchery practices, smolt quality, disease control, and developing technologies for full utilization of bycatch and fish processing waste.

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 effective area swept of a survey trawl

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

Density calculations from fishery-independent bottom trawl surveys can be scaled up to provide relative abundance estimates and population trends that are used for stock assessments. The Northwest Fisheries Science Center uses an Aberbeen bottom trawl net with sweeps outfitted with mud gear during its annual trawl survey. In situ video was used to quantify flatfish responses to the sweeps of this trawl in order to determine effective area swept and to improve survey accuracy. A total of 632 flatfish were observed and their behavior recorded from video collected during four tows. Fish were not randomly oriented with respect to the trawl sweeps; over 90% had a heading between 90 and 270° away from the mud gear, an indication of herding. The effect of fish size on the herding response was not significant and only 1.3% of fish were observed escaping over or under the mud gear. The mean distance that a stationary fish reacted to the gear was 36.6 cm (± 2.0 SE) and 50% of the observed fish that reacted to the mud gear did so at a distance of 73.76 cm (± 3.4 SE). The mean fish lengths estimated during video analysis was significantly smaller than the actual lengths of fish measured in the catch from 2 of 3 tows. Although 10 cm fish were commonly recorded during video analysis, 10 cm fish were almost completely absent from the catch. Flatfish herding is occurring along the mud gear of the Aberdeen bottom trawl net used in this study. Therefore, area swept calculations for the purpose of providing relative abundance estimates for stock assessments would ideally include some portion of the area swept by the mud gear. However, additional work will be necessary in order to determine the extent of herding along the entire length of the sweeps.

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

b) Can trip limits and time-area closures keep commercial catches of longnose skate and spiny dogfish shark below their harvest limits?

Investigators: D. Erickson, J. Cope and C. Niles

Commercial catches of spiny dogfish shark (*Squalus suckleyi*) and longnose skate (*Raja rhina*) off the U.S. west coast have recently reached levels that would exceed their annual harvest specifications. In general, both are incidentally caught in commercial trawl and fixed gear fisheries targeting other groundfish species. Limited commercial markets exist for these species, so targeting may occur, especially for dogfish shark. Life history characteristics of both species limit their resilience to overfishing. For example, dogfish sharks may not reach sexual maturity until approximately 35 years old, and may produce only 2-16 pups per litter over an 18-22 month gestation period. Such slow dynamics

would translate into long recovery times if harvest were to reduce these populations to low levels. Setting appropriate harvest levels is therefore of high importance for these species. The most common management measures used to control fishing mortality for west coast commercial groundfish fisheries are landing ("trip") limits and time-area closures. Such measures may have limited effectiveness for spiny dogfish shark and longnose skate. The geographic distribution of each is broad, extending along the entire U.S. west coast at depths from < 50 fathoms to > 600 fathoms. In addition, both species are often discarded at sea due to their limited marketability.

We examined the potential use of trip limits and time-area closures to control the fishing mortality of longnose skate and spiny dogfish shark off Washington, Oregon, and California. We evaluated the potential efficacy of these management measures through analysis of logbook, fish ticket, and at-sea observer data, and also discussed the potential impacts such management measures may have on commercial fisheries and coastal communities.

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

c) Temporal and spatial summer groundfish assemblages in trawlable habitat off the U.S. West Coast: 1977 to 2009

Investigators: J. Cope and M. Haltuch

Multispecies interactions are increasingly being considered by U.S. management councils during decision making, highlighting the need for the identification of fish assemblages across varying spatial and temporal resolutions. On the U.S. West Coast, previous groundfish assemblage analyses have focused either on particular species groups (i.e. *Sebastes*) or over limited time frames and/or geographic regions within the groundfish fishery. This work expands those previous studies to identify groundfish assemblages across the full spatial extent of the West Coast groundfish fishery from 1977-2009 by using two fishery-independent trawl surveys. Species assemblages were identified using two clustering methods (partitioning analysis and hierarchical analysis) and two realizations of the data (presence-absence and log+1 transformed CPUE). The analysis using presence-absence data provides information on species that co-occur while the CPUE data provides information on species that occur at similar magnitudes. Temporally and spatially persistent assemblages were detected by both clustering methods through most years. Assemblages identified using CPUE were often subsets of those identified using presence-absence, indicating that the members of an assemblage may occur together, but not necessarily at the same magnitude, a result that should be considered when choosing the clustering metric. Identification of species assemblages is applicable to bycatch models and informative when evaluating the implementation of spatial management measures, thus germane to current challenges faced by marine resource managers.

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

d) 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 2000, 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 δ15N between years. Depleted δ13C values were indicative of diets based on primary production from a more offshore origin. 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.

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e) 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.

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

f) 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 yielded only a limited and potentially biased view of their trophic feeding behavior. As an alternative we measured δ13C and δ15N of *D. gigas* and their prey from the northern California Current ecosystem, and applied a stable isotope Bayesian mixing model to assess the proportional contributions of prey groups to their diet. Cluster analysis of prey taxa by their respective δ13C and δ15N values was first applied to consolidate prey into groups, which were then incorporated into a stable isotope mixing model (SIAR) as source groups to the diet mixture. Model results showed lower trophic-level feeding by *D. gigas* relative to previous diet-based studies, with greatest contributions from macrozooplankton and ichthyoplankton (median 50% credibility interval contribution = 0.26-0.43), and nekton of yearling-juvenile rockfish, market squid, sand lance, and juvenile hake (0.22). Prey groupings composed of myctophids and other deep water benthic-pelegic species, yearling-adult hake, other squid species, sardine and anchovy, juvenile salmonids and other nekton displayed negligible contributions (≤ 0.01). Sensitivity analyses of the SIAR model based on varying isotopic fractionation factors of δ13C (0, 0.39, 0.8, and 1.2‰) and δ15N (2.6, 3.0, and 3.4‰) showed that proportional contributions of prey to squid diets were fairly resilient to change. Analyses of size-specific shifts in δ13C and δ15N showed weak but significant relationships with increasing mantle length.

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g) Co-occurrence of demersal fish species in the US west coast bottom trawl fishery.

Investigators: E. Heery and J. Cope

This study presents a comprehensive and current view of species co-occurrence onboard commercial vessels in the bottom trawl fishery using data from a mandatory at-sea observer program conducted yearly from 2002. Three major questions were explored: (1) Are there identifiable associations between species caught in the bottom trawl fishery? (2) Do overfished species cluster with certain target groups in a consistent and predictable way? (3) Do overfished species cluster at particular spatial scales or are

relationships spatially consistent across the whole data set? Results indicate two particularly significant assemblages when evaluating data from the entire geographic range of the fishery: a deepwater/slope group that included Dover sole, sablefish, and shortspine thornyhead, and a shallower shelf group dominated by English sole and petrale sole. Results also indicate that our ability to predict bycatch events of rare overfished species based on the catch of target species is extremely limited. Associations between overfished rockfish and other groundfish species simply are not evident over large spatial scales.

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

h) Variation is age and growth of greenstriped rockfish (*Sebastes elongatus*) along the U.S. west coast (Washington to California)

Investigators: A.A. Keller, K. Molton, A.C. Hicks, M. Haltuch and C. Wetzel

Greenstriped rockfish, *Sebastes elongatus,* are a common commercial and recreational species often taken as by catch in commercial west coast fisheries. We evaluated weight-length relationships and size-at-age using von Bertalanffy growth models for greenstriped rockfish sampled along the U.S. west coast from 2003 to 2008. Based on regression analyses, populations were subdivided into two depth strata (55 -122 m and 122 - 450 m) and four geographic regions (48°10'N – 48°28'N, 40°26'N – 48°10'N, 34°27'N – 40°26'N and 32°30'N – 34°27'N) and differences in length, age and growth examined by gender. Strong evidence of variation in weight-length relationships was found north and south of Cape Mendocino (40°26'N) but little variation was noted for depth or gender. In contrast, variations in von Bertalanffy growth models were highly dimorphic between sexes with consistent patterns across depth and geographic regions. Females grew more slowly and reached larger asymptotic sizes (L_∞, cm) relative to males in all regions examined. Asymptotic size for both males and females tended to increase at higher latitude and increased depth; however the smallest asymptotic sizes occurred in the region from Pt. Conception to Cape Mendocino, CA (34°27'N – 40°26'N), rather than lower latitudes south of Pt. Conception (32°30'N – 34°27'N). Greenstriped rockfish growth rates (k, yr^{-1}) exhibited a more complex pattern. Higher growth rates were associated with regions within the northern California Current system characterized by high productivity.

For more information please contact Aimee Keller at Aimee.Keller@noaa.gov

i) Variations in Eastern North Pacific demersal fish biomass based on the U.S. West Coast groundfish bottom trawl survey (2003–2010)

Investigators: A.A. Keller, J. Wallace, B. Horness, O. Hamel and I. Stewart

In response to declining biomass of Northeast Pacific groundfish in the late 1990s and to improve the scientific basis for management of the fishery, the Northwest Fisheries Science Center standardized and enhanced their annual bottom trawl survey in 2003. The survey was expanded to include the entire area along the U.S. West Coast at depths of

55–1280 m. Coast-wide biomass and species richness significantly decreased during the first eight years (2003–2010) of this fishery-independent survey. We observed an overall tendency towards declining biomass for 62 dominant taxa combined (fishery target and non-target species) and four of seven subgroups (including cartilaginous fish, flatfishes, shelf rockfishes, and other shelf species), despite increasing or variable biomass trends in individual species. These decreases occurred during a period of reduced catch for groundfish along the shelf and upper slope regions relative to historical rates. We utilized information from multiple stock assessments to aggregate species into three groups: with or without large recruitment in 1999 or unknown recruitment level. For each group, we evaluated if declining biomass was primarily related to depletion (using year as a proxy) or environmental factors (i.e., variation in the Pacific Decadal Oscillation). Based on Akaike's Information Criterion, changes in aggregate biomass for species with strong recruitment were more closely related to year while those with no strong recruitment were more closely related to climate. The significant decline in biomass for species without strong recruitment confirms that factors other than depletion of the exceptional 1999 year class may be responsible for the observed decrease in biomass along the U.S. West Coast.

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j) Preliminary life history variability of longnose skate (*Raja rhina*) across two large marine ecosystems: Gulf of Alaska and California Current System

Investigators: C. Gburski, T. Helser, V.V. Gertseva, J.R. King and D.A. Ebert

The longnose skate, *Raja rhina*, is common in the eastern North Pacific Ocean ranging from the Bering Sea to Baja California and occurs from close inshore to a maximum of 1000 m depth. In the Gulf of Alaska (GOA), it has a maximum total length and age of 145 cm and 25 years, respectively. A directed fishery for *Raja* spp. off Kodiak Island, Alaska was initiated in 2003, ending in 2005. An experimental fishery in Prince William Sound, Alaska was reinstated in 2009. The vulnerability of elasmobranchs to over exploitation from commercial fishing, either from bycatch or a directed fishery, is well-documented. This inter-agency and institutional (AFSC, NWFSC, DFO and MLML/PSRC) collaborative study quantitatively compares growth and age/size at sexual maturity of the longnose skate across two large marine ecosystems, the GOA and California Current Ecosystem (CCE), on a spatial and temporal scale. Potential environmental (e.g., bottom water temperature) and oceanographic influences on life history traits between the GOA and CCE are also examined. Vertebrae (n=500) for this study were collected off the GOA, British Columbia (BC) 'current break' and U.S. west coast states between 2001 and 2009 from research surveys and via port sampling. Ages were estimated from vertebrae prepared with the standard (unstained) thin sectioning technique in this preliminary study. A new histological (stained) method will be applied to archival vertebrae in the future. Age estimates from the standard technique and a new histological method will be compared to validated ages from a longnose skate 14C study. The methods estimated ages that best fit the validated ages will be used to standardize ageing criteria among agencies therefore optimizing age determination for use in stock assessment and management.

For more information, please contact Vlada Gertseva at Vladlena.Gerseva@noaa.gov

k) Recent increase in *Nybelinia surmenicola* prevalence and intensity in Pacific hake (*Merluccius productus*) off the United States west coast

Investigators: D. Bryan, K. Jacobson and J. Buchanan

A larval marine cestode was found in 82.0% of 834 Pacific hake (*Merluccius productus*) stomachs collected from 341 trawl stations along the United States west coast during the summers of 2008 and 2009. Morphology and DNA sequencing were used to identify the cestode as *Nybelinia surmenicola*. In an examination of 131 Pacific hake stomachs collected from the same region in 1999, *N. surmenicola* prevalence was 35.1%. The results from a general linear model suggested that their prevalence is influenced by year and latitude, Pacific hake size, and sex. Mean intensity of *N. surmenicola* in 2008–2009 was 20.22 (±1.13 SE) and was positively related to Pacific hake length and the latitude of collection. Year-1 Pacific hake (<27 cm length) had significantly lower prevalence and intensity of *N. surmenicola* compared to older and larger fish. Pacific hake collected south of Point Conception, California (32.5 to 35ºN) had lower prevalence and intensity of *N. surmenicola* compared to those collected in northern latitudes (35.1 to 48.4ºN). Higher *N. surmenicola* prevalence in Pacific hake in recent years suggests food-web fluctuations in the northern California current ecosystem caused by changes in ocean transport of zooplankton or pelagic fish distributions and warrants future monitoring as a metric for ecosystem change.

For more information, please contact John Buchanan at John.Buchanan@noaa.gov

l) Light availability during bottom trawls affects catchability of Eastern Pacific groundfish species

Fisheries assessments depend on fisheries-independent surveys to provide relative indices of biomass and abundance. Trawl survey catch rates vary across gradients of environmental variables. We tested the effect of near-bottom light levels on catch rates and catch probability for four common groundfish: arrowtooth flounder (*Atheresthes stomias*), greenstriped rockfish (*Sebastes elongatus*), longnose skate (*Raja rhina*), and Pacific hake (*Merluccius productus*). Downward irradiance was measured with net-mounted archival tag during annual West Coast trawl surveys in 2009 and 2010. Near-bottom light levels were recorded for 822 hauls completed at <400 m water depth. For all four species, there was a significant linear relationship between the catch per swept area (CPUE) and near-bottom irradiance ($p<0.05$). CPUE of Pacific hake decreased 17% for every unit increase in log 10 photon flux ($\mu E\ m^{-2}\ s^{-1}$), conditioning for depth and latitude. Irradiance, depth, and latitude explained 17% of the variance in CPUE. CPUE of arrowtooth flounder decreased 23% for every unit increase in log 10 photon flux ($\mu E\ m^{-2}\ s^{-1}$), conditioning for depth and latitude. Irradiance, depth, depth^2, and latitude explained 48% of the variance in CPUE. CPUE of longnose skate decreased 19% for every unit increase in log 10 photon flux ($\mu E\ m^{-2}\ s^{-1}$), conditioning for depth and latitude. Irradiance, depth, depth^2, and latitude explained 22% of the variance in CPUE. CPUE of

greenstriped rockfish increased 37% for every unit increase in log 10 photon flux (μE m^{-2} s^{-1}), conditioning for depth and latitude. Irradiance, depth, $depth^2$, and latitude explained 27% of the variance in CPUE. The probability of catch for all four species was affected by near-bottom irradiance. At 100 m depth, the probability of catch decreased as irradiance increased for all fish. For arrowtooth flounder, greenstriped rockfish, and longnose skate there was an interaction between irradiance and depth. The relationship between near-bottom irradiance, CPUE, and availability of these groundfish can explain the variability in catch rates for bottom trawl surveys.

For more information, please contact Mark Bradburn at Mark.Bradburn@noaa.gov

m) Fine-scale analysis of arrowtooth flounder (*Atherestes stomias*) catch-per-unit-effort reveals spatial trends in abundance and diet

Investigators: S. Zador, K. Aydin and J.M. Cope

Multiple lines of evidence suggest that changes in the marine climate in the eastern Bering Sea are leading to numerical and distributional shifts in fish populations that may affect the balance of predator−prey relationships. A rapidly increasing arrowtooth flounder *Atheresthes stomias* population has prompted concern about the growing threat of arrowtooth flounder predation on economically valuable walleye pollock *Theragra chalcogramma*. The goal of this study was to investigate the overall increasing trend of arrowtooth flounder at a finer spatial resolution to better understand the potential spatial variability in their predatory impact under a changing climate. The specific objectives were to determine whether arrowtooth flounder were increasing equally throughout the eastern Bering Sea and, if not, (1) identify areas with dissimilar abundance trends and (2) explore physical and biological habitat characteristics that may be contributing to these differences. Clustering arrowtooth survey catch per unit effort revealed 4 distinct spatial groups showing stable, increasing, and variable trends. Increasing bottom water temperature and depth were associated with higher proportions of trawls containing arrowtooth and higher catch rates. Age-1 and -2 pollock were the predominant prey in all areas, but higher rates of non-empty stomachs in the northwest region indicated that current predatory impacts on pollock may be higher there. Favorable physical habitat (deep and warm) and diet trends (full stomachs) suggest that arrowtooth flounder in the northwest region of the eastern Bering Sea have the potential to increase further, perhaps to the abundance levels seen in the high-density area where they may have reached carrying capacity.

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

n) Identifying potential habitats from multibeam echosounder imagery to estimate abundance of groundfish: a case study at Heceta Bank, OR, USA

Investigators: J.E.R. Getsiv-Clemons, W.W. Wakefield, C.E. Whitmire and I.J. Stewart

The Habitat and Conservation Engineering group contributed a case study (Getsiv-Clemons et al. 2012) to the recently published "Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of Seafloor Geomorphic Features and Benthic Habitats" (P.T. Harris and E.K. Baker, eds., Elsevier, Amsterdam, 2011). The Atlas provides an integrated look at seafloor lithologies and marine benthic habitats including background information on the concepts of taking a geohabitat approach to habitat science, including

habitat classification schemes, techniques for mapping benthic habitats, and the importance of habitat science to resource management. The volume includes fifty-six case studies from around the world. The NWFSC's contribution is for Heceta Bank, Oregon.

Heceta Bank is one of the largest banks off the western coast of North America, extending 55 km from north to south and rising above the continental shelf to 67 m water depth. Due to heterogeneous substrate of varying relief, the bank supports a diverse assemblage of demersal fishes and is an important fishing ground off the coast of Oregon, USA. The top of the bank is comprised of boulders and cobbles eroded from outcrops of sedimentary rocks, while layers of finer grain size material cover the lower-relief flanks. Using observations of fish-substrate associations from 19 remotely operated vehicle dives, we identified 57 distinct substrate types and 9 habitat types. In a separate exercise, we overlaid observations of substrate types onto high-resolution multibeam imagery to delineate 4 potential habitat classes. Using this map of potential habitats, we estimated bank-wide abundance and variance values for a select group of resident fishes.

For more information please contact Waldo Wakefield at Waldo.Wakefield@noaa.gov, or Julia Getsiv-Clemons (julia.clemons@noaa.gov)

o) A relative index of age-1 Pacific hake (*Merluccius productus*) abundance off the west coast of North America, 2003-2011

Investigators: J.E.R. Getsiv-Clemons, R.E. Thomas and I.J. Stewart

Pacific hake (*Merluccius productus*) are an ecologically and commercially important groundfish species in the California Current ecosystem. The relative abundance and distribution of the adult (age-2+) portion of the Pacific hake stock is monitored through a biennial acoustic survey conducted jointly by the U.S. and Canada. The survey covers the North American coast from 50-1500 m water depth and 35°-55° north latitude, with systematic transects generally oriented perpendicular to the coastline and spaced 10-20 nm apart. Mid-water and bottom trawls are deployed to sample the species composition of observed acoustic backscatter and to collect biological information for hake including size, age, weight, and sex. Although more difficult to survey than the adult stock, acoustic and trawl data are also collected for age-1 hake. We investigated these data with regard to the schooling behavior of age-1 hake, as well as the observed spatial distributions across latitude and depth. We calculated a relative index of age-1 hake abundance for each survey year from 2003-2011. We then compared this index with recent stock assessment results to investigate its use as a predictive tool for the strength of future incoming year classes. This analysis may eventually be helpful to both the stock assessment and joint international hake fishery management in reducing the large uncertainty in strong recruitment events prior to the observation of these year-classes in other data sources.

For more information please contact Julia Clemons at Julia.Clemons@noaa.gov

p) Five-year review of essential fish habitat for Pacific coast groundfish

The current designations of EFH for Pacific Coast groundfish, as described in Amendment 19 to the Pacific Coast Groundfish FMP, were approved by NMFS in May 2006. Initial EFH designations were based on the best available data that were assimilated and developed from 2002 to 2005. Beginning in 2010, the Pacific Fisheries Management Council, NW and SW Fisheries Science Centers, and the NMFS Regional Offices initiated the first mandatory 5-year review for EFH provisions of the groundfish fishery management plan, and in this context, the Council formed an ad hoc EFH Review Committee. The groundfish EFH review is a three-phase process. Phase I includes the evaluation of published scientific literature and unpublished scientific reports; solicitation of information from interested parties; and the review of previously unavailable or inaccessible data. Information will be updated on the distribution and extent of seafloor maps of bathymetry and interpreted groundfish habitat types; the distribution and extent of groundfish fishing effort; the distribution of biogenic habitat; spatial management boundaries; prey species for groundfishes; known or potential anthropogenic impacts to habitats (including groundfish prey); and habitat associations for 91 groundfish species. At the end of Phase I, the new information will be presented to the Council, its advisory bodies, and the public, and the Council will solicit proposals to modify EFH and Habitat Areas of Particular Concern (September 2012). The 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 of Magnuson-Stevens Fishery Conservation and Management Reauthorization Act.

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q) NOAA Habitat Blueprint: A framework to improve habitat for fisheries, marine life, and coastal communities

NOAA is developing and implementing new habitat-based solutions to support healthy and productive ecosystems – the Habitat Blueprint. To this end, NOAA will expand our partnerships, prioritize its activities, and direct its focus to better understand, protect, and restore habitat for the benefit of our living marine resources and coastal communities. The Habitat Blueprint consists of a four-pronged approach: 1) Implementing regional initiatives, 2) Establishing geographic priorities, 3) Implementing a systematic and strategic approach to habitat science, and 4) Strengthening policy and legislation. While the NOAA Habitat Blueprint starts with increasing efficiencies within NOAA and across its programs and offices, it is also designed to foster collaboration across federal, state, and local levels.

A part of NOAA's Habitat Blueprint will be the implementation of regional habitat initiatives to explore new collaborative approaches to habitat science and conservation. These initiatives will preserve or improve habitat conditions within a defined geographic area to address specific challenges to living marine and coastal resources. There are two initiatives for the Pacific coast. The initiative for the Northwest will focus on Puget Sound. The State of Washington has lost more than 70 percent of its estuarine wetlands and 50 percent of its riparian habitat, with losses continuing to mount. To address these losses and the impacts on threatened Chinook salmon in the Puget Sound, NOAA Fisheries will work with federal, state, tribal, and local partners to develop new strategies

to conserve salmon habitat. NOAA will integrate scientific modeling and monitoring with regulatory and restoration programs. Actions include reconnecting floodplains and restoring ecosystem functions through dike removal and levee setbacks, leading to restoration of more than 500 hundred acres in the Nooksack, Skagit, Puyallup/White, and Snohomish watersheds. While efforts will focus on habitat restoration in the near-term, NOAA will provide a critical scientific framework for long-term recovery.

In the Southwest, the initiative will focus on the Southern California Bight. The Bight is rich with important fisheries and other marine life, including endangered white abalone, deep-sea corals, and sponges. To address impacts caused by fishing and non-fishing activities, NOAA Fisheries will assess and monitor deep-water ecosystems. NOAA will use a variety of advanced survey tools and approaches to improve our assessments of living marine resources and their habitats in water depths 20 to 900 meters off southern California. These assessments and enhanced delivery of information to managers will improve conservation recommendations for Pacific coast groundfish. We will also evaluate the effectiveness of protected areas as a tool for resource conservation along the West Coast, particularly for rockfish and deep-sea corals.

For more information go to: http://www.habitat.noaa.gov/blueprint/

r) Demersal fish species composition and biomass in relation to low oxygen conditions along the U.S. West Coast

Investigators: A. A. Keller, V. Simon, K. Bosley. M. Bradburn, D. Kamikawa, J. Buchanan, W.W. Wakefield, J.A. Barth and S. Pierce

Understanding the relationship between environmental variables and fish distribution and abundance has long been a goal of fisheries biologists. Since 2002, hypoxic conditions have been observed on the continental shelf off the coast of the Pacific Northwest in a region not previously characterized by low oxygen conditions. In addition, major declines in dissolved oxygen have been observed in the oxygen minimum zone (OMZ) within the California Current as well as a shoaling of the OMZ. Despite these recent increases in frequency, duration, and spatial extent of hypoxia and the recognition of hypoxia as a threat to worldwide fish production, little is known about its effects on upper trophic levels. In 2007, the Northwest Fisheries Science Center (NWFSC) initiated studies on the extent of hypoxic conditions on the continental shelf and slope along the west coast and the influence of hypoxia on demersal fishes and invertebrates, including commercially important groundfish. This project was developed as an extension of the NWFSC West Coast Groundfish Bottom Trawl Survey.

In 2011, we sampled a range of oxygen conditions extending from the upper to the lower limit of the OMZ as well as across the boundaries of the OMZ. We collected data on the composition, distribution, and biomass of demersal groundfish species in relation to bottom oxygen concentration within the Eastern North Pacific oxygen minimum zone (OMZ) along the U.S. West Coast from May 16 – July 26, 2011 (pass 1) and August 15 – Oct. 25, 2011 (pass 2). The 2011 catch data have not yet been analyzed but results for 2009 – 2010 are included below. We measured bottom oxygen concentrations on 360

successful tows conducted during the 2009 West Coast Groundfish Bottom Trawl Survey and 621 successful tows conducted during the 2010 survey. Our results indicate that DO ranged from 0.08 to 4.25 ml l^{-1} in 2009 with 240 stations experiencing hypoxic conditions (DO < 1.43 ml l^{-1}). In 2010, near bottom DO ranged from 0.02 to 3.97 ml l^{-1} with 376 stations located in hypoxic waters. Throughout this project, the NWFSC Center has collaborated with a group of physical oceanographers at Oregon State University to develop procedures and protocols for integrating the collection of oceanographic quality temperature, salinity, and dissolved oxygen data into the West Coast Groundfish Bottom Trawl Survey.

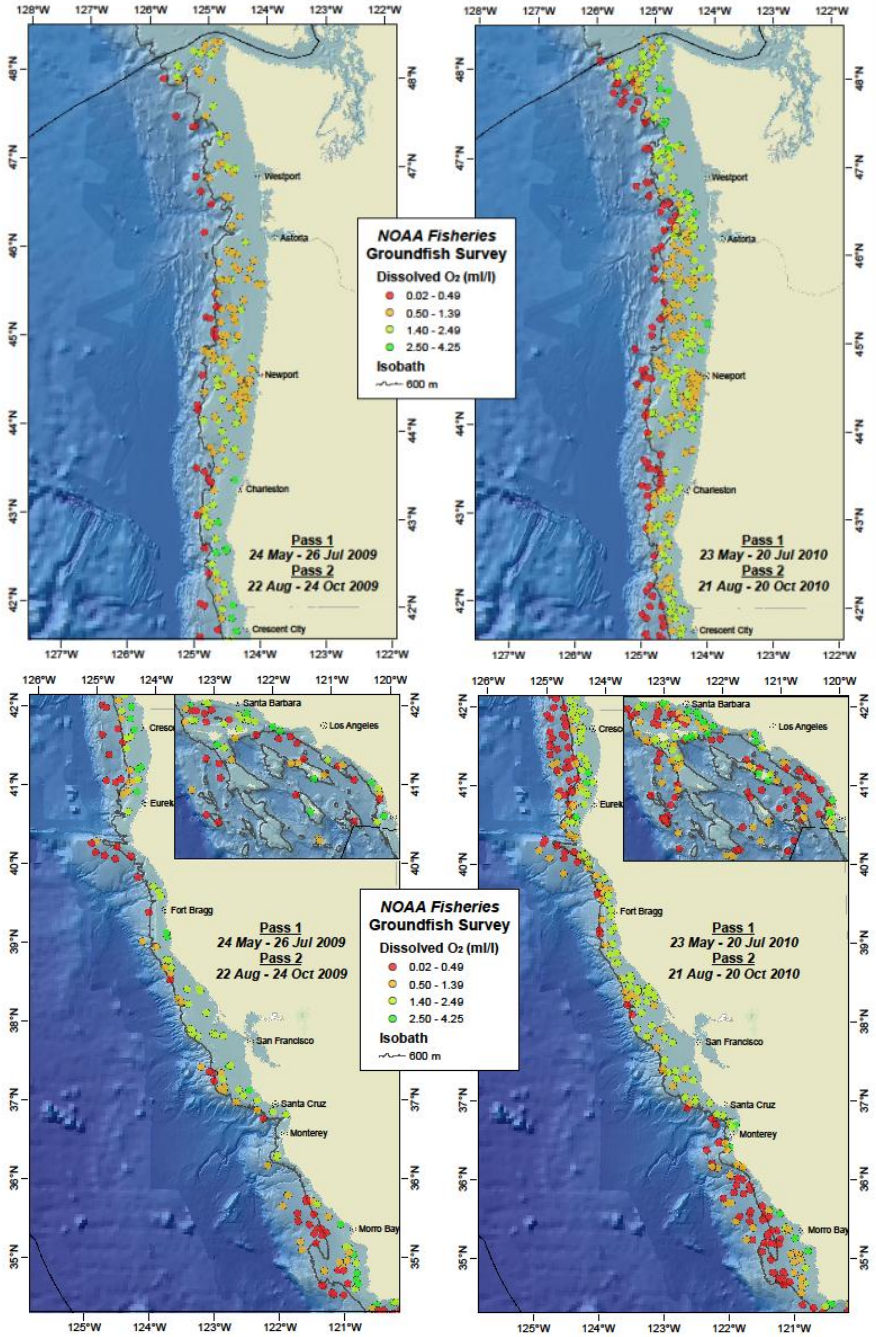

Figure 1 demonstrates the distribution of near bottom oxygen concentration during Pass 1 and Pass 2 of the 2009 and 2010 surveys. Sampling during the groundfish surveys

indicates low DO in deep water within the OMZ during both passes of the survey. Low DO appeared to move shoreward as the summer progressed and later in the season occurred in shallower water offshore of both Washington and Oregon. In the southern California Current low DO was more widespread in July (pass 1) than Oct. (pass 2) with the geographic distribution of low DO waters variable between passes.

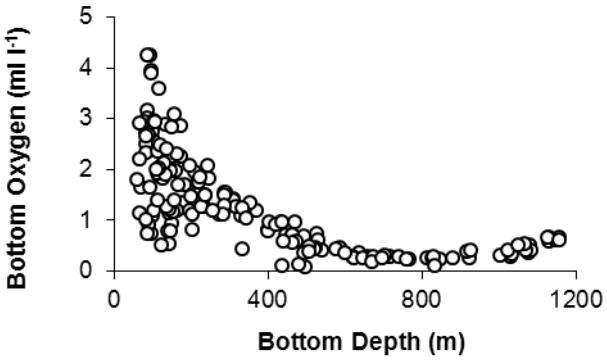

Figure 2 demonstrates the relationship observed between near bottom oxygen concentration and tow depth during the 2009 survey and clearly demonstrates the presence of low oxygen at greater depths.

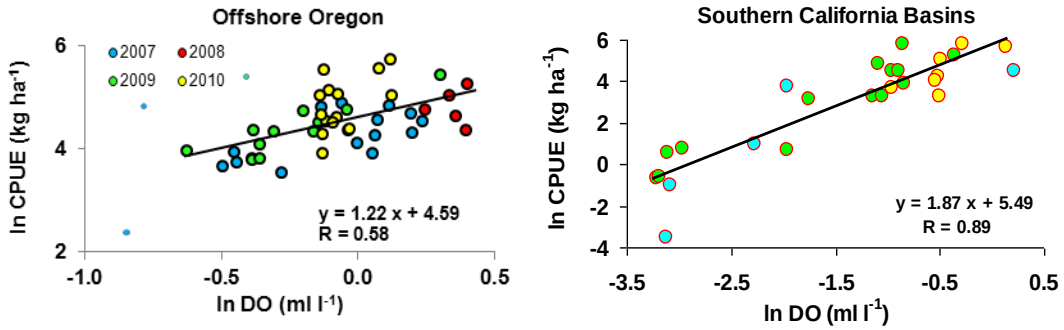

Figure 3 demonstrates the significant relationships between demersal organisms (catch per unit effort, CPUE, ln kg ha^{-1}) and near bottom oxygen concentrations (ln ml l^{-1}) during 2007 – 2010 in an hypoxic area offshore of Oregon (three outliers shown are smaller symbols) and during 2008, when 39 bottom trawls were made in the vicinity of the Santa Barbara Basin (SBB, n=19, green), the Santa Monica Basin (SMB, n=9, blue) and adjacent areas (ADJ, n=11, yellow). Results were similar, although less variable, to those seen offshore Oregon, with significant positive relationships between CPUE and near-bottom oxygen for tows within hypoxic waters (n=26).

Results from coast-wide hypoxic stations in 2009 – 2010 (Figure 4) were similar to those observed in 2007 – 2010 off Oregon and 2008 off California. CPUE (fish plus invertebrates) was significantly ($P<0.0001$) and positively related to near-bottom oxygen concentrations within hypoxic areas. Further analysis, using stepwise regression confirmed the importance of depth in the relationship between CPUE and near bottom

DO. Both variables were retained in the relationship with an overall r^2=0.29 when all data in hypoxic waters, DO<1.4 ml l^{-1} (2007 – 2010) were included in the analysis.

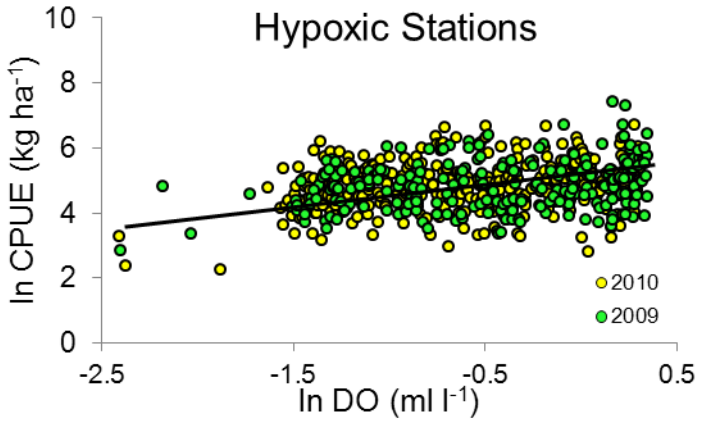

Figure 4, average near-bottom DO along the tow tracks are shown for the 616 hypoxic tows sampled coast wide in 2009 – 2010, using a Sea-Bird SBE 19*plus* attached to the net.

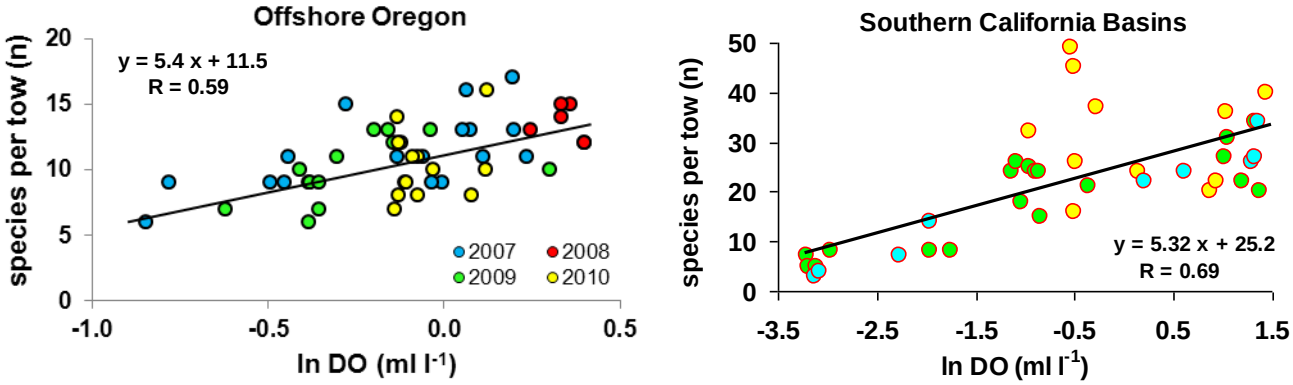

Figure 5 demonstrates that species richness (demersal fish and benthic invertebrates) varied significantly and positively with bottom oxygen concentration both offshore Oregon and within the hypoxic area of the southern California basins (green: Santa Barbara Basin; blue: Santa Monica Basin; yellow: adjacent areas). This relationship was not significant when examined using all data (coast wide and all depths) suggesting that both depth and/or geographic areas may influence the relationship.

Figure 6 shows the probability of occurrence of four selected species (spotted ratfish, Petrale sole, greenstriped rockfish and Dover sole) from the 2008 – 2010 surveys in relation to bottom depth (m) and near bottom dissolved oxygen (DO, ml l^{-1}). Probability values are estimated from a binomial Generalized Additive Model fit to the presence/absence data of the 2008 – 2010 NWFSC West Coast Groundfish Bottom Trawl Survey. For each examined species, in addition to the interaction term between depth and DO the species models also included terms for: position (longitude and latitude), time of the day, day of the year, salinity and near-bottom water temperature. In each plot, the

grey dots indicate the actual sample values of DO and depth. The R^2 values indicate the amount of variance explained by the full model (including all terms). N = number of sampled stations.

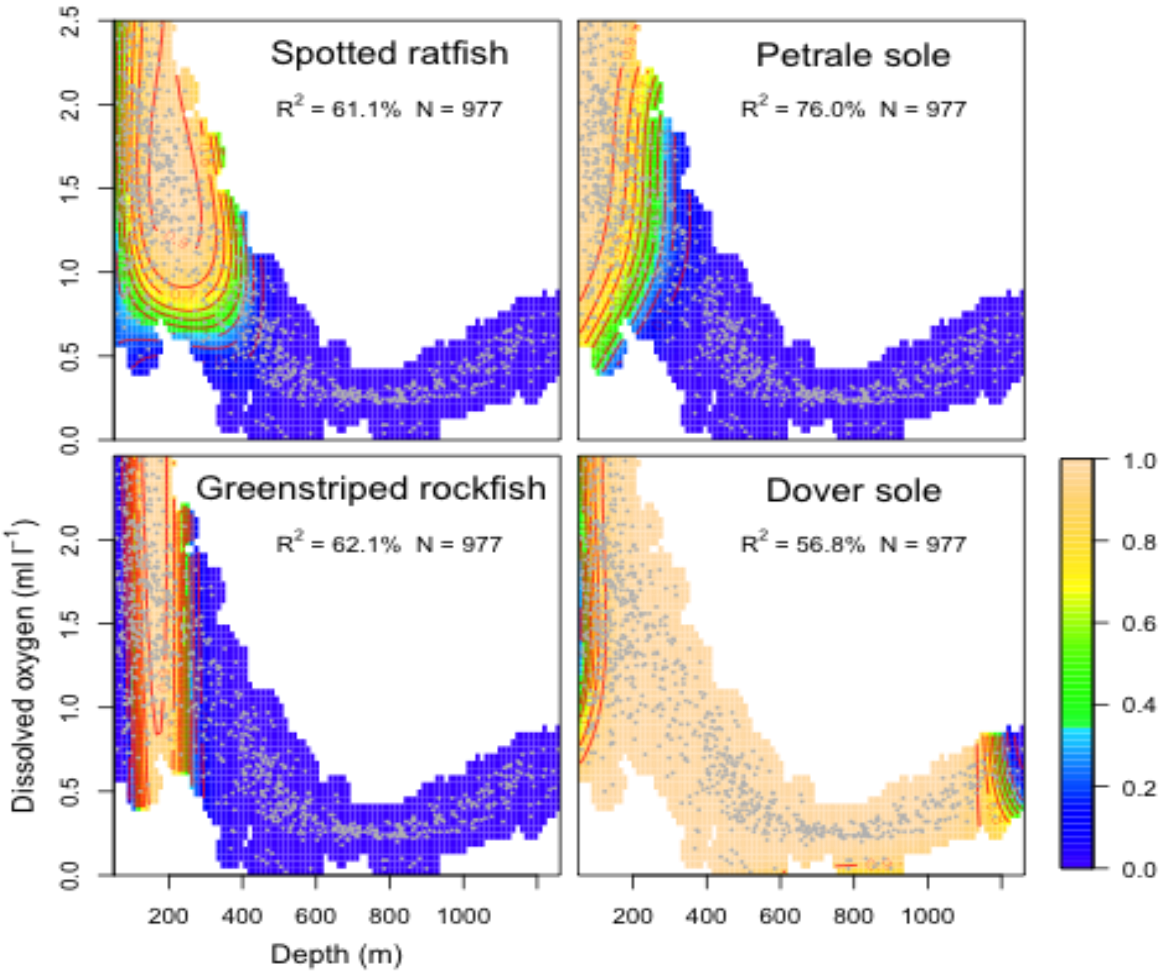

Figure 6. The probability of occurrence of four selected species (spotted ratfish, Petrale sole, greenstriped rockfish and Dover sole) from the 2008 – 2010 surveys in relation to bottom depth (m) and near bottom dissolved oxygen (DO, ml l^{-1}).

Results indicate that spotted ratfish and petrale sole (top two plots) are most sensitive to changes in near bottom DO, while greenstriped rockfish and Dover sole show no changes in probability of occurrence in relation to changes in DO. The probability of occurrence for spotted ratfish decreases sharply once DO goes below 1 ml l^{-1}. Greenstriped rockfish, petrale sole and spotted ratfish are mostly found in the upper slope region (depth <400 m) while the probability of catching Dover sole increases in the deeper slope areas (depth > 200 m), even when DO values are < 0.5 ml l^{-1}.

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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 3.23b as of November 2011).

In 2011 Stock Synthesis was featured in the following non NWFSC publications as well as numerous publications reported below in section 10:

Piner, K.R., Lee, H-H., Maunder, M.N. 2011. A simulation-based method to determine model misspecification: examples using natural mortality and population dynamics models. Mar. Coast. Fish. 3(1): 336-343.

Maunder, M.N., Wong, R.A. 2011. Approaches for estimating natural mortality: Application to summer flounder (*Paralichthys dentatus*) in the U.S. mid-Atlantic. Fisheries Research 111, 92– 99.

Wetzel, C.R., Punt, A.E. 2011. Performance of a fisheries catch-at-age model (stock synthesis) in data-limited situations. Mar. Freshwat. Res. 62:927-936.

He, X., Ralston, S., MacCall, A.D. 2011. Interactions of age-dependent mortality and selectivity functions in age-based stock assessment models. Fish. Bull. 109:198–216.

For more information, please contact Richard Methot at Richard.Methot@noaa.gov

b) Estimating natural mortality within a fisheries stock assessment model: an evaluation using simulation analysis based on twelve stock assessments

Investigators: H-H. Lee, M.N. Maunder, K.R. Piner and R.D. Methot

Natural mortality (*M*) is one of the most influential and difficult to estimate number of losses in fisheries stock assessment and management. Typically, natural mortality is

estimated using indirect methods, such as correlation with measurable life history factors and rarely relies on direct data such as tagging studies. In contemporary stock assessments, natural mortality may be estimated within the model by integrating different types of data into the analysis. We evaluated the estimability of *M* using simulation analyses based on 12 groundfish stock assessments conducted using Stock Synthesis. The advantages of utilizing this set of peer-reviewed assessment models were that various types of data were used over a wide range of model parameterization. Our results suggest that, in many cases, *M* is estimable with appropriate data. Profile likelihood analyses suggested that informative length or age composition data is needed to reliably estimate *M*.

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c) Adjusting for bias due to variability of estimated recruitments in fishery assessment models

Investigators: R. Methot and I. Taylor

Integrated analysis models provide a tool to estimate fish abundance, recruitment, and fishing mortality from a wide variety of data. The flexibility of integrated analysis models allows them to be applied over extended time periods spanning historical decades with little information from which to estimate the annual signal of recruitment variability to modern periods in which more information about recruitment variability exists. Across this range of data availability, the estimation process must assure that the estimated log-normally distributed recruitments are mean unbiased to assure mean unbiased biomass estimates. We examined how the estimation method implemented in the integrated analysis model, Stock Synthesis, achieves this unbiased characteristic in a penalized likelihood approach that is comparable to the results from Markov chain Monte Carlo. The total variability in recruitment was decomposed into variability among annual recruitment estimates based on information in the data and a residual variability. Because data are never perfectly informative, we demonstrated that estimated recruitment variability will always be less than the true variability among recruitments and that the method implemented here can be used to iteratively estimate the true variability among recruitments.

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d) Performance of a fisheries catch-at-age model (stock synthesis) in data-limited situations

Investigators: C.R. Wetzel and A.E. Punt

Limited data are a common challenge posed to fisheries stock assessment. A simulation framework was applied to examine the impact of limited data and data type on the performance of a widely used catch-at-age stock-assessment method (Stock Synthesis). The estimation method provided negatively biased estimates of current spawning-stock biomass (*SSB*) relative to the unfished level (final depletion) when only recent survey

indices were available. Estimation of quantities of management interest (unfished *SSB*, virgin recruitment, target fishing mortality and final depletion) improved substantially even when only minimal-length-composition data from the survey were available. However, the estimates of some quantities (final depletion and unfished *SSB*) remained biased (either positively or negatively) even in the scenarios with the most data (length compositions, age compositions and survey indices). The probability of overestimating yield at the target *SSB* relative to the true such yield was ~50%, a risk-neutral result, for all the scenarios that included length-composition data. Our results highlight the importance of length-composition data for the performance of an age-structured assessment model, and are encouraging for the assessment of data-limited stocks.

For more information, please contact Chantell Wetzel at Richard.Methot@noaa.gov

e) Can data collected from marine protected areas improve estimates of life-history parameters?

Investigators: T.M. Garrison, O.S. Hamel and A.E. Punt

One of the argued research-related benefits of marine protected areas (MPAs) to fisheries management is that because there is no fishing inside of an MPA, it may be possible to precisely estimate the rate of natural mortality and better determine growth and maturity rates, parameters that are often prespecified in stock assessments. This study assessed the degree to which having an MPA increased the ability to estimate these parameters in an integrated stock assessment model, Stock Synthesis; how long it would take for these benefits to be reflected in improved estimates of management quantities; and the extent to which these improvements will be reduced or lost if there is movement of adults (i.e., spillover) from the MPA to the fished area. A two-area, age- and length-structured simulation model was used to examine these benefits on estimation performance for Stock Synthesis. Given the data and process assumptions explored here, the extent of improvement in estimation of growth and maturity parameters with data collected from MPAs was small, but estimation of natural mortality was substantially improved compared with directly estimating these parameters using fishery data. The extent of this improvement depends on the degree of spillover and the complexity of the assessment model.

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

f) Summary of stock status for assessed Pacific Coast groundfish species

Investigators: J. Hastie, S. Miller and J. Cope

Over the past decade, an increasing number of species have been assessed using methods that allow stock status to be estimated. Some stocks have been found to be in need of rebuilding, and they have had a substantial impact on the management of all sectors of the groundfish fishery. Of these rebuilding stocks, those which have not yet reached rebuilding targets have exhibited continuing growth throughout this period (to the extent that the available data are adequate to discern a trend). A high percentage of the other

assessed species, as of their most recent assessments, are either near or above their target levels of spawning potential. We summarized trends in the status of assessed Pacific coast groundfish stocks over the last half-century, with particular focus on the recent rebuilding period. We also highlighted data, research, and methods that are needed to improve the number and quality of stock-status determinations that are available to inform future management.

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

g) Fisheries science and management of U.S. west coast groundfishes in resource-limited situations

New management mandates require catch limits for every managed fish stock in U.S. waters. This necessitates improved data analysis and assessment methods that inform management despite limited resources. Not anticipating a windfall of resources available to assess every managed stock each biennial assessment cycle required a creative approach. This is the story of the Pacific Fishery Management Council's attempt to manage 90+ species in the Groundfish Fishery Management Plan, only a third of which have been formally assessed. The Council advisory bodies' establishment of a framework to categorize species by assessment type, data availability, and uncertainty was examined. From there, alternative ways of devising science-informed catch limits were developed to provide overfishing limit estimates for stocks lacking assessments. The application of vulnerability analyses to help prioritize stocks for future assessment, provide guidance for data collection, and help formulate stock complexes for stocks without assessments was described. The ultimate goal is to both inform the management of species lacking assessments while attempting to develop the information needed to move those stocks toward formal assessment of their populations. Using otolith weights to obtain ages rather than reading annuli was discussed as an approach to move towards that final goal by greatly reducing the resources needed to access age data, a particularly important data type for stock assessment.

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h) Investigating rapid age determination methods using otolith morphometrics for four groundfish species

Investigators: J. Cope, P. McDonald, O. Rodriguez and K. Munk

Age-at-length information is one of the most informative types of data available for stock assessment modeling. Ageing structures, typically otoliths, record individual fish age by growing with the fish through time. Counting of incremental rings laid annually is the most widely recognized otolith characteristic used to define fish age. But while this approach has proven very useful, the application of this method requires a mix of both skill and art. Even with highly trained age readers, ageing error can remain significant. In addition, the technique can be time intensive. The Northwest Fisheries Science Center Groundfish Trawl survey has collected thousands of otoliths, many of which remain to be aged. The need to collect age data from these structures for stock assessment is a high

priority, but resource limitation reduces the numbers obtainable. Previous studies in other fishes have explored the potential of alternative measures of otolith morphometrics such as weight, length, width, and thickness to more rapidly age fish. Attributes of these methods should include faster ageing with no reduction in accuracy, but a possible increase in precision, thus decreasing subjective analysis. Four species with very different otolith morphologies (Pacific hake, petrale sole, sablefish, and splitnose rockfish) were chosen to demonstrate how useful these measures may be as predicators of fish age. Samples sizes of 100-125 previously aged otoliths per sex per species were analyzed. The preliminary results demonstrated how useful otolith weight is as a predicator of age.

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i) Rags to Fishes II: Quantitative comparison of data-poor methods for fisheries management

Investigators: K. Honey, A. Apel, J. Cope, E.J. Dick, A. MacCall and R. Fujita

There is great need for reliable ways to assess the status of fish stocks when data sources are limited. We compared characteristics of three data-poor methods: Depletion-Corrected Average Catch, Depletion-Based Stock Reduction Analysis, and Length-Based Reference Point. We applied these peer-reviewed data-poor methods using common sets of data and input assumptions. These methods were compared to each other, as well as to the most current data-rich stock assessment to determine whether a method meets minimum federal requirements for setting the annual catch limit and how well the method performed relative to the stock assessment and the other data-poor methods. To summarize results, we estimated the relative degree of accuracy, precaution, and risk associated with the reference points derived from each data-poor method. All three data-poor methods produced sustainable yield estimates comparable, although somewhat lower and more risk-averse, to those generated from the most current stock assessment for stocks in relatively healthy conditions. These methods, however, performed least well for overfished and rebuilding stocks. Because of their simplicity, limited data requirements, and relative ease of use, data-poor methods may lend themselves to collaborative research efforts by fishermen and scientists. We concluded with management recommendations, caveats, and suggestions for on-going work to improve the management of data-poor species.

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j) Analysis of fishery-independent hook and line-based data for use in the stock assessment of bocaccio rockfish (*Sebastes paucispinis*)

Investigators: J.R. Wallace, J.H. Harms and I.J. Stewart

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 paper introduces a standardized hook and line survey for rockfish conducted by NOAA Fisheries' Northwest Fisheries Science Center in the Southern California Bight. The survey uses fishing gear similar to that used in many recreational fisheries to sample approximately 120 locations covering a wide range of depths and habitats. To provide an example of how these data can be analyzed for direct inclusion in stock assessments, we standardize catch rates of bocaccio rockfish from 2004–2008 using a Bayesian Generalized Linear Model to account for site, fishing time, survey vessel, angler, and other statistically significant effects. Results indicate that the bocaccio stock vulnerable to this survey in the Southern California Bight has shown a relatively flat trend over recent years. Length frequency distributions indicate the presence of several strong cohorts that should be detectable in future stock assessments of bocaccio for use in U.S. West Coast groundfish management. This survey is the only available tuning index for the adult portion of the bocaccio population in recent years as historically used recreational catch per unit effort indices have been compromised due to changes in bag limits and other management restrictions.

For more information, please contact John Harms at John.Harms@noaa.gov

k) Distribution and life history characteristics for vermilion rockfish (*Sebastes miniatus*) and 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. Using specimens and catch data collected during the hook and line survey, NWFSC researchers analyzed depth and latitudinal differences and similarities between vermilion and sunset rockfish and developed unique life history characteristics for the two species. These include age at length, annual growth estimates, length-weight relationships, and age at maturity. This information can be combined with the unique indices of abundance outlined in the previous paper to support separate stock assessments for vermilion and sunset rockfish.

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

Investigators: J.R. Wallace, I.J. Stewart and J.H. Harms

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 120 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 available ongoing 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.

For more information, please contact John Harms at John.Harms@noaa.gov

m) Change we can perceive in: Using the concepts of "status", "scale", and "productivity" to interpret changes in management quantities across stock assessments as applied to U.S. west coast groundfishes

Investigators: J. Cope, O. Hamel, C. Niles, J. DeVore, E.J. Dick, J. Grebel and R. Jones

Fisheries stock assessments provide the scientific information used to calculate management quantities (e.g., maximum sustainable yield, the overfishing level, and time to rebuild) for application in precautionary fisheries management. Uncertainty in data inputs and model specification, though, can change our perception of a stock's population dynamics from assessment to assessment, and thus the resultant management quantities. These changes can be complex and technical in nature, sometimes resulting in what may seem to be contradictory outcomes. For instance, a new assessment may demonstrate that an overfished stock is more depleted than previously determined, yet able to support higher forecasted catches. Changes in assessment results like these have been particularly consequential to the Pacific Fishery Management Council's efforts to rebuild overfished stocks. We examined three general stock assessment concepts that help reconcile such apparent management contradictions: (1) "Status" refers to what proportion of a stock's abundance remains since fishing began; (2) "Scale" describes the absolute level of biomass; and (3) "Productivity" is the internal capacity of a population to grow. We represent these three dimensions using simple metrics and demonstrate how changes in these metrics from assessment to assessment can explain directional changes in the management quantities. We apply this method to six groundfishes currently under the Pacific Fishery Management Council's rebuilding plans This approach allows one to anticipate and interpret changes in important management quantities without requiring a detailed understanding of the technical complexities involved in modeling past, current, and future trends in stock status and abundance.

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n) Evaluating the law and policy of rebuilding overfished groundfish at the Pacific Fishery Management Council

Investigators: C. Niles, J. Budrick, J.M. Cope, E.J. Dick, D.L. Erickson, J. Grebel, R. Jones, R.A. Kosaka, L. Mattes, H.J. Reed and E.C. Waters

The Pacific Fishery Management Council (PFMC) manages eight groundfish stocks under rebuilding plans, all but one being rockfishes of the genus *Sebastes*. The Magnuson Stevens Fishery Conservation and Management Act (MSA) requires the rebuilding to be "as short as possible" (i.e. by closing the fishery) unless delay is justifiable based on specific factors, with "the needs of the fishing communities" being the most prominent. The MSA limits delay to 10 years for stocks able to rebuild that quickly, yet is ambiguous on the outer time limit for stocks that cannot.

The rebuilding rockfishes present extreme circumstances for these MSA rebuilding provisions. Even absent fishing, some would not be expected to rebuild for decades. The incidental catch allowed in support of commercial and recreational targeting of other groundfish extends the expected rebuilding timeline decades longer for some species. These long rebuilding times have attracted 10 years of litigation. The courts have overturned individual rebuilding plans on two occasions, most recently in April 2010. On both occasions, the courts' main finding was that the long rebuilding times place disproportionate emphasis on short-term economic concerns.

The rebuilding plans are of consuming focus at the PFMC. We focused on key aspects of the courts' analysis while providing context for two related PFMC's rebuilding experience. We evaluated the courts' treatment of rebuilding against the principles of fisheries science and management and described how the lines between law, science, and policy have blurred. We paid particular attention to the assumption about overemphasis of short-term economics; described how this assumption has gone untested, and then argued for analysis of the MSA's rebuilding provisions based on long-term conservation tradeoffs.

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o) 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 2011 field season was the eighth year in a time series of catch-per-unit-effort data and other biological parameters that are used to calculate an index of relative abundance for several important rockfish species

including bocaccio, vermilion rockfish, greenspotted rockfish, and speckled rockfish. Bocaccio and vermilion rockfish, two primary species of interest, have been encountered at over 65% of survey sites in every year of the survey. Survey personnel are currently working with 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 past two years work has been conducted to estimate size at maturity for the vermilion, sunset, and bocaccio rockfish. Efforts to collect video habitat information and further develop genetic biopsy hooks continue to move forward. The survey is improved by its collaboration with the sportfishing industry and has strengthened the working relationship between NOAA Fisheries and stakeholders in the region.

p) Reconciling uncertain and conflicting trends in petrale sole abundance

Investigators: M.A. Haltuch, J.D. Hastie, A. Hicks and C.E. Whitmire

Petrale sole are a commercially important flatfish that migrate seasonally between feeding and spawning grounds, and have recently been declared overfished. The summer trawl survey shows a decline in petrale sole abundance since 2005 similar to the unstandardized summer catch per unit of effort (CPUE) from the fishery. However, many stakeholders disagree that petrale sole abundance has been declining, instead choosing to focus on the unstandardized winter CPUE that shows a strong increase beginning in 2000. The assessment attributes the increasing trend in winter CPUE to management actions that forced the fleet to: 1) increase fishing effort during the winter; and 2) conduct winter fishing in locations with high historical catch rates. Standardized fishery CPUE was not used in the assessment due to changing management regulations beginning in the late 1990s and the high likelihood of a winter CPUE index showing hyper-stability due to the fishery focusing on the aggregated spawning stock. Given the potential discrepancy between the assessment results and the experience of the groundfish fleet, particularly during the winter fishing season, and the limited conclusions that can be drawn from unstandardized CPUE, this work explores the utility of the summer and winter fishery CPUE series as indices of abundance for the petrale sole stock assessment.

While the 2011 CPUE analysis attempted to account for the impact of management measures on the fishery it is unable to account for changes in fishing behavior, or changes in spawning aggregation dynamics in the winter. Changes in the CPUE indices from approximately the years 2000-2003 forward could be due to management measures, fishing behavior, and spawning aggregation dynamics (winter only) that have not been captured in this analysis. For example, industry reports that the 2003 vessel buyback removed some of the more productive vessels in the fleet, but there is not information on

the skippers that fished those vessels, many of which may have switched to fishing on different vessels. This CPUE analysis is also unable to capture changes in fishing behavior and targeting strategies for petrale sole and the dover-thornyhead-sablefish deep water fishery, which likely increased, as rockfish fishing opportunities became increasingly limited between the late 1990s and present. In the summer, the spatial management restrictions have changed on an annual basis and are captured only at a gross level in this analysis. In the winter, the spatial areas that have remained open to fishing since 2003 have been more stable, however, little is known about petrale sole spawning aggregation dynamics and how these spawning aggregation dynamics change as the stock increases from historical low levels in the 1990s to higher levels in the mid-2000s. There is some ancillary evidence that the timing of spawning (historically December - February) has shifted to be later in the winter season. This issue may have been captured by limiting the data used in the analysis to January-February. However little is known about how the timing of peak spawning, the duration of the spawning season, size of spawning aggregations, and density of spawning aggregations change with changes in the size of the spawning stock. It is not possible to capture these dynamics in the CPUE analysis competed for the 2011 stock assessment as there is a lack of understanding between how changes in catch rates and changes in the true population are related.

The pre-STAR review draft of the 2011 stock assessment included the main effects commercial summer CPUE indices for each state as a sensitivity model run and excluded the winter CPUE indices due to the issues discussed above. Discussions during the STAR panel lead to the removal of the summer CPUE as a viable index for the model due to the annual changes in spatial management. While the summer CPUE indices were removed from the assessment the general trends in the commercial summer CPUE are the same as the trend from the NWFSC fishery independent survey during the period of overlap. In the summer fishery, CPUE generally increased from 1987 through the middle of the past decade, but has decreased in the last few years for all three states. STAR panel discussions lead to the inclusion of the winter main effects CPUE indices due to the more consistent management during the winter, regardless of the possible issues with spawning aggregation dynamics. The winter fishery CPUE begins to increase about the year 2000, compared with the early part of the time series. While the California and Oregon CPUE indices continue to increase in the last few years, Washington (which has the largest data set of the three states) has declined since 2005. The winter commercial CPUE index from Washington shows a similar trend to the NWFSC summer fishery independent survey index. These winter CPUE indices were included in the 2011 base model of the petrale sole stock assessment.

For more information, contact Melissa Haltuch at Melissa.Haltuch@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 2011, along with the update review meeting and the 2012 Hake Scientific Review Group meeting, is shown in Table 1.

Table 1. 2011 Review Schedule for Full Groundfish Assessments.

STAR PANEL	STOCK	AUTHOR(S)	REVIEW PANEL DATES	STAR PANEL LOCATION
1	Data Poor Methods/ Examples	Jason Cope	April 25-29, 2011	Santa Cruz, CA
Updates	Bocaccio Canary Cowcod Darkblotched Yelloweye	John Field John Wallace E.J. Dick Andi Stevens Ian Taylor	June 6, 2011	Spokane, WA
2	Pacific Ocean Perch Petrale sole	Owen Hamel Melissa Haltuch	June 20-24, 2011	Seattle, WA
3	Widow Spiny dogfish	Xi He Vlada Gertseva	July 11 – 15, 2011	Seattle, WA
4	Sablefish Dover sole	Ian Stewart Allan Hicks Chantel Wetzel	July 25 -29, 2011	Hatfield Marine Science Center Barry Fisher Bldg., Room 101, 2032 SE Oregon State University Drive, Newport, OR 97365
5	Greenspotted Blackgill	John Field E.J. Dick	August 8-12, 2011	Southwest Fisheries Science Center 110 Shaffer Road Santa Cruz, CA 95060
Hake	Pacific hake/ whiting	Ian Stewart Robin Forrest Nathan Taylor Chris Grandin Allan Hicks	February 21-24, 2012	Seattle, WA

1. Shelf Rockfish - West Coast

a) Stock assessments

Full assessments of greenspotted rockfish and widow rockfish were conducted in 2011. Updates of the bocaccio rockfish, canary rockfish, and yelloweye rockfish assessments, and a status report for cowcod rockfish were also conducted in 2011.

Greenspotted rockfish

The complete version of: "Status of Greenspotted Rockfish, *Sebastes chlorostictus*, in U.S. Waters off California" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

Widow rockfish

The complete version of: "Status of the Widow Rockfish Resource in 2011" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

Bocaccio rockfish

The complete version of: "Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas as Updated for 2011" and "Rebuilding Analysis for Bocaccio, Based on the 2011 Stock Assessment" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

Canary rockfish

This updated assessment reports the status of the canary rockfish (*Sebastes pinniger*) resource off the coast of the United States from southern California to the U.S.-Canadian border using data through 2010. As in 2007 and 2009, the resource is modeled as a single stock. Historical (pre-1981) catches of canary rockfish catch were reconstructed for the 2009 assessment and resulted in substantial reductions compared to what was used in the 2007 assessment. Since the 2009 assessment, Oregon's commercial landings prior to 1986 have been reconstructed and those data are included in this updated assessment. The revised Oregon landings are higher in most of the years between 1941 and 1986. The net result of this revision is that the total estimated catch, from 1916 to 1986, is 36.5% higher than in 2009, and only 4.3% lower than in 2007.

Recent canary rockfish catches were revised based on current total mortality estimates (2002-2009) and the GMT scorecard (2010). In cases where only aggregated catches were available, they were pro-rated to modeled fleets as was done in the 2007 and 2009 assessments. The model data sources are unchanged, including updated catch, length- and age-frequency data from 11 fishing fleets. Biological data is derived from both port and on-board observer sampling programs. The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) bottom trawl survey's relative biomass indices and biological sampling provide updated fishery independent information on

relative trend and demographics of the canary rockfish stock. The Southwest Fisheries Science Center (SWFSC)/NWFSC/Pacific Whiting Conservation Cooperative (PWCC) coast-wide pre-recruit survey provides an updated indicator of recent recruitment strength. The use of time-varying selectivity (for commercial fisheries) and catchability (Triennial bottom trawl survey) is unchanged from the 2007 and 2009 assessments.

As in 2007 and 2009, the base-case assessment model includes parameter uncertainty from a variety of sources but underestimates the considerable uncertainty in recent trend and current stock status. For this reason, in addition to asymptotic confidence intervals (based upon the model's analytical estimate of the variance near the converged solution), two alternate states of nature regarding stock productivity (expressed via the steepness parameter of the stock-recruitment relationship) are presented. The base-case model (steepness = 0.51) is considered to be twice as likely as the two alternate states (steepness = 0.35, 0.72), based on the results of a 2007 meta-analysis of west coast rockfish (M. Dorn, personal communication). In order to best capture this source of uncertainty, all three states of nature will again be used as probability-weighted input to the rebuilding analysis.

Based on the revised catch series, canary rockfish were very lightly exploited until the early 1940's, when catches increased and a decline in biomass began. The spawning biomass experienced an accelerated rate of decline during the late 1970s, and finally reached a minimum (10.8% of unexploited, below the estimate of 12% from the 2009 assessment) in the mid-1990s. Current depletion is estimated to have increased by over 50% since 2002. The canary rockfish spawning stock biomass is estimated to have been gradually increasing since that time, in response to reductions in harvest and above average recruitment in the preceding decade. However, this trend is very uncertain.

The degree to which canary rockfish recruitment declined over the last 50 years is closely related to the level of productivity (stock-recruit steepness) modeled for the stock. High steepness values imply little relationship between spawning stock and recruitment, while low steepness values indicate a strong positive correlation. After a period of above-average recruitments, recent year-class strengths (1997-2010) have generally been low, with only 2 of the 10 years (2001 and 2007) producing large estimated recruitments (the 2011 recruitment is based only on the stock-recruit function). The strength of the 2007 year-class is subject to greater uncertainty than other strong recruitment events in the last 30 years because of the limited number of years in which it has been observed. As the larger recruitments from the late 1980s and early 1990s move through the population in future projections, the effects of recent poor recruitment may tend to slow the rate of recovery.

Unfished spawning stock biomass, in the base-case model, was estimated to be 27,846 mt (7% higher than the 2009 estimate of 25,993, and 14.5% lower then the 2007 estimate of 32,561 mt). The target stock size ($SB_{40\%}$) is therefore 11,138 mt and the overfished threshold ($SB_{25\%}$) is 6,962 mt. Maximum sustained yield (MSY) applying current fishery selectivity and allocations (a 'bycatch-only' scenario) was estimated in the assessment model to occur at a spawning stock biomass of 10,464 mt and produce an MSY catch of 803 mt (down from the 960 mt estimate in the 2009 update). This sustainable yield is achieved at an SPR of 52.5%, nearly identical to the estimate from the 2007 assessment

(52.9%). This is nearly identical to the yield, 801 mt, generated by the SPR (54.0%) that stabilizes the stock at the $SB_{40\%}$ target. The fishing mortality target/overfishing level (SPR = 50.0%) generates a yield of 799 mt at a stock size of 9,545 mt.

The abundance of canary rockfish was estimated to have dropped below the $SB_{40\%}$ management target in 1983 and the overfished threshold in 1990. In hindsight, the spawning stock biomass passed through the target and threshold levels at a time when the annual catch was averaging more than twice the current estimate of the MSY. The stock remains slightly below the overfished threshold (unlike the 2007 estimate), although the spawning stock biomass still appears to have been steadly increasing since 1999. The degree of increase is very sensitive to the value for steepness (which is included in the decision table as a state of nature), and is projected to slow as recent, and largely below average recruitments, begin to contribute to the spawning biomass. Fishing mortality rates in excess of the current F-target for rockfish of $SPR_{50\%}$ are estimated to have begun in the late 1970s and persisted through 1999. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since before 1999, and relative exploitation rates (catch/biomass of age-5 and older fish) are estimated to have been less than 1% since 2001. These patterns are largely insensitive to the three states of nature. Following the 1999 declaration that the canary rockfish stock was overfished, the canary OY was reduced by over 70% in 2000 and by the same margin again over the next three years. Managers employed several tools in an effort to constrain catches to these dramatically lower targets including reductions in trip/bag limits for canary and co-occurring species, implementing spatial closures, and new gear restrictions intended to reduce trawling in rocky shelf habitats and the coincident catch of rockfish in shelf flatfish trawls.

As in the 2007 and 2009 assessments, parameter uncertainty is explicitly captured in the asymptotic confidence intervals reported throughout this assessment for key parameters and management quantities. These intervals reflect the uncertainty in the model fit to the data sources included in the assessment, but do not include uncertainty associated with alternative model configurations, weighting of data sources (a combination of input sample sizes and relative weighting of likelihood components), or fixed parameters. Specifically, there appears to be conflicting information between the length- and age-frequency data regarding the degree of stock decline, making the model results sensitive to the relative weighting of each. This issue was not revisited as part of the update. The relationship between the degree of domed shape in the selectivity curves and the increase in female natural mortality with age remains a source of uncertainty that is included in model results, as it has been in previous assessments for canary rockfish. Uncertainty in the steepness parameter of the stock-recruitment relationship is significant and will likely persist in future assessments; this uncertainty is included in the assessment and rebuilding projections through explicit consideration of the three states of nature. Given the change in this update caused by the revised historical Oregon catch estimates, future assessments are likely to be sensitive to additional revised estimates from ongoing efforts in Washington state should they prove appreciably different from the time-series used here.

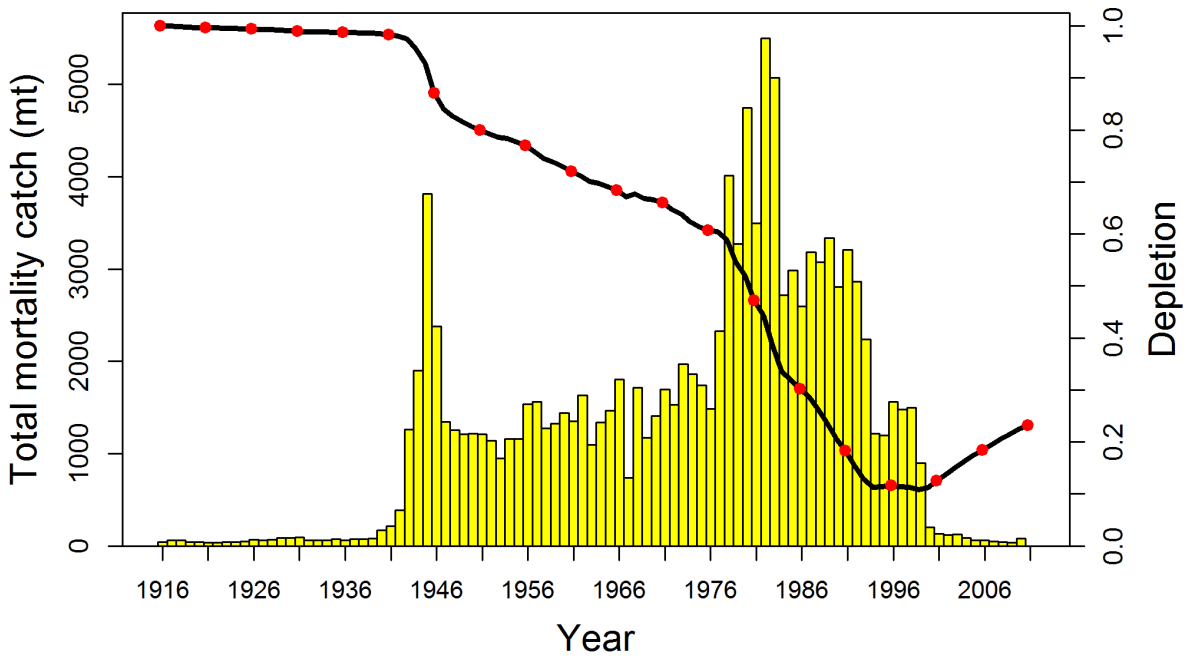

Figure 7. Level of estimated depletion (line) and total catch (bars) for canary rockfish, 1916-2011.

The complete versions of: "Status update of the U.S. canary rockfish resource in 2011" and "Rebuilding analysis for canary rockfish based on the 2011 updated stock assessment" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/
For more information on the canary rockfish assessment please contact John Wallace at John.Wallace@noaa.gov

Yelloweye rockfish

The 2011 updated assessment reports the status of the yelloweye rockfish (*Sebastes ruberrimus*) resource off the coast of the United States from southern California to the U.S.-Canadian border using data through 2010. As in 2009, the resource was modeled as a single stock, but with three explicit spatial areas: Washington, Oregon and California. Each area was modeled simultaneously with its own unique catch history and fishing fleets (recreational and commercial) but the dynamics follow the current understanding of yelloweye stock structure: large stocks linked via a common stock-recruit relationship with negligible adult movement among areas.

Yelloweye rockfish catches were estimated from a variety of sources, including a new reconstruction of historical catch in Oregon for the years 1916-1986. Catches remain uncertain due to the relatively small contribution of yelloweye to rockfish market categories (prior to sorting requirements) and the relatively large scale of recreational removals (average 60% of the total in the past 10 years). The accuracy of estimates of rebuilding rates will therefore depend in part on the accuracy of the recreational catch

data. Catches include estimates of discarding after 2001 when management restrictions resulted in nearly all yelloweye caught by recreational and commercial fishermen being discarded at sea. Recent catches were based on current total mortality estimates (2002-2009) and the GMT scorecard (2010). Estimated catches increased gradually throughout the first half of the 20th century, with the exception of a brief period of higher removals around World War II. Catches peaked in 1982 at 463 mt, an estimate that was slightly higher than the previous assessment due to the inclusion of a new catch reconstruction for Oregon. Removals were estimated as remaining in excess of 200 mt for all years between 1977 and 1997. Uncertainty in catches was treated explicitly throughout this analysis.

As in the 2009 assessment, uncertainty from two sources was reported through alternate states of nature bracketing the base case results and included explicitly in the decision table. The magnitude of the estimated catch time-series was found to have a large influence on the perception of current stock size and the estimate of steepness of the stock-recruit relationship was closely linked to the projected recovery rates. Alternate values of each were selected to bracket the best estimates with marginal probabilities one-half as likely. For historical catch these values, 75% and 150% of the estimated catch series prior to 2000, were subjective, but reflect both the lack of a comprehensive catch reconstruction in Washington and the change in likelihood of the fit to data sources over a reasonable range of catch levels. For steepness the 12.5th and 87.5th percentiles were calculated from the likelihood profile as a proxy for the probability distribution about this point estimate. The most optimistic and pessimistic of the nine combinations from these two axes (weighted 6.25% each relative to 25% for the best estimate on each dimension) are reported in this document and all combinations used to provide a more realistic degree of uncertainty for future projections, decision tables and rebuilding analyses.

A fecundity relationship is used for yelloweye specifying that spawning output per unit weight increases with fish weight; therefore all references to spawning output were in terms of eggs produced, instead of spawning biomass. Yelloweye rockfish were estimated to have been lightly exploited until the mid-1970's, when catches increased and a rapid decline in biomass and spawning output began. Spawning output is estimated to have reached a minimum in 2000, at 15.7% of unexploited levels (very similar to the 15.8% from the 2009 assessment). Yelloweye rockfish spawning output was estimated to have been gradually increasing since that time, in response to large reductions in harvest. Although the relative trend in spawning output is quite robust to uncertainty in the estimated removals, the absolute scale of the time series is very sensitive global shifts in removals. The estimated relative depletion level in 2009 is 20.2% (very similar to the estimate of 20.3% from the 2009 assessment) and 21.4% in 2011, corresponding to 219 million eggs. The range over states of nature indicates less uncertainty in level of depletion (18.9-24.0%) than in the absolute scale of the estimated spawning output: 146-371 million eggs in 2011. The portions of the total spawning output within each of the three states differs, with California and Oregon having very similar estimates of spawning output at unexploited equilibrium, with Washington considerably lower. Oregon was estimated to have the largest 2011 spawning output, followed by California, then Washington. Relative depletion also varies by state, with California estimated to be at 17.3% of unexploited conditions, Oregon, 23.9%, and Washington, 27.2%.

The coast-wide abundance of yelloweye rockfish was estimated to have dropped below the $SB_{40\%}$ management target in 1988 and the overfished threshold in 1994. In hindsight, the spawning output passed through the target and threshold levels with annual catch averaging almost five times the current estimate of the *MSY*. The coast-wide stock remains below the overfished threshold, although the spawning output was estimated to have been increased by 36% since 2000 (from 161 to 219 million eggs), in response to reductions in harvest. The degree of increase is largely insensitive to the magnitude of historical catch and only moderately sensitive to the value of steepness, but the absolute scale of the population reflects alternate removal series very closely. Fishing mortality rates were estimated to have been in excess of the current *F*-target for rockfish of $SPR_{50\%}$ from 1976 through 1999. Relative exploitation rates (catch/biomass of age-8 and older fish) are estimated to have peaked at 12.7% in 1992, but have been at or less than 1.1% after 2001. The alternate states of nature result in estimated exploitation rates ranging from less than 0.9% to less than 1.7% of the period 2002-2010.

Data for yelloweye rockfish are sparse and relatively uninformative, especially regarding current trend. Historical catches are very uncertain, as yelloweye comprise a small percentage of overall rockfish removals and actual species-composition samples are infrequently available for historical analyses. Currently available fishery-independent indices of abundance are imprecise and not highly informative. It was unclear whether increased rates of recovery (or lack thereof) will be detectable without more precise survey methods applied over broad portions of the coast. Fishery data are also unlikely to produce conclusive information about the stock for the foreseeable future, due to lack of retention and active avoidance of yelloweye among all fleets. For these reasons, it was unlikely that the major uncertainties in this assessment will soon be resolved.

Current medium-term forecasts predict increases in coast-wide abundance under the SPR=71.9% rebuilding strategy, however these increases are largely driven by the California and Oregon portions of the stock. In fact, the Washington portion was projected to remain at current levels under recent allocation of catch; however, this result was likely to be sensitive to future revision of the estimated Washington historical catch series. The estimated ACL values for 2013 and 2014 are only slightly larger (17.7, 18.0) than the 17.0 value set for 2011 and 2012 and less that that predicted from the 2009 rebuilding analysis (21.0, 20.5), which was based on a higher fishing mortality associated with a 71.9% SPR.

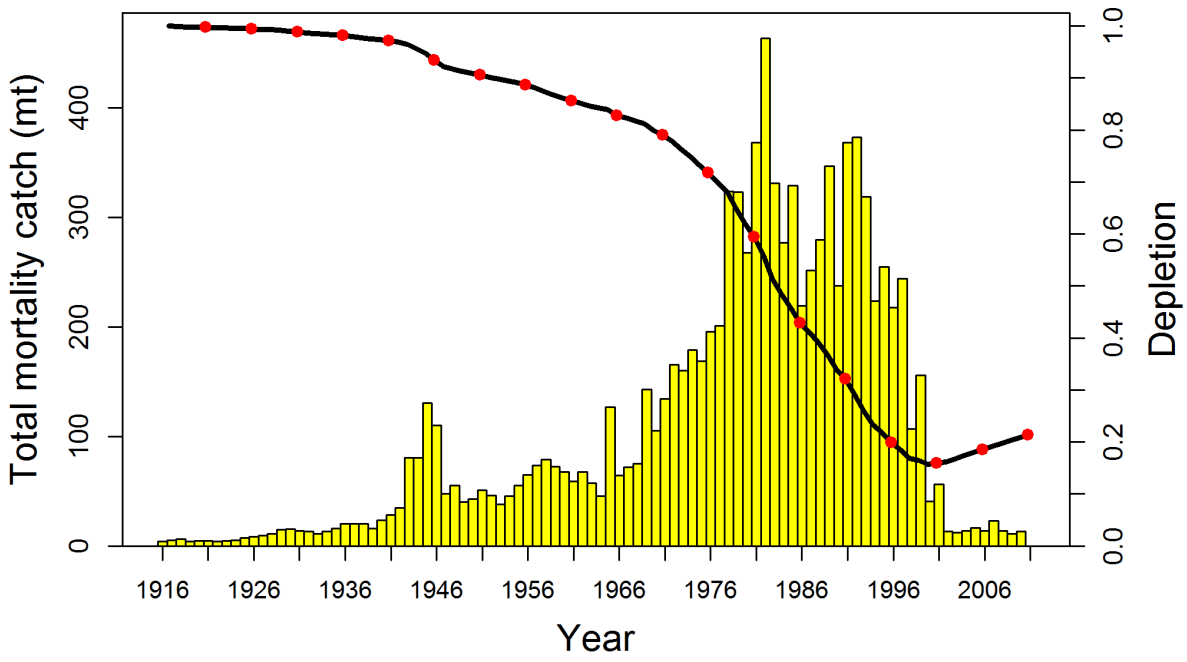

Figure 8. Level of estimated depletion (line) and total catch (bars) for yelloweye rockfish, 1916-2009.

The complete versions of: "Status of the U.S. yelloweye rockfish resource in 2011 (Update of 2009 assessment model)" and "Rebuilding analysis for yelloweye rockfish based on the 2011 update stock assessment" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

For more information on the yelloweye rockfish assessment please contact Ian Taylor at Ian.Taylor@noaa.gov

Cowcod rockfish

The complete version of: "Cowcod status report" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

2. Slope Rockfish

a) Stock assessments

Full assessments of Pacific ocean perch rockfish and blackgill rockfish and an update of the darkblotched rockfish assessment were conducted in 2011.

Pacific ocean perch

This assessment applies to the Pacific ocean perch (*Sebastes alutus*) (POP) species of rockfish off of the U.S. West Coast from Northern California to the Canadian Border.

Measurable harvest of Pacific ocean perch off of the northern half of the U.S. West Coast first occurred in 1940 and ramped up rapidly from under 300 mt in 1948 to over 2,000 in 1952. Estimated landings averaged 2,200 mt from 1952 to 1960, and then increased to between 5,000 and 20,000 mt during the mid-1960s. The largest removals in 1966-1968 were largely the result of harvest by foreign vessels. The fishery proceeded with more moderate removals of between 1,000 and 3,000 metric tons per year from 1969 through 1980, with the foreign fishery ending in 1977, and between 1,000 and 2,000 mt per year from 1981 through 1994. Management measures further reduced landings which fell steadily thereafter until reaching between 60 and 150 metric tons per year from 2002 through 2010, with total yearly catch, including discard, estimated to have been between 75 and 210 metric tons during those years.

This is the first full assessment of Pacific ocean perch since 2003 and the first one conducted in Stock Synthesis (SS, version 3.21d, R. Methot) since those conducted in the original version of Synthesis in the 1990s. The resultant SS model treats the data somewhat differently than the stand-alone forward-projection statistical catch-at-age model (Ianelli et al. 2000; Hamel et al. 2003; Hamel 2005, 2007, 2009). In addition, nearly all of the sources of data for Pacific ocean perch have been re-evaluated for 2011. Changes of varying degrees have occurred in the data from those used in previous assessments. These current data represent the best available scientific information. The landings history has been updated and extended back to 1940, since records indicate that harvest was negligible before that year. Survey data from the Alaska and Northwest Fisheries Science Centers have been used to construct series of indices using a GLMM model (J. Wallace, pers. comm) as well as length, age and conditional age-at length compositions consistent with the stratifications used for constructing the indices.

The assessment uses landings data and discard-fraction estimates; catch-per-unit-of-effort (CPUE) and survey indices; length or age composition data for each year and fishery or survey (with conditional age at length compositional data and mean-length at age data used in preliminary models); information on weight-at-age, maturity-at-age, and fecundity-at-age; priors on natural mortality (by sex) and the steepness of the Beverton-Holt stock-recruitment relationship (for preliminary models and sensitivities); estimates of ageing error; and (iteratively) sigma-r (representing the variability of the recruitments about the stock-recruitment curve) as inputs to the forward projection age structured model (SS). Recruitment at "equilibrium biomass", length-based selectivity of the fishery and surveys, retention of the fishery, catchability of the surveys, the time series of biomass, age and size structure, and current and projected future stock status are outputs of the model. Growth, natural mortality and steepness were fixed in the final model after being estimated in preliminary models. This was done to simplify the models and due to relatively flat likelihood surfaces, such that fixing parameters and then varying them was deemed the best way to characterize uncertainty.

A number of sources of uncertainty are explicitly included in this assessment. For example, allowance is made for uncertainty in survey catchability coefficients. Furthermore, this assessment, unlike previous assessments, includes gender differences in growth and survival, a non-linear relationship between individual spawner biomass and effective spawning output, and a more complicated relationship between age and

maturity, based upon published information. As is always the case, overall uncertainty is greater than that predicted by a single model specification. Among other sources of uncertainty that are not included in the current model are the degree of connectivity between the stocks of Pacific ocean perch off of Vancouver Island, British Columbia and those in PFMC waters, and the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of Pacific ocean perch.

A reference case was selected which adequately captures the central tendency for those sources of uncertainty considered in the model. For West Coast rockfish, a stock is considered overfished when it is below 25% of virgin spawning biomass. Currently, the spawning stock is believed to be near 20% of the unfished level; roughly 40% higher than the low of 14% reached in 1999. POP is not expected to reach the rebuilding target (40% of the unfished level) for more than 30 years. This is in contrast to the 2009 and other recent assessments which indicated a higher depletion level (near 30%) and a shorter rebuilding time. This is due to the increase in the estimated virgin biomass (B_0) in the current assessment rather than a change in current estimated biomass (which is nearly the same). POP has not been subject to overfishing since 2000. Although catches were generally near or below harvest guidelines during the 1990s, the current assessment suggests that exploitation rates throughout most of the 1980s and 1990s were higher than those identified in more recent assessments as sustainable. POP are essentially managed on a regional basis, as they occur almost exclusively off of Oregon and Washington for the West Coast. Management and assessment of stock status might be improved through greater cooperation with British Columbia, as the stock extends northward into Canadian waters. Recent catch and levels of depletion are presented in Figure 9.

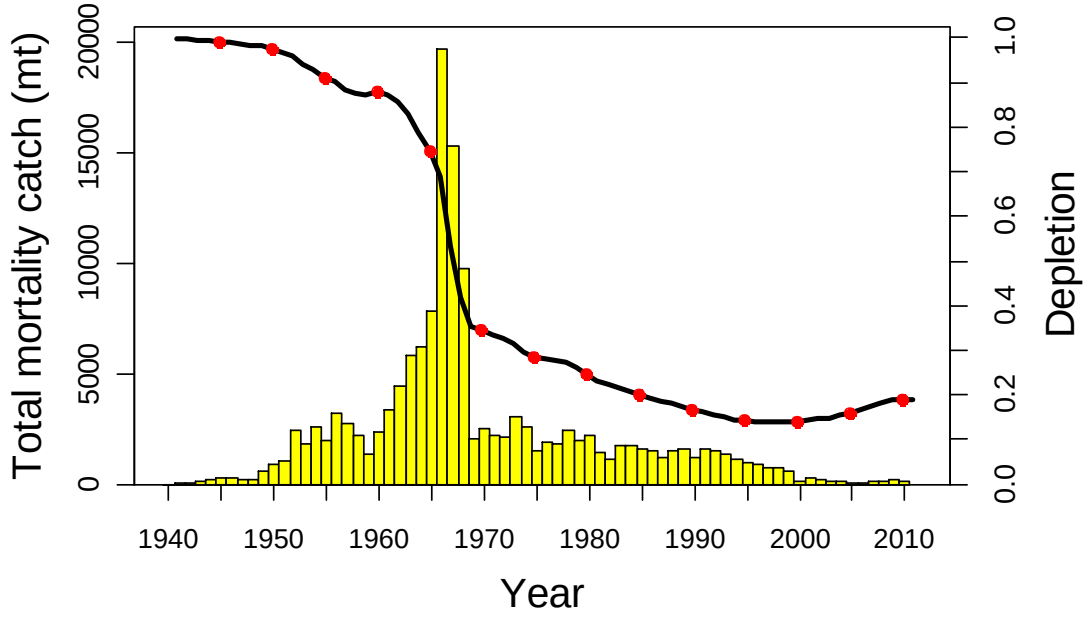

Figure 9. Level of catch (bars) and depletion (line) for Pacific ocean perch, 1940-2011.

The complete versions of: "Stock of Pacific Ocean Perch in Waters off of the U.S. West Coast in 2011" and "Rebuilding Analysis for Pacific Ocean Perch in 2011" can be viewed at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

For more information on this assessment contact Owen Hamel at: Owen.Hamel@noaa.gov.

Darkblotched rockfish

This assessment applies to the darkblotched rockfish (*Sebastes crameri*) for the combined U.S. Vancouver, Columbia, Eureka and Monterey INPFC areas. The largest landings (removals between 2,300 and 4,200 metric tons) of darkblotched were taken from 1966-1968, primarily by foreign vessels. From 1969 to 1981, the fishery proceeded with more moderate landings of between 200 and 1,000 mt per year, with the foreign fishery ending in 1977. A second peak in landings occurred between 1982 and 1993, with landings exceeding 1,100 mt in 10 of 12 years, reaching over 2,400 mt in 1987. Management measures reduced landings to below 950 mt since 1994, below 400 mt since 1999, and below 200 mt in recent years. This update used the SS model, version 3.03a and data through 2008. Based on this assessment, darkblotched rockfish on the West Coast remain below the overfished threshold, but the spawning biomass appears to have increased steadily over the past 7 or 8 years to 27.5% of the unfished level. Since 2001, overfishing occurred only once, with estimated catch exceeding the ABC by 2 mt (0.8%) in 2004.

A number of sources of uncertainty were explicitly included in this assessment. For example, allowance was made for uncertainty in natural mortality and the parameters of the stock-recruitment relationship. There were also other sources of uncertainty that were not included in the current model, including the degree of connection between the stocks of darkblotched rockfish off British Columbia and those in PFMC waters; the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of darkblotched rockfish; and gender-based differences in survival. With the stock extending northwards into Canadian waters, management and assessment of stock status might be improved through greater cooperation with British Columbia.

The recruitment pattern for darkblotched rockfish is similar to that of many rockfish species, with highly variable recruitment from year to year. With a few exceptions, the 1980s and 1990s provided rather poor year-classes compared with average historical recruitment levels. Although the 1999 and 2000 year-classes appear to be among the largest year-classes since 1975, they are only now reaching the age of 50% maturity, and will not be fully mature for another decade (when their fecundity will also be over 3 times what it is now). As a result, the full impact of these recruits will not be felt for years to come. 2008 saw another large year-class whose impact will not be evident for years. The exploitation rate (percent of biomass taken) on fully-selected animals peaked historically near 14% in the intensive foreign fishery of the mid-1960's. The exploitation rate dropped by the late 1960's, but increased slowly and steadily from the late 1970's to 1987, at roughly 15%, and stayed high until 1998, with the continuing decline in exploitable biomass. Over the past 10 years the exploitation rate has fallen from a peak of 16% in 1998 to under 3%. This stock is no longer overfished, however spawning biomass

remains below the management target of 40% of unfished spawning biomass, and a rebuilding analysis was conducted in conjunction with the 2011 update assessment. The history of recruitment and levels of depletion in the fishery are presented in Figure 4.

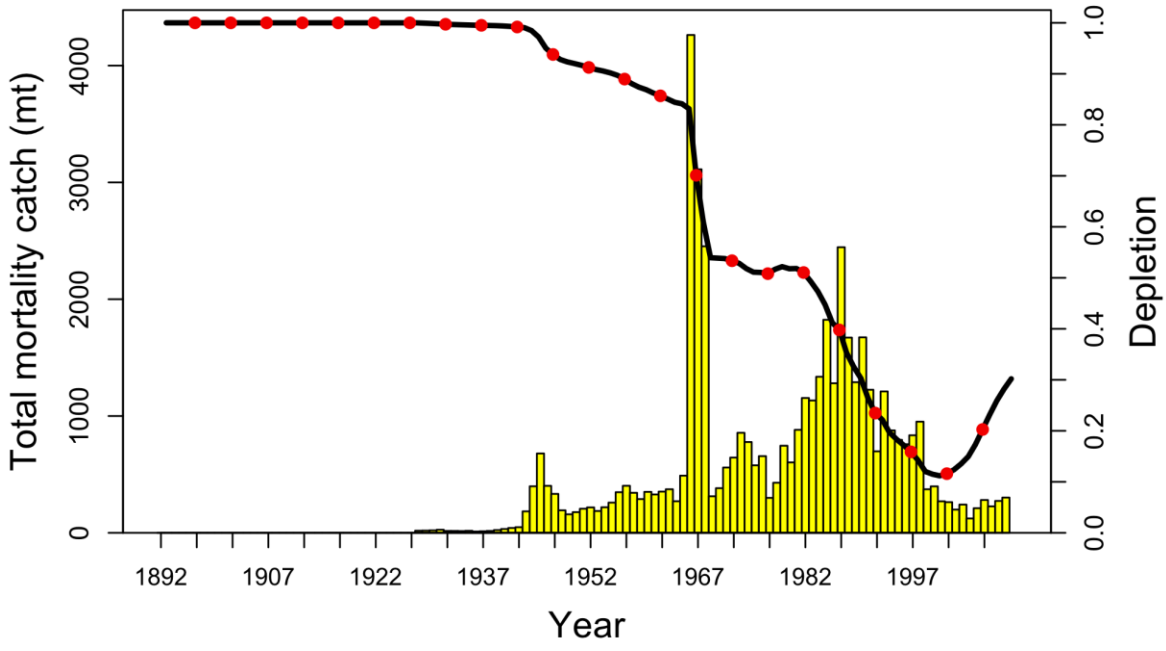

Figure 10. Level of depletion (line) and total catch (bars) for darkblotched rockfish, 1892-2011.

The complete versions of: "Status and Future Prospects for the Darkblotched Rockfish Resource in Waters off Washington, Oregon, and California as Updated in 2011" and " Rebuilding analysis for darkblotched rockfish in 2011" can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-species/

For more information on this assessment contact Andi Stephens: Andi.Stephens@noaa.gov

3. Thornyheads

a) Stock assessment

No thornyhead assessments were conducted during 2011.

4. Sablefish

a) Stock assessment

A full sablefish assessment was conducted in 2011.

Sablefish

This assessment reports the status of the sablefish (*Anoplopoma fimbria*, or 'black cod') resource off the coast of the United States from southern California to the U.S.-Canadian border. Sablefish landings were small (< 5,000 mt), and were primarily harvested by hook-and-line fisheries until the end of the 1960s. A very large catch by foreign vessels fishing pot gear in 1976 resulted in the largest single-year removal of over 25,000 mt from the stock. This was followed by a rapid rise in domestic pot and trawl landings, such that over 240,000 mt of sablefish were landed between 1975 and 1990. Annual landings have remained below 10,000 mt in subsequent years, divided approximately 44% from hook-and-line, 14% from pot and 43% from trawl gear during the most recent decade. Model estimates of discarding result in total dead catches that are an average of 7.8% larger than reported landings over the last decade. The data sources for this stock assessment include: landings, length- and age-frequency data from both the retained and, in recent years the discarded portion of the commercial catch. Discard rates as well as mean observed individual body weight in the discards are also included. The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) shelf-slope trawl survey relative biomass index is the primary source of stock trend information, updated to cover the period 2003-2010 and including depths from 55-1,280 m. Other (discontinued) survey indices contributing information on trend and sablefish demographics include: the NWFSC slope survey conducted from 1998-2002, the AFSC slope survey (1997-2001), and the AFSC/NWFSC triennial shelf trawl survey (1980-2004). Environmental time-series including both sea-surface height (used in previous sablefish assessments) and zooplankton abundance were also investigated.

All externally estimated model parameters, including those defining the weight-length relationship, maturity schedule, and fecundity relationships, have been revisited and, in some cases, revised from the values used in previous assessments. The assessment explicitly estimates parameters describing dimorphic growth and mortality differences between male and female sablefish. Recruitment uncertainty is included via a full time-series of estimated deviations from the stock-recruit curve. Uncertainty in leading parameters such as natural mortality, the unexploited equilibrium level of the stock-recruit function and catchability coefficients of the survey indices are explicitly included in the model results. The available data for sablefish are largely uninformative about the absolute size and productivity of the stock. This is due to the 'one-way-trip' nature of the historical series: a slow and steady decline in spawning biomass consistent with a larger less productive stock, a smaller more productive stock, or many combinations in between. Historical catches provide some information about the minimum stock size needed to have supported the observed time-series but little information about the upper bounds for the stock size. Likelihood profiles, parameter estimates and general model behavior illustrate that small changes in many parameters can result in differing point estimates for management reference points, however the uncertainty about these estimates remains large unless leading model parameters, such as natural mortality, survey catchability, as well as historical recruitments, are fixed at arbitrarily selected values. This assessment includes the uncertainty for these unknown quantities, with the exception of steepness. This uncertainty will remain until a more informative time-series and better quality demographic and biological information is accumulated for the stock.

Sablefish are estimated to have been exploited at a modest level through the first half of the 20th century. Following a period of recruitments estimated to have been above average, but highly uncertain, the spawning stock biomass rebounded to nearly unexploited levels in the late 1970s. Large harvests during those years, and throughout the 1980s, are estimated to have caused the stock to decline nearly monotonically to the present. The coast-wide abundance of sablefish was estimated to have dropped below the $SB_{40\%}$ management target in 2009 and is currently declining steeply. The cause of this trend appears to be primarily due to relatively poor recruitments, as the fishing intensity remained below relative SPR target rates between 1988 and 2008. The relative spawning biomass is estimated to be at only 33% of unexploited levels in 2011; however this value is highly uncertain (~95% intervals range from 18-49%). It appears that large 1999 and 2000 year classes briefly slowed the rate of stock decline between 2002 and 2005. An above-average 2008 cohort is currently moving through the population, however it has yet to mature, and therefore is not currently contributing to the trend in spawning biomass. Since 2001, the total estimated dead catch has been only 79% of the sum of the OFLs (ABCs at the time) and 87% of the ACLs (OYs at the time). In only one year of the last 10, 2008, did the estimated dead catch exceed the ACL (and OFL) by 5% (3%). In retrospect both relative SPR and exploitation fraction are estimated to be increasing rapidly over the last four years. This assessment estimates that the 2010 SPR is 104% of the SPR=45% management target. Recent catch and levels of depletion are presented in Figure 11.

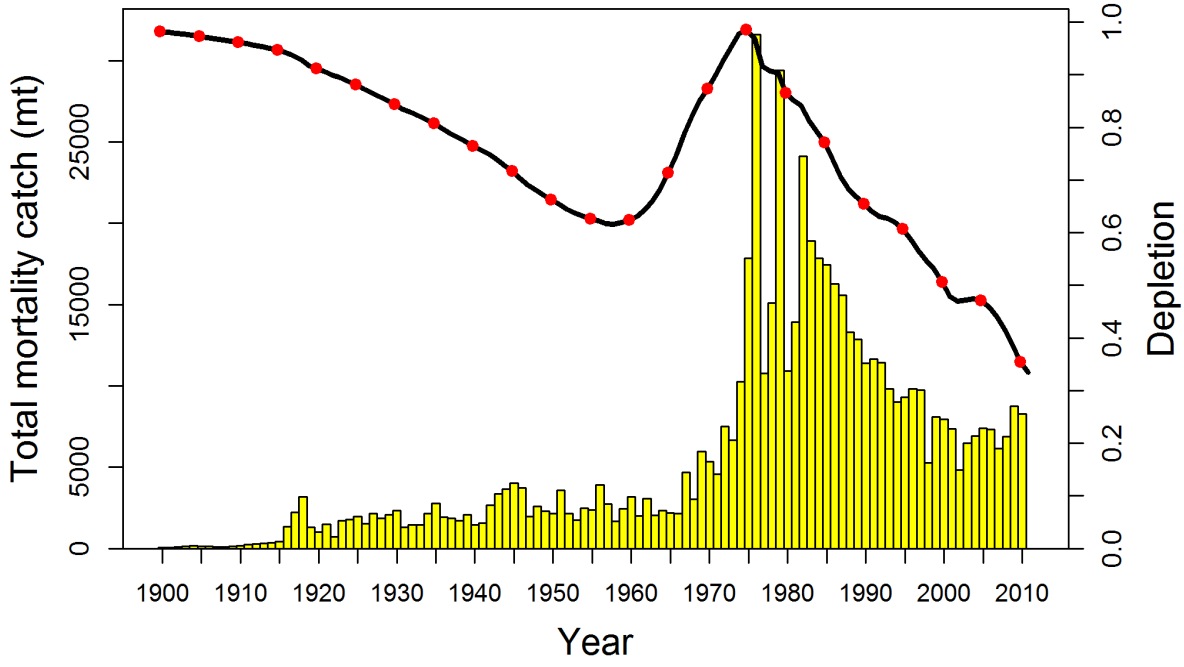

Figure 11. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for sablefish, 1900-2011.

The complete document: *Status of the U.S. sablefish resource in 2011* can be viewed online at: http://www.pcouncil.org/groundfish/stock-assessments/by-year/gf2011/.

For more information on the sablefish assessment please contact Ian Stewart at Ian.Stewart@noaa.gov.

5. Flatfish

a) Stock assessment

Full assessments were conducted for Dover sole and Petrale sole in 2011.

Dover sole

This was an assessment of Dover sole (*Microstomus pacificus*) that reside in the waters off California, Oregon and Washington from the U.S./Canadian border in the north to the U.S./Mexico border in the south. Dover sole are also harvested from the waters off British Columbia and in the Gulf of Alaska, and although those catches were not included in this assessment, it is not certain if those populations contribute to the biomass of Dover sole off of the U.S. West Coast.

Dover sole were first landed in California in the early part of the 20th century and the fishery began increasing landings in Oregon and Washington in the 1940's. Landings remained relatively constant throughout the 1950's and 1960's before increasing rapidly into the early 1990's. Subsequently, the landings declined (mostly in California) until 2007 when harvest guidelines increased the allowable catch. Groundfish trawl fisheries land the majority of Dover sole while fixed gears, shrimp trawls, and recreational fisheries make up a very small amount of fishing mortality. Some discarding of Dover sole occurs in the fisheries, and appears to have different patterns based on location. These discards were estimated in the model and total catches are reported, as opposed to landings.

The estimated spawning biomass has shown a slight decline over the entire time series with two periods of more significant decline (the early 1960's and the 1980's). Even though catches continued to increase in the 1970's, the spawning biomass also increased because of larger than average recruitment in the early 1960's. A period of smaller than average recruitments in the late 1970's and early 1980's along with the highest catches on record caused a decline in spawning biomass throughout the 1980's. More recently, spawning biomass has been increasing, although a recent increase in catch and low estimated recruitment in the early 2000's seem to be resulting in a slight downturn in spawning biomass.

Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is high. Sensitivities showed that this uncertainty can be largely attributed to uncertainty in natural mortality. The estimates of spawning biomass from the 2005 assessment are contained within the intervals estimated from this assessment, but the average spawning biomass from this assessment is approximately 40% larger. The 95% confidence interval of estimated depletion (67–100%) is well above the target of 25% of unfished spawning biomass.

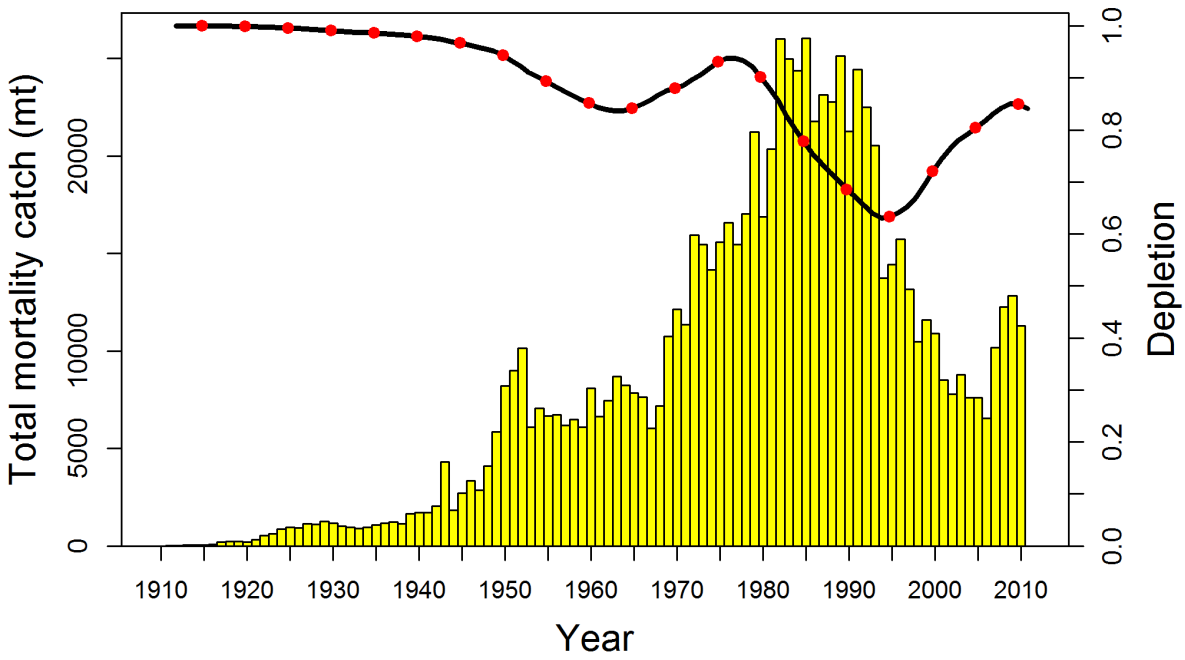

Figure 12. The time-series of total removals (bars) and estimated depletion (line) for Dover sole, 1910–2011.

The complete version of "The Status of Dover Sole (*Microstomus pacificus*) along the U.S. West Coast in 2011" can be found online at:
http://www.pcouncil.org/groundfish/stock-assessments/

For more information on the Dover sole assessment, please contact Allan Hicks at Allan.Hicks@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 2010. 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 1981–2010 range between 701-3,056 mt (Figure 13). 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. 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.

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 13). 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 13). 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 13). 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. Note that these fish are not yet fully mature so this increase is not strongly reflected in the spawning biomass. The estimated relative depletion level in 2011 is 18% (~95% asymptotic interval: ±3.6%, ~ 75% interval based on the range of states of nature: 15.1-21.4%), corresponding to 4,720 mt (~95% asymptotic interval: ±493 mt, states of nature interval: 4,440-5,052 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 1956.

Unfished spawning stock biomass was estimated to be 26,278 mt in the base case model. The target stock size ($SB_{25\%}$) is therefore 6,570 mt which gives a catch of 2,578 mt. Model estimates of spawning biomass at MSY and MSY yield are slightly lower than 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 2,588 mt, occurring at a spawning stock biomass of 5,805 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.

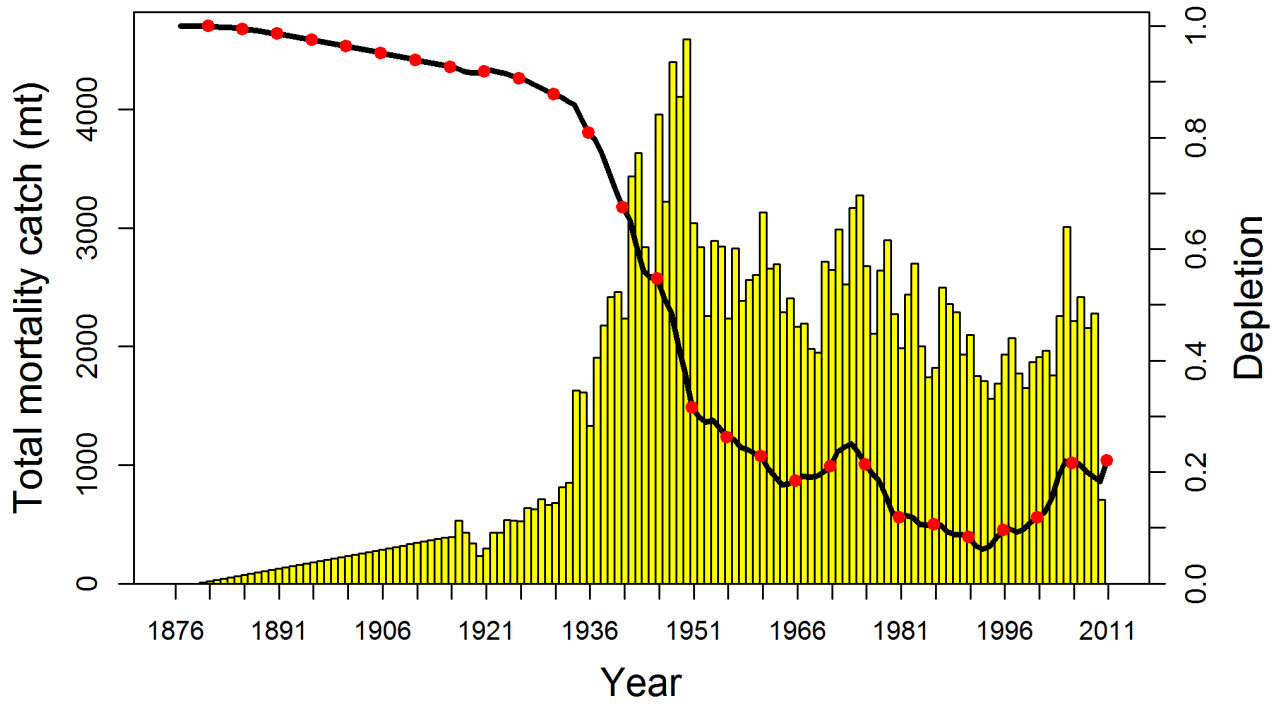

Figure 13. Time series of spawning biomass and catch for petrale sole.

The complete versions of: "Status of the U.S. petrale sole resource in 2010" and "Rebuilding analysis for petrale sole" 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

6. Pacific hake

This stock assessment reports the collaborative efforts of the official U.S. and Canadian JTC members, as well as one previous assessment participant, contributing to the first analysis conducted according to the Agreement between the government of the United States and the Government of Canada on Pacific hake/whiting, signed at Seattle, Washington, on November 21, 2003, and formally established in 2011. The assessment reports 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 2011, 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 2007-2011 have been above the long term average, at 261 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 2011, U.S. fisheries caught mostly 3-year old fish from the 2008 year class, while the Canadian fisheries encountered older fish from the 2005 and 2006 year classes more frequently than the U.S.

fisheries. The current treaty between the United States and Canada, establishes U.S. and Canadian shares of the coast-wide TAC at 73.88% and 26.12%.

Following the 2010 assessment, nearly all of the data sources available for Pacific hake were reconstructed and thoroughly re-evaluated for 2011 from the original observations using consistent, and in some cases improved methods. These improved data streams have been updated for 2012 with the addition of new age distributions from the 2011 fishery and acoustic survey, as well as the 2011 acoustic survey biomass index. The assessment depends primarily upon the acoustic survey biomass index (1995, 1998, 2001, 2003, 2005, 2007, 2009 and 2011) for information on the scale of the current hake stock. The 2011 index value is the lowest in the time-series. The aggregate fishery age-composition data (1975-2011) and the age-composition data from the acoustic survey contribute to the assessment model's ability to resolve strong and weak cohorts. Both sources show a strong 2008 cohort, but differ somewhat in the relative magnitude of the weaker 2005 and 2006 cohorts. The assessment is fully Bayesian, with the base-case model incorporating prior information on two key parameters (natural mortality, *M*, and steepness of the stock-recruit relationship, *h*) and integrating over estimation and parameter uncertainty to provide results that can be probabilistically interpreted. Although the Bayesian results presented include estimation uncertainty, this within-model uncertainty is likely a gross underestimate of the true uncertainty in current stock status and future projections, since it does not include structural modeling choices, data-weighting uncertainty and scientific uncertainty in selection of prior probability distributions. 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, and a biennial rather than annual fishery-independent acoustic survey, will continue to result in highly uncertain estimates of current stock status and even less-certain projections of future stock trajectory. Currently uncertainty in this assessment is largely a function of the disparate survey indices in 2009 and 2011 coupled with the large, but uncertain 2008 year-class. The vast uncertainty in current status and future trends will likely persist as long as the acoustic survey is conducted only every other year, since the dynamics of Pacific hake are elastic enough for the assessment model to respond dramatically to each new biennial survey observation.

The base-case stock assessment model indicates that the Pacific hake female spawning biomass was well below the average 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 rapidly 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 as the exceptionally large 1999 year class matured. The stock is then estimated to have declined with the aging 1999 year class to a time-series low in 2009. The current median posterior spawning biomass is estimated to be 32.6% of the average unfished equilibrium level. However, this estimate is quite uncertain, with 95% posterior credibility intervals ranging from historical lows to above the average unfished equilibrium levels. Estimates of historical Pacific hake recruitment indicate very large year classes in 1980, 1984, 1999, and 2008. The U.S. fishery and acoustic age compositions both show the 2008 year class comprised a very large proportion of the observations in 2010 and 2011.

Uncertainty in estimated recruitments is substantial, especially for 2008, 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. 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 four of the last five years. Recent catch and levels of depletion are presented in figure 14.

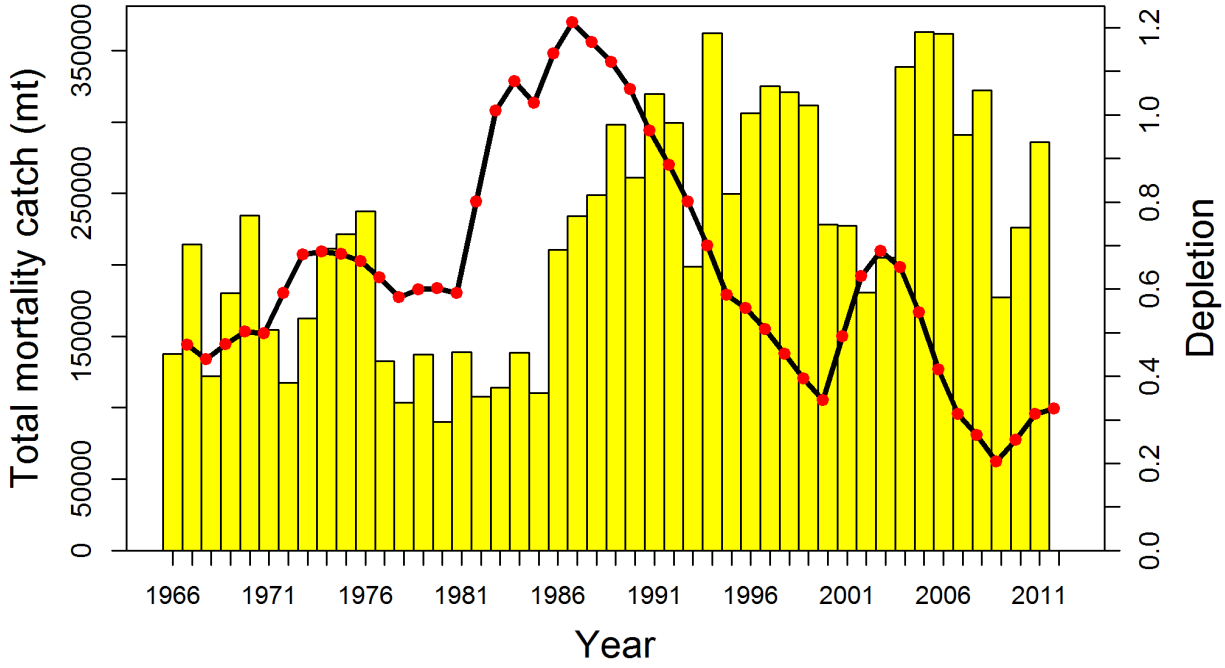

Figure 14. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Pacific hake, 1966-2012.

The complete document: "Status of the Pacific hake (Whiting) stock in U.S. and Canadian Waters in 2012" can be viewed online at: http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Whiting-Management/Treaty-docs.cfm.

For more information on the Pacific hake assessment please contact Ian Stewart at Ian.Stewart@noaa.gov.

7. Other species

a) Stock assessments
A full assessment for spiny dogfish was conducted in 2011.

Spiny dogfish

Spiny dogfish (*Squalus suckleyi*) in the Northeast Pacific Ocean occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts. This assessment focuses on a portion of a 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 assessment area does not include Puget Sound or any other inland waters. The population within this area is treated as a single coast-wide stock, given the migratory nature of the species and the lack of data suggesting the presence of multiple stocks.

The spiny dogfish stock included in this assessment likely has interaction and overlap with dogfish observed off British Columbia. A spatial population dynamics model, which included data from several tagging studies in the Northeast Pacific Ocean, estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. Given this relatively low estimated rate of exchange, it was considered appropriate to proceed with the assessment for the limited area of species range, recognizing that the scope of this assessment does not capture all of the removals and dynamics which likely bear on the status and trends of the larger, transboundary population.

In the coastal waters of the U.S. west coast, spiny dogfish has been utilized since early 20^{th} century. The history of dogfish utilization included a brief but intense fishery in the 1940s, which started soon after it was discovered that livers of spiny dogfish contain high level of vitamin A. During the vitamin A fishery, removals averaged around 6,821mt per year reaching their peak of 16,876 mt in 1944. The fishery ended in 1950 with the advent of synthetic vitamins. In the mid-1970s, a food fish market developed for dogfish when the species was harvested and exported to other counties, primarily Great Britain. This fishery existed until very recently and the landings averaged around 450 mt per year. For the last 10 years landings ranged between 164 and 876 mt.

Even though spiny dogfish was heavily harvested in the 1940s, in general this species is not highly prized and is mostly taken as bycatch in other commercially important fisheries. It is often discarded when bycaught. It has been taken by three major gear groups, including trawl, hook-and-line and a variety of nets. Since 2002, the discard rates in the trawl fishery were on average 85% of all encountered dogfish catch and in the hook-and-line fishery 52%.The vast majority of commercial catch (more than 90%) has been landed in Washington. A small portion of the catch is taken recreationally.

The assessment shows that the stock of spiny dogfish off the continental U.S. Pacific Coast is currently at 63% of its unexploited level and, therefore, not overfished. Historically, the spawning output of spiny dogfish showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 70% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, and the spawning output started to increase (mostly as a result of maturation of younger dogfish that were not selected by the vitamin A fishery). For the last thirty five years, spawning output of spiny dogfish has been slowly but steadily declining due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock. The time-series of total mortality catch (landings plus discards) and estimated depletion for spiny dogfish since 1940 are presented in Figure 15.

The assessment model captures some uncertainty in estimated size and status of the stock through asymptotic confidence intervals estimated within the model. Also, uncertainty from two sources, natural mortality and catch time series, is reported via alternate states of nature in the decision table bracketing the base model results. The estimate of natural mortality was found to have a relatively large influence on the perception of current stock size. The estimated catch time series were included in the decision table to account for lack of historical records on dogfish discard even though sensitivity analysis showed little model sensitivity to alternative historical discard assumptions.

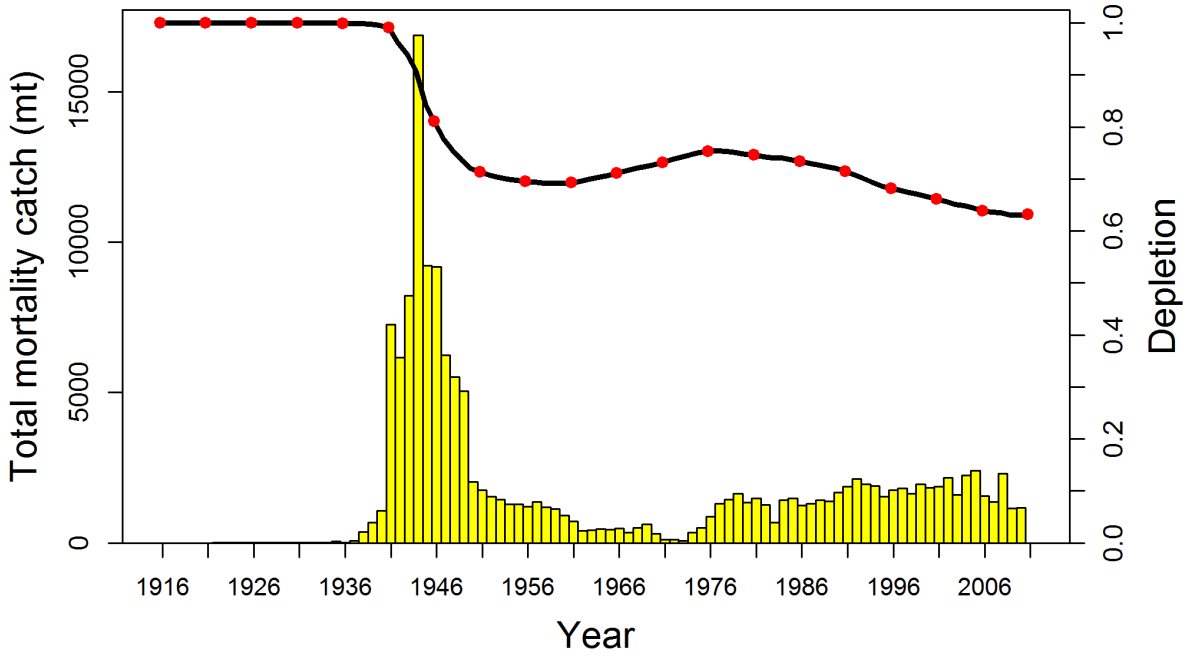

Figure 15. The time-series of recent total mortality catch (bars) and estimated depletion (line) for spiny dogfish, 1940-2010.

The complete version of "Status of the spiny dogfish shark resource off the continental U.S. Pacific Coast in 2011" can be found online at:
http://www.pcouncil.org/groundfish/stock-assessments/by-species/

For more information on the spiny dogfish assessment, contact Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

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 2012, the Active Tectonics and Seafloor Mapping Lab will 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.

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

2. Bycatch Reduction Research

In 2011, the west coast limited entry groundfish trawl fishery began management under a Groundfish Trawl Rationalization Catch Share Program (Pacific Fisheries Management Plan Amendments 20 and 21). This new program establishes annual catch limits and individual fishing quotas along with individual bycatch quotas. These complex fishery management measures have created increased demand for bycatch solutions in the groundfish trawl fishery. Currently, bycatch of overfished species in the west coast groundfish trawl fishery constrains the fishery such that a substantial portion of available harvest is left in the ocean. The NWFSC's Habitat and Conservation Engineering team, working in collaboration with the Pacific States Marine Fisheries Commission, has continued work on a wide range of research projects and outreach to reduce bycatch in

Pacific coast fisheries, and recently, to respond to industry needs resulting from the Catch Share Program.

Reducing Chinook Salmon and Rockfish Bycatch in the Pacific hake Fishery

Since 2009, the NWFSC has iteratively developed and tested an open escape window bycatch reduction device (BRD) to reduce Chinook salmon and overfished or rebuilding rockfish species (e.g., darkblotched, canary, and widow) bycatch in the Pacific hake fishery (e.g., Lomeli and Wakefield 2012). In 2011, this BRD was tested using a recapture net to quantify fish escapement rates under normal commercial fishing operations (Figures 16 - 20). Of particular interest was the gear's performance under high volume catches of Pacific hake. Results from this study showed reductions in Chinook salmon, yellowtail rockfish, and widow rockfish bycatch by 21.4, 8.3, and 8.3%, respectively. Escapement of Pacific hake, the target species, was 1.2%. Earlier studies conducted on the same BRD employed artificial illumination, whereas, escapement rates measured with the recapture net were made in the absence of artificial illumination (Lomeli and Wakefield 2012).

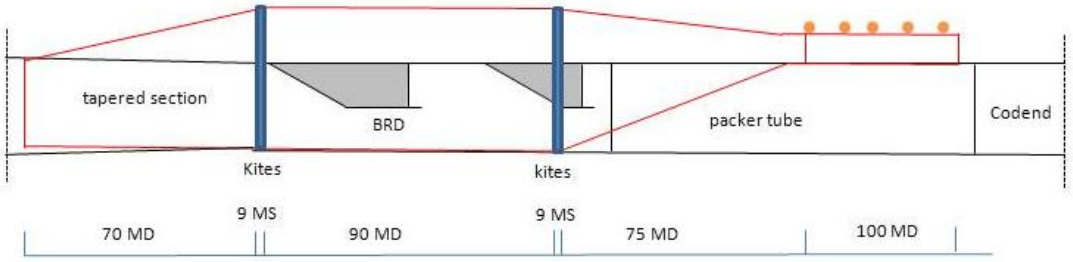

Figure 16. Schematic design of the recapture net incorporated into the open escape window bycatch reduction device used during the current study.

Figure 17. Recapture net under construction and integration with bycatch reduction device in a net loft in Newport, Oregon.

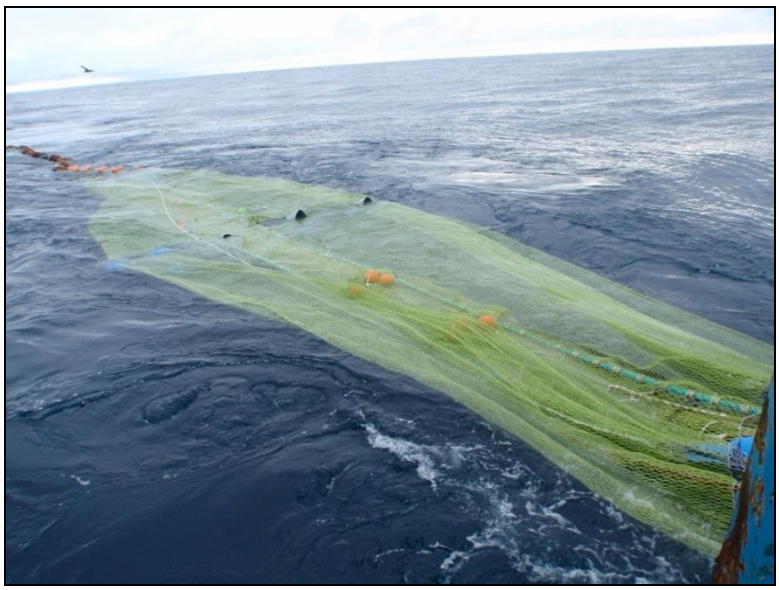

Figure 18. Bycatch Reduction Device and recapture net being deployed aboard a commercial fishing vessel off Washington during July 2011.

Figure 19. Bycatch Reduction Device and recapture net being deployed aboard a commercial fishing vessel off Washington during July 2011. Blue objects encircling recapture net are kites used to hydrodynamically open the net.

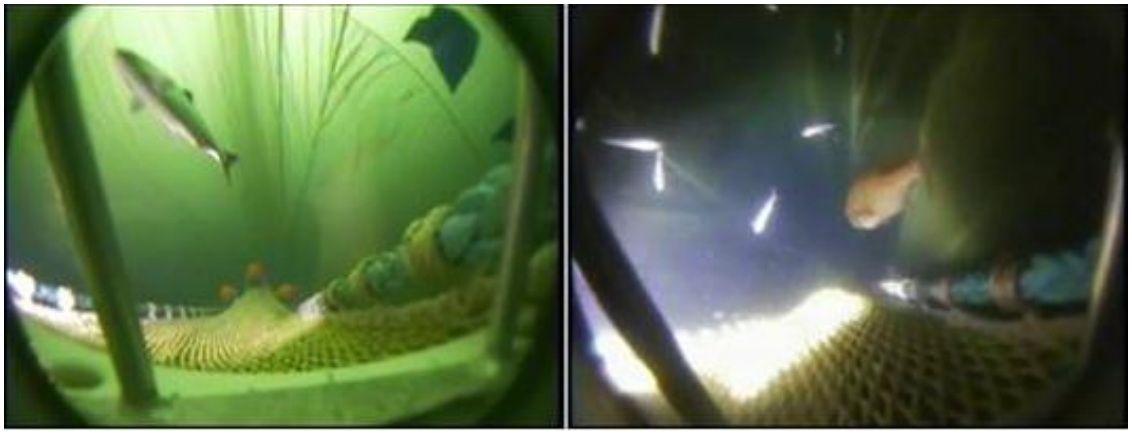

Figure 20. Video frame grabs showing Chinook salmon (left image), and widow rockfish with Pacific hake (right image) swimming inside the recapture net surrounding the BRD.

Reducing Pacific Halibut Bycatch in Bottom Trawl Fisheries

In a second project and in response to fishermen's concern about Pacific halibut bycatch, the NWFSC's Habitat and Conservation Engineering Team, working with the Pacific States Marine Fisheries Commission (PSMFC) and the fishing industry, tested the efficacy of a flexible sorting grate bycatch reduction device (BRD) designed to reduce Pacific halibut bycatch. The BRD is built around a four-seam tube of netting that is inserted between the trawl's intermediate and codend and includes two vertical panels (7.5" mesh) and an exit ramp (5.5" mesh) constructed of AQUAPEX® (cross-linked polyethylene tubing), The flexible grate sorts fish by size as they move towards the codend (Figure 21 – bottom left photo). The concept of design is that fish smaller than the sorting grate openings will be retained, whereas fish greater than the sorting grate openings will be excluded from the trawl via the exit ramp (Figure 22 – bottom right photo).

For this project, a recapture net was used to quantify the escapement rates of target and non-target species. Results showed Pacific halibut bycatch reduced numerically by 57% and gravimetrically by 62%. A significant difference in the mean total length was also noted between Pacific halibut caught in the trawl codend and the recapture net codend; with larger fish occurring in the recapture net. Target species loss ranged from 9% to 22%.

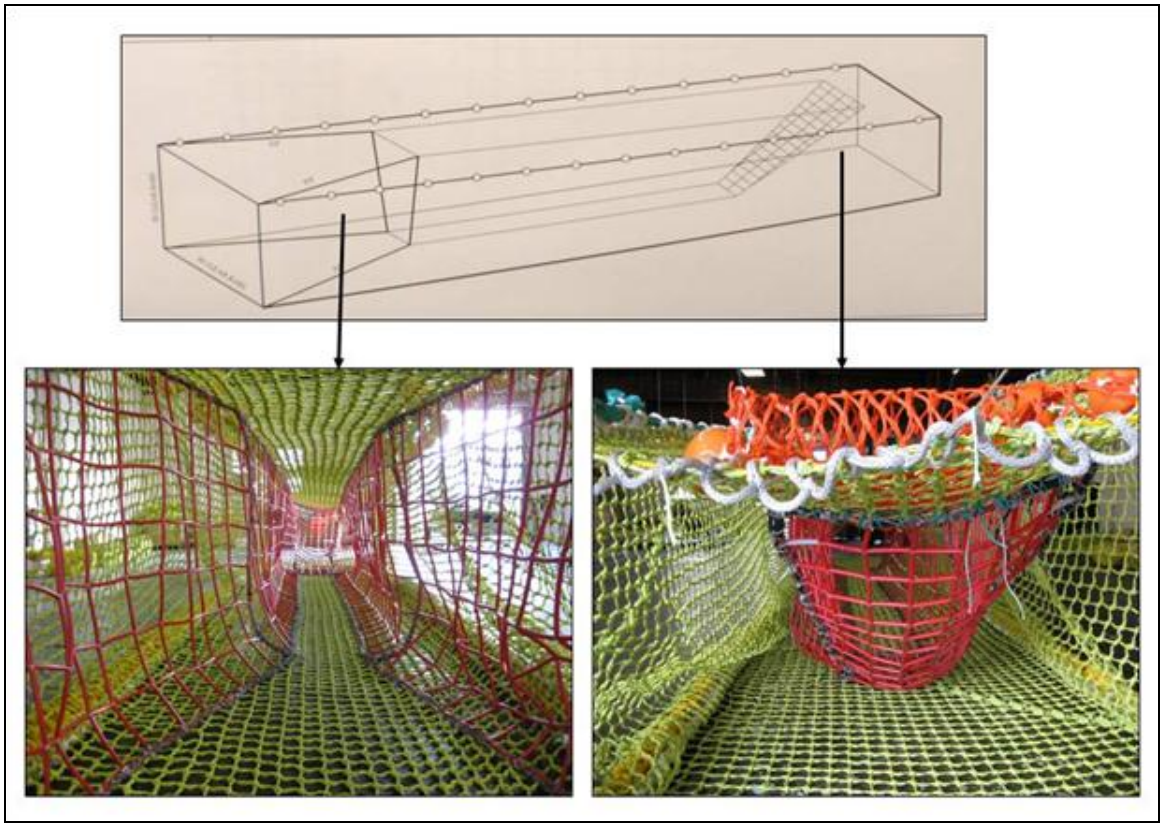

Figure 21. Schematic 3D view of a Pacific halibut flexible sorting grate excluder (top); aft- looking view of the forward portion of the excluder where fish enter and encounter the device (bottom left); forward view of the aft end of the excluder where fish larger than the sorting grate openings would be guided and excluded from the trawl out an exit ramp (bottom right). Image and design is courtesy of Dantrawl, Inc., Seattle, WA.

Figure 22. Comparison of fish caught between the trawl codend and recapture codend during one tow.

Providing Direct Observation Video Camera Systems to Fishermen for Use in Evaluating Industry-Designed Approaches to Reducing Bycatch and Impacts to Benthic Habitats

In 2010, the Northwest Fisheries Science Center (NWFSC) received funding from the NMFS National Bycatch Reduction Engineering Program to build and deploy two video imaging systems and make these 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 three additional video systems to the pool (Figures 23-24) and has successfully operated the loaner program for one year. These camera systems have been used over 20 times across the Pacific hake midwater trawl fishery, groundfish bottom trawl fishery, and the pink shrimp trawl fishery.

Figure 23. One of five autonomous direct observation video camera systems developed at the NWFSC.

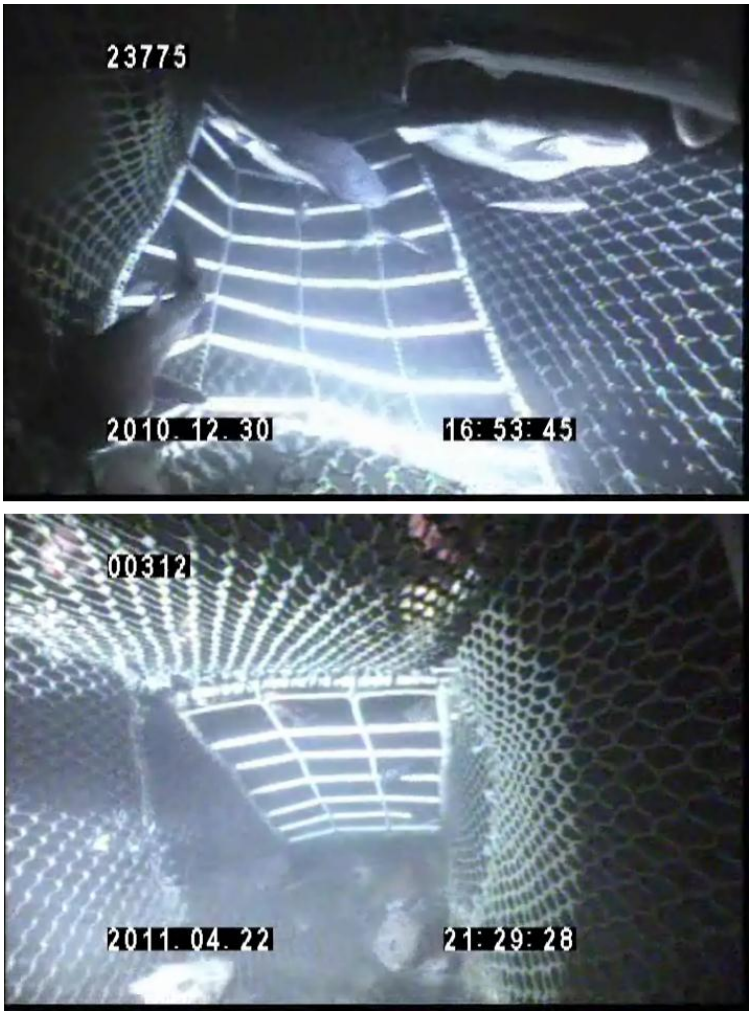

Figure 24. Video frame grabs showing flexible sorting grates developed by the fishing industry to reduce Pacific halibut bycatch in the groundfish bottom trawl fishery. Information gained from the videos was used to improve the performance of the grates.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov 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 2011, CAP finished ageing the following species for inclusion in assessments: Dover sole, petrale sole, canary rockfish, Pacific ocean perch, darkblotched rockfish, Pacific hake, and sablefish. CAP also began routinely recording otolith weights prior to breaking and burning, in support of research into alternative methods of age determination.

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 fourteenth annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2011 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 NWFSC chartered commercial fishing vessels to conduct independent, replicate surveys using standardized trawl gear. Fishing vessels *Ms. Julie, Excalibur, Noah's Ark* and *Raven* were contracted to survey the area from Cape Flattery, WA to the Mexican border in Southern California, beginning in the later part of May and continuing through October. Each vessel was chartered for 11-12 weeks with the *Ms Julie* and *Noah's Ark* surveying the coast during the initial survey period from May to July. The *Excalibur,* and *Raven* operating in tandem, surveyed the coast during a second pass from mid-August to late October. 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 consisted of 752 sampling locations, with a minimum of 30 tows per strata.

In 2011, 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) Maternal effects on larval quality in rockfishes - Southwest Fisheries Science Center; 2) Maturity investigations for blackgill rockfish (*Sebastes melanostomus*) - Southwest Fisheries Science Center; 3) Collection of *Solaster exigus* from northern and southern extremes of range - AFSC; 4) Record all sightings of basking sharks - Moss Landing Marine Laboratories; 5) Collections of sandpaper skate, *Bathyraja kincaidii* - Moss Landing Marine Laboratories; 6) Collection of any Pacific black dogfish, *Centroscyllium* nigrum - Moss Landing Marine Laboratories; 7) 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; 8) Collection of all unusual or unidentifiable sharks including small sleeper sharks, *Somniosus pacificus* - Moss Landing Marine

Laboratories; 9) Collection of any chimaera that is not *Hydrolagus colliei*, including: *Harriotta raleighana*, *Hydrolagus* spp. and *Hydrolagus trolli* - Moss Landing Marine Laboratories; 10) Collection of voucher specimens for multiple fish species – Northwest Fisheries Science Center .

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 and Pacific hake; 4) Collection and identification of cold water corals; 5) Fish distribution in relation to bottom dissolved oxygen concentration in the oxygen minimum zone; 6) Fish distribution in relation to bottom dissolved oxygen concentrations in a known hypoxic area off OR; 7) Composition and abundance of benthic marine debris collected during the 2011 West Coast Groundfish Trawl Survey from May to October 2011; and 8) Collection of ovaries from shortspine thornyheads and canary rockfish to assess maturity.

For more information please contact Aimee Keller at Aimee.Keller@noaa.gov.

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

In early Fall 2011, FRAM personnel conducted the eighth 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*), and the vermilion rockfish complex (e.g., *S. miniatus* and *S. crocotulus*) within the SCB.

The F/V *Aggressor* (Newport Beach, CA) and F/V *Mirage* (Port Hueneme, CA) were each chartered for 11 days of at-sea research, with nine biologists participating during the course of the survey. The two vessels sampled a total of 111 sites ranging from Point Arguello in the north to 9 Mile Bank and the US-Mexico EEZ boundary in the south. Approximately 3,247 lengths, 3,252 weights, 3,156 fin clips, and 2,862 otolith pairs were taken during the course of the entire survey representing 31 different species of fish and 1 invertebrate species.

Several ancillary projects were also conducted during the course of the survey. Ovaries were collected from key species to develop 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 are also constructing a new underwater video sled to capture visual observations for habitat analysis, species composition, and fish behavior studies. Work with a patented non-lethal biopsy hook to capture genetic information *in situ* is ongoing.

For more information please contact John Harms at John.Harms@noaa.gov

c) 2011 Joint U.S.-Canada hake acoustic survey and the processing of the collected data

The Joint U.S./Canada Integrated acoustic and trawl survey was conducted in U.S. waters from June 26 to Aug. 12, 2011 by the U.S. Team (NWFSC/FRAMD) on the NOAA ship Bell M. Shimada. In Canadian waters the survey ran from Aug. 17 to Sep. 9, 2011 with the Canadian Team (DFO/PBS) on the CCGS W.E. Ricker. The Ricker and Shimada worked jointly in Canadian waters from Aug 23 to Aug 30, 2012. 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 Pacific coast from 35.2°N to 54.9°N with acoustic transects spaced 10-20 nm apart. Data were collected on 18-, 38-, 70-, 120-, and 200-kHz EK60 echo sounder on the Shimada, and 38 and 120 kHz EK60 echosounder on the Ricker. The survey resulted in 126 transects with 4,123 nautical miles of acoustical transect. Aggregations of Pacific hake were detected along the continental shelf break from just south of Morro Bay to the southern Haida Gwaii Islands. The highest concentrations of Pacific hake were observed off Cape Mendocino. Closed-net midwater trawls equipped with a camera system, along with a bottom trawl, were conducted to verify size distribution and species composition and to obtain biological information (i.e., age composition, sex). A total of 80 successful trawls (49 by U.S.) resulted in a total hake catch of 11,508 kg (9,686 kg from U.S.). The coastal Pacific hake stock surveyed in 2011 was dominated by age 3 hake. The data analysis was completed by 20 Feb to provide necessary information to the hake stock assessment group. The estimated total biomass of Pacific hake was 0.521 million metric tons (0.480 million metric tons from U.S.). Pacific hake numbers off the west coast, especially Canada, were low relative to previous years.

Also on the joint U.S./Canadian survey, the NWFSC Video Plankton Recorder (VPR) was used aboard Shimada to give a complete picture of the plankton community, including gelatinous zooplankton not identifiable from net tows. The goal of this work is to identify plankton that affects acoustic backscatter during hake surveys.

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

d) Preliminary results from the 2010 inter-vessel comparison (IVC) of the EK60 scientific echosounder between two NOAA ships, the *Miller Freeman* and *Bell M. Shimada*

The FRAM Acoustics Team conducted an inter-vessel comparison (IVC) of the EK60 scientific echosounder using two NOAA ships, the *Miller Freeman* and *Bell M. Shimada* in June-July 2010. The *Miller Freeman* has previously been used by FRAM for the Joint US/Canada Integrated Acoustic and Trawl Hake Survey and was compared to the *Bell M. Shimada*, a noise-reduced vessel. The IVC was conducted to examine if results from FRAM's ongoing acoustic survey onboard the *Miller Freeman* are comparable to results obtained using NOAA's new noise-reduced fisheries survey vessels (FSV), the *Bell M. Shimada*, and/or to document any differences due to either the vessels' equipment or to fish behavior in response to noise-reduction. The IVC consisted of both vessels surveying

an area in tandem, running either follow-the-leader or parallel transects with random selection of the lead, or north/south, vessel. Most vessel operations were identical to the normal FRAM hake acoustic survey operations, with additional time devoted to the follow-the-leader transects.

The 2010 Inter-Vessel Calibration (IVC) between the NOAA Ships *Miller Freeman* and *Bell M. Shimada* for the Pacific hake (*Merluccius productus*) acoustic survey was completed on July 26, 2010. The original plan was to conduct a hake IVC and to study the acoustic signatures of Humboldt squid (*Dosidicus gigas*). Since Humboldt squids were not sighted or collected during the IVC, effort focused solely on hake. During the IVC, four sets of 50 nm mini-grids were completed using both ships, with 1 to 1.5 nm spacing between transects. For the IVC, there were two operating modes: follow-the-leader (FL) and side-by-side (SS). In the follow-the-leader mode, one ship followed the other along the same transect separated by about 0.5 nm. In the side-by-side mode, the two ships were horizontally separated by 0.5 - 1.0 nm. For mini-grid IVC operations, two sets were follow-the-leader mode (*Bell M. Shimada* led once and the *Miller Freeman* led once), and two sets were side-by-side mode.

The preliminary results from the IVC are summarized in Figures 25 and 26 for FL and SS modes, respectively. During the FL comparison, the *Miller Freeman* consistently saw 5% more hake than the *Bell M. Shimada*. For the SS comparison, the *Bell M. Shimada* saw more hake for the B-transects but results were mixed for the C-transects. Overall the *Bell M. Shimada* detected 13% more hake than the *Miller Freeman*. The standard deviations for the FL and SS are 0.12 and 0.31, respectively. Such results are expected since the comparison with the FL mode is based on the assumption that both vessels see the same hake aggregations and are highly correlated. The comparison with the SS mode is based on the assumption that both vessels see hake aggregations that are uncorrelated or loosely correlated, hence more measurements of hake aggregations are required.

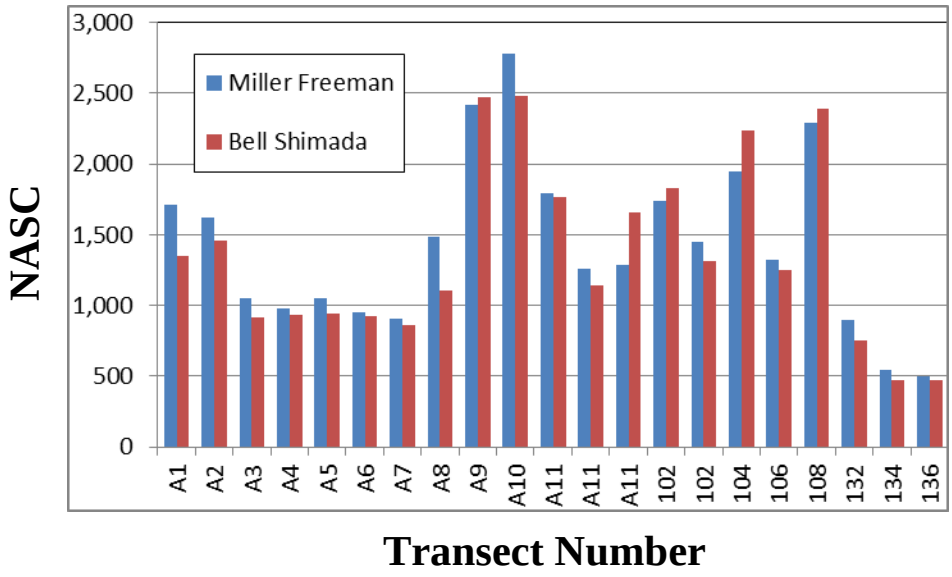

Figure 25. Comparison of the NASC values from the NOAA Ships *Miller Freeman* and Bell Shimada in follow-the-leader (FL) mode.

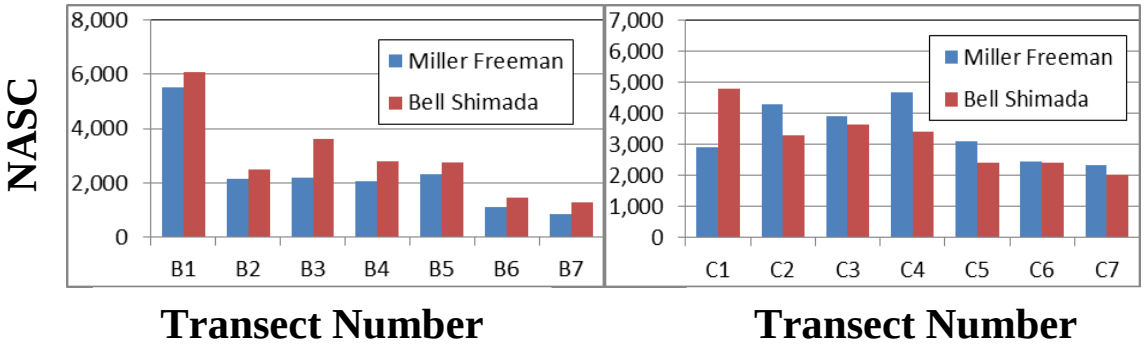

Figure 26. Comparison of the NASC values from the NOAA Ships *Miller Freeman* and Bell Shimada in side-by-side (SS) mode: (a) Mini-grid B-transects; (b) mini-grid C-transects.

The preliminary results indicate the differences between the two vessels range from 5% to 13%, however additional IVC work is required to obtain more conclusive results.

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

e) Joint NWFSC-SWFSC hake pre-recruit survey

A joint Fish Ecology Division and Fisheries Resource Analysis and Monitoring Division pre-recruit survey was conducted in 2011 to determine the spatial distribution and abundance of young-of-year (YOY) Pacific hake and rockfish along the U.S. West Coast. The survey occurred in May-June 2011 using the chartered fishing vessel *Excalibur*. A minimum of 5 trawl stations were sampled on transects located at 30 nm intervals with stations located over waters between approximately 50 m and 1200 m depth. The survey was conducted using the research gear and survey protocol developed by the NMFS Santa Cruz laboratory for surveys of juvenile rockfish (*Sebastes* spp.). Trawling was done at night at a speed of 2.7 kt for 15 minutes duration at target depth. A modified-Cobb midwater trawl with a 26 m (86') headrope and a 9.5 mm (3/8") codend liner was used. Target headrope depth was 30 m except in areas with shallow bottom depths, in which case the target headrope depth was 10 m. All fish and invertebrates captured were identified to the lowest taxonomic level and enumerated. All hake caught were counted and measured and data summarized and transferred to the NWFSC within 3 months of the end of the survey. Rockfish collected were bagged, labeled, frozen and delivered to the NWFSC for identification.

All planned transect lines were sampled, with an extra night of sampling on Heceta Head. Additionally, an opportunistic night of gear comparisons were made between this survey and the SAIP survey off of Columbia River, resulting in 18 transects. A total of 102 mid-water trawls were completed between Cape Mendocino, CA to Cape Flattery, WA. During some nights poor weather prevented sampling some stations due to increased transit time, but on average 5.3 stations were sampled per night.

Young-of-the-year (YOY) of commercially-important species have been sorted, measured, and tentatively identified (some species require genetic testing to confirm or determine identification). YOY rockfish and Pacific hake densities appear to be much lower than in past years, as referenced from the similar NWFSC FE Stock Assessment Improvement Program (SAIP) survey. Flatfish were highly diverse and appeared to be very abundant in 2011. However, these surveys are not directly comparable, so the differences could be due to other factors such as gear used and time of sampling.

For more information please contact Rick Brodeur at Rick.Brodeur@noaa.gov.

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

Project Title: 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 lead 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 in order 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.

6. Ecosystem Studies

a) Fish Ecology Division Summary Report

The Fish Ecology Division completed five monthly field surveys in 2011 for larval fishes using plankton nets and juvenile fishes using trawls. Field surveys are used to assess spawning success of a variety of groundfish species in relation to oceanographic conditions and climate variability, with the intent of establishing recruitment success indices to enhance stock assessment. all five cruises were done aboard the chartered fishing vessel *Miss Sue*. All larval and juvenile fish have been sorted and identified for 2011. Preliminary results have shown a substantial decrease in the abundance of rockfishes in our plankton nets and trawls in the past year as opposed to the last couple of years were they were a dominant species caught. However, there have been moderate increases in flatfish larvae/juveniles of several commercially important species. We have been examining diets of four of the most common rockfish species using direct stomach and stable isotope analysis and have recently submitted a manuscript on this. We are also continuing to look at the species composition of rockfish based on genetics.

Products:

- Oral presentation at the ICES Annual Meeting in Gdansk Poland entitled, "Larval and juvenile recruitment dynamics of rockfishes in the Northern California Current." R.D. Brodeur, T.D. Auth, E.A. Daly, T.A. Britt, M.C.C. Litz, and R.L. Emmett.
- Auth, T.D. 2011. Analysis of the spring-fall epipelagic ichthyoplankton community in the northern California Current in 2004-2009 in relation to environmental forcing factors. *CalCOFI Rep.* 52:148-167.
- Auth, T.D., J. Peterson, W.T. Peterson, and R.D. Brodeur. In prep. Anomalous ichthyoplankton distributions and concentrations in the northern California Current resulting from the 2010 El Niño and La Niña events.
- Toole, C.L., R.D. Brodeur, C.J. Donohoe, and D.F. Markle. 2011. Seasonal and interannual variability in the community structure of small demersal fishes off the central Oregon coast. *Mar. Ecol. Prog. Ser.* 428: 201-217.

- Auth, T.D., R.D. Brodeur, H.L. Soulen, L. Ciannelli, And W.T. Peterson. 2011. The response of fish larvae to decadal changes in environmental forcing factors off the Oregon coast. *Fish. Oceanogr.* 20:314-328.
- Litz, M.N.C., A.J. Phillips, R.D. Brodeur, and R.L. Emmett. 2011. Occurrences of Humboldt squid (*Dosidicus gigas*) in the northern California Current. CalCOFI Rep.52:97-108.
- Bjorkstedt, E.P., R. Goericke, S. McClatchie, E. Weber, W. Watson, N. Lo, B. Peterson, B. Emmett, R. Brodeur, and 21 other authors. 2011. State of the California Current 2010-2011: Regionally variable responses to a strong (but fleeting?) La Niña. CalCOFI Rep.52:36-58.
- Bosley, K.L, T.W. Miller, R.D. Brodeur, K. Bosley, A. Van Gaest and A. Elz. MS. Feeding ecology of juvenile rockfishes off Oregon and Washington: insights into life history patterns based on stomach content and stable isotope analyses. Submitted to *Mar. Biol.*
- Miller, T.W., K. L. Bosley, J. Shibata, R.D. Brodeur, K. Omori and R.L. Emmett. MS. A stable isotope-based perspective on the contribution of prey to Humboldt squid (*Dosidicus gigas*) in the northern California Current. Submitted to Mar. Ecol. Prog. Ser.
- Oral presentation at the 2011 Salmon Ocean Ecology Meeting in Seattle, WA (March 2011) entitled, "Winter ichthyoplankton biomass: predictor of summer prey fields and ultimate survival of juvenile salmon?" Elizabeth A. Daly, Richard D. Brodeur, Toby D. Auth, William T. Peterson, and Edmundo Casillas.
- Oral presentation at the 2011 Annual Larval Fish Conference in Wilmington, NC (May 2011) entitled, "Anomalous ichthyoplankton distributions and concentrations in the northern California Current resulting from the 2010 El Niño and La Niña events." Toby D. Auth.

For more information please contact Rick Brodeur at Rick.Brodeur@noaa.gov.

b) Integrated Ecosystem Assessment of the California Current: Ecosystem health, Salmon, Groundfish and Green Sturgeon

Editors: Phil Levin and Frank Schwing

An Integrated Ecosystem Assessment (IEA) is a formal synthesis and quantitative analysis of information on relevant natural and socio-economic factors in relation to specified ecosystem management goals. In this first iteration of the California Current IEA we focus on a series of ecosystem components and ecosystem pressures that are of keen interest to resource managers, policy makers and the public: ecosystem health, salmon, groundfish and green sturgeon. The goal is to provide the technical underpinnings of future IEA documents that will target stakeholders and managers. We report on 1) a process to develop a limited set of scientifically credible indicators; and 2) the status and trends of these indicators. We then develop a new method for conducting ecosystem risk assessment, and report on pilot evaluations of management scenarios. This report is the first in a series of efforts to complete a full IEA of the California Current. The next iteration of the IEA will improve analytical techniques and models, fill data gaps, will include more ecosystem components and pressures.

A 30 page summary of IEA findings, as well as the full Technical Memorandum, will be available this spring at http://www.nwfsc.noaa.gov/publications/scientificpubs.cfm

For more information please contact Phil Levin at Phil.Levin@noaa.gov

c) Screening California Current Fishery Management Scenarios Using the Atlantis End-to-End Ecosystem Model

Investigators: I.C. Kaplan, P.J. Horne and P.S. Levin

End-to-end marine ecosystem models link climate and oceanography to the food web and human activities. These models can be used as forecasting tools, to strategically evaluate management options and to support ecosystem-based management. Here we report the results of such forecasts in the California Current, using an Atlantis end-to-end model. We worked collaboratively with fishery managers at NOAA's regional offices and staff at the National Marine Sanctuaries (NMS) to explore the impact of fishery policies on management objectives at different spatial scales, from single Marine Sanctuaries to the entire Northern California Current. In addition to examining status quo management, we explored the consequences of several gear switching and spatial management scenarios. Of the scenarios that involved large scale management changes, no single scenario maximized all performance metrics. Any policy choice would involve trade-offs between stakeholder groups and policy goals. For example, a coast-wide 25% gear shift from trawl to pot or longline appeared to be one possible compromise between an increase in spatial management (which sacrificed revenue) and scenarios such as the one consolidating bottom impacts to deeper areas (which did not perform substantially differently from Status Quo). Judged on a coast-wide scale, most of the scenarios that involved minor or local management changes (e.g. within Monterey Bay NMS only) yielded results similar to Status Quo. When impacts did occur in these cases, they often involved local interactions that were difficult to predict a priori based solely on fishing patterns. However, judged on the local scale, deviation from Status Quo did emerge, particularly for metrics related to stationary species or variables (i.e. habitat and local metrics of landed value or bycatch). We also found that isolated management actions within Monterey Bay NMS would cause local fishers to pay a cost for conservation, in terms of reductions in landed value. However, this cost was minimal when local conservation actions were part of a concerted coast-wide plan. The simulations demonstrate the utility of using the Atlantis end-to-end ecosystem model within NOAA's Integrated Ecosystem Assessment, by illustrating an end-to-end modeling tool that allows consideration of multiple management alternatives that are relevant to numerous state, federal and private interests.

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d) From krill to convenience stores: forecasting the economic and ecological effects of fisheries

Investigators: I.C. Kaplan and J. Leonard

There is a need to better understand the linkages between marine ecosystems and the human communities and economies that depend on these systems. Here those linkages are drawn for the California Current on the US West Coast, by combining a fishery ecosystem model (Atlantis) with an economic model (IO-PAC) that traces how changes in seafood landings impact the broader economy. The potential effects of broad fisheries management options are explored, including status quo management, switching effort from trawl to other gears, and spatial management scenarios. Relative to Status Quo, the other scenarios here involved short-term ex-vessel revenue losses, primarily to the bottom trawl fleet. Other fleets, particularly the fixed gear fleet that uses pots and demersal longlines, gained revenue in some scenarios, though spatial closures of Rockfish Conservation Areas reduced revenue to fixed gear fleets. Processor and wholesaler revenue tracked trends in the bottom trawl fleet, which accounted for 58% of total landings by value. Income impacts (employee compensation and earnings of business owners) on the broader economy mirrored the revenue trends. The long-term forecast (15 years) from the Atlantis ecosystem model predicted substantial stock rebuilding and increases in fleet catch. The 15 year projection of Status Quo suggested an additional ~$27 million in revenue for the fisheries sectors, and an additional $23 million in income and 385 jobs in the broader economy, roughly a 25% increase. Linking the ecological and economic models here has allowed evaluation of fishery management policies using multiple criteria, and comparison of potential economic and conservation trade-offs that stem from management actions.

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e) Modeling growth and reproduction of chilipepper rockfish under variable environmental conditions

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

Chilipepper rockfish (*Sebastes goodei*), a long-lived, highly fecund commercial species in the California Current ecosystem, contend with a variable environment on several time scales. Using a bioenergetics model, we simulated alternate strategies of energy allocation by female chilipeppers under variable conditions, and examined resulting patterns in age-dependent size and fecundity. Variable conditions consisted of single climate events (one anomalous year, one 4-year regime shift, or one 10-year regime shift) that occurred at different points over the lifespan of the fish and were either "poor" or "good" relative to baseline conditions. Poor years or regimes reduced growth and fecundity, while good years or regimes increased growth and fecundity. Fecundity losses during poor conditions could be mitigated by partially or fully reallocating energy from gonadal production into somatic growth, thereby increasing potential fecundity in future years. However, when mortality was incorporated, those energetic re-routing strategies only increased lifetime reproductive output if we assumed that old (≥age 8) females

produce more viable larvae than young females, and if the event occurred prior to age 8. Young females also increased output of larvae beyond age 8 if they skipped spawning or reallocated reproductive energy during good conditions, instead investing the surplus energy into additional somatic growth and enhancing future fecundity. Our results are consistent with recent estimates of growth rate variability in the chilipepper population, and with observations of young females of other rockfish species skipping spawning during poor conditions. Models like this may help improve stock assessment parameters and biological reference points for species with environmentally driven variability in size at age.

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f) Climate forcing and the California Current ecosystem

Investigators: J.R. King, V.N. Agostini, C.J. Harvey, G.A. McFarlane, M.G.G. Foreman, J.E. Overland, E. Di Lorenzo, N.A. Bond and K.Y. Aydin

The Climate Forcing and Marine Ecosystem (CFAME) Task Team of the North Pacific Marine Science Organization (PICES) was formed to address climate forcing impacts on ecosystem structure and productivity of marine species. For the California Current system, the Task Team described the physical processes, built an overview of species across trophic levels, and described how the population dynamics of these species have changed over time. Focal groundfish included Dover sole (*Microstomus pacificus*), Pacific hake (*Merluccius productus*), sablefish (*Anoplopoma fimbria*), and rockfish (*Sebastes* spp.). Based on the synthesis work, conceptual models were developed describing the potential pathways linking climate forcing, oceanography, and species' responses. The resultant empirical data scenarios draw on ecosystem histories to provide a synopsis of expected change given global climate change. The multidisciplinary team faced challenges and limitations in their attempt to draw connections between the outputs from global climate models (GCMs), the physical processes, and the subsequent impacts on species via the identified pathways. To some degree, there was a mismatch of variables that fishery scientists identified as important in determining species' response to climate and physical forcing and the variables that current GCMs can now resolve at the regional level. These gaps will be important for researchers to consider as they begin to develop higher resolution climate and regional oceanographic models for forecasting changes in species' productivity.

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g) Comparison of fine-scale acoustic monitoring systems using home range size of lingcod

Investigators: K.S. Andrews, N. Tolimieri, G.D. Williams, J.F. Samhouri, C.J. Harvey and P.S. Levin

We compared the results from fixed acoustic transmitters and transmitters implanted in lingcod *Ophiodon elongatus* provided by two fine-scale passive acoustic monitoring

systems: the older Vemco© Radio Acoustic Positioning (VRAP) system and the newer VR2W Positioning System (VPS) with either three or four receivers. The four-receiver VPS method calculated five times more positions of lingcod than VRAP and more than twice as many as the three-receiver VPS. Calculated positions of fixed transmitters were less precise with VRAP than either VPS approach. Measurements of home range for lingcod were similar between the four-receiver VPS and VRAP, which were both greater than the three-receiver VPS. Comparisons varied when lingcod were in/near complex habitats. As new technology develops, it is important to understand how new methods compare to previous methods. This may be important when describing patterns of movement or habitat use in the context of changes in habitat or management efforts.

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h) Combining fishing and acoustic monitoring data to evaluate the distribution and movements of spotted ratfish *Hydrolagus colliei*

Investigators: K.S. Andrews and T.P. Quinn

Direct and indirect methods have been used to describe patterns of movement of fishes, but few studies have compared these methods simultaneously. We used 20 years of trawl survey data and one year of acoustic telemetry data to evaluate the vertical and horizontal movement patterns of spotted ratfish *Hydrolagus colliei* in Puget Sound, WA, USA. Densities of large ratfish (≥ 30 cm) were higher at the deepest depths trawled (70 m) during daylight hours, whereas densities were similar across depth zones (to 10 m) at night. Acoustic tracking of ratfish showed distinct diel patterns of movement and activity level; ratfish moved into shallow, nearshore habitats at night from deeper, offshore habitats during the day and made ~3 times more moves at night than day in shallow habitats. Broader spatial patterns depended on where ratfish were tagged: one tag group remained in one general location with few excursions, whereas a second tag group moved within a 20-km band with some individuals moving > 90 km. These data will help inform food web models' abilities to quantify interspecific interactions between ratfish and other components of their community.

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

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

The impact of predators in an ecosystem is directly related to how much time they spend in specific habitats and the manner in which they move throughout the environment. In order to investigate the predatory impact of spiny dogfish in Puget Sound, we combined acoustic telemetry with bioenergetics modeling. We used large-scale arrays of passive acoustic receivers in Puget Sound and along the US West Coast to monitor the movement patterns of 17 spiny dogfish *Squalus suckleyi* for up to four years. Spiny dogfish consistently entered Puget Sound in early summer, remained until late autumn, migrated

through the Strait of Juan de Fuca and inhabited coastal waters (as far south as Long Beach, CA) the remainder of the year before returning to Puget Sound the subsequent summer. Individuals returning to Puget Sound showed remarkable consistency in the timing of movements into and out of Puget Sound across years. However, individuals varied in the duration of months spent in Puget Sound (2-7 months) and the ultimate destination within Puget Sound (50 - >120km southward). We then constructed a bioenergetics model to calculate predatory impact based on consumption rates of the spiny dogfish population in each month of the year in Puget Sound. We compared models with and without the patterns of movement detected by acoustic monitoring. When patterns of movement are included, the annual predatory impact of spiny dogfish in Puget Sound was 53% lower than when movement is excluded. The strength of interspecific interactions is ultimately determined by the amount of time species interact and this analysis shows the importance of including movement patterns into any effort to quantify food web interactions.

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j) Scale and pattern of broadnose sevengill shark *Notorhyncus cepedianus* movement in estuarine embayments.

Investigators: G.D. Williams, K.S. Andrews, S.L. Katz, M.L. Moser, N. Tolimieri, D.A. Farrar and P.S. Levin.

The detailed movements of 32 acoustically tagged broadnose sevengill shark *Notorynchus cepedianus* were documented in and around north-east Pacific Ocean estuarine embayments from 2005 to 2007. Arrangements of passive acoustic receivers allowed analysis of movement at several spatial scales, with sex and size examined as possible factors influencing the pattern and timing of these movements. *N. cepedianus* exhibited a distinctly seasonal pattern of estuary use over three consecutive years, entering Willapa Bay in the spring, residing therein for extended periods of time during the summer and dispersing into nearshore coastal habitats and over the continental shelf during the autumn. *N. cepedianus* within Willapa Bay showed spatio-temporal patterns of segregation by size and sex, with males and small females using peripheral southern estuary channels early in the season before joining large females, who remained concentrated in central estuary channels for the entire season. Individuals displayed a high degree of fidelity not only to Willapa Bay (63% were documented returning over three consecutive seasons), but also to specific areas within the estuary, showing consistent patterns of site use from year to year. Cross-estuary movement was common during the summer, with most fish also moving into an adjacent estuarine embayment for some extent of time. Most winter and autumn coastal detections of *N. cepedianus* were made over the continental shelf near Oregon and Washington, U.S.A., but there were also examples of individuals moving into nearshore coastal habitats further south into California, suggesting the feasibility of broad-scale coastal movements to known birthing and nursery grounds for the species. These findings contribute to a better understanding of *N. cepedianus* movement ecology, which can be used to improve the holistic management of this highly mobile apex predator in regional ecosystems.

For more information please contact Greg Williams at Greg.Williams@noaa.gov

k) 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. We 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. Our results suggest failing to account for the full extent of a fish's time overestimates the effectiveness of marine reserves.

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l) Precipitous decline in exploited predators causes ecosystem reorganization in the California Current

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

Indicators are an essential component of ecosystem-based management. For indicators to be useful they need to be rigorously linked to changes in structure and function of the ecosystems they track. Mean trophic level (MTL) of fisheries catch measures the relative abundance of exploited species across a spectrum of trophic levels. The ubiquity and causes of a general decline in catch MTL through time have engendered much attention and debate. However, the consequences of this pattern for broader ecosystem structure and function, inclusive of unexploited species, remain virtually unexplored. Here, we use a fisheries-independent data set to document a pronounced decline in the MTL of the groundfish community along the Pacific U.S. Coast from 2003-2010 caused by decrease in biomass of higher trophic level fishes. Using a food web model, we illustrate how these shifts in ecosystem structure may have resulted in short-term positive responses by many lower trophic level species. In the longer-term, our model predicts that initial patterns of prey release may be tempered in part by lagged responses of non-groundfish, higher trophic level species, such as seals and seabirds. Importantly, the model suggests that aggregate ecosystem functions should change little following the initial reorganization of biomass from groundfish to other components of the food web. Our findings imply that efforts to manage and conserve marine ecosystems will benefit from a

fuller consideration of the information content contained within, and implied by, fisheries-independent trophic level indicators.

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m) Atlantis ecosystem model summary

Editor: H.N. Morzaria Luna

This short document describes the basic structure and capabilities of the Atlantis ecosystem model, and presents groundfish case studies from the US and Mexico. The document is intended for scientific and fisheries management audiences, rather than modelers.

The document is available from the NWFSC website, at:
http://www.nwfsc.noaa.gov/publications/documents/atlantis_ecosystem_model.pdf

For more information, please contact Phil Levin at Phil.Levin@noaa.gov

n) Potential effects of ocean acidification on larval growth and otolith development in China rockfish

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

The effects of CO_2-driven changes in ocean carbon chemistry, or ocean acidification (OA), on shell-building organisms have received much attention, but information regarding the effects of OA on fish is limited. High levels of pCO_2 in vertebrates can lead to lethal or sub-lethal hypercapnia-induced acidification of body fluids. Fish can tolerate brief exposures to high pCO_2, although it is energetically costly. Larval fish, which must meet the added daily energy requirements for growth and development, may not have enough energy to contend with the extra energetic expense of increased ion transport needed to maintain acid-base equilibrium. China rockfish (*Sebastes nebulosa*) larvae were reared in 3 different pH treatments, pH 7.70, 8.05, or 8.10. These conditions approximate past (280 ppm), present (400 ppm), and future (1000 ppm) global average atmospheric pCO_2 levels. Larvae exposed to future pCO_2 conditions had significantly lower survival over a 20-day period (21%) than larvae exposed to present pCO_2 conditions (70%). After two weeks of exposure to treatment conditions, larvae that survived in the future pCO_2 treatment were shorter than larvae that survived in the past and present pCO_2 treatments, though they had greater body depth than larvae in the present pCO_2 treatment. At the end of the experiment, larval size and shape were similar in all treatments. Otolith diameter relative to body size in the present (400 ppm) treatment was significantly larger than the past (280 ppm) and future (1000 ppm) treatments by 6.5 and 4.5%, respectively. From these results, we conclude that high CO_2 conditions can negatively impact the growth, development and survival of larval China rockfish.

o) Cryptic population structure near Point Conception, CA in the severely depleted cowcod, *Sebastes levis*

Investigators: J. Hess, P. Chittaro, A. Elz, L. Gilbert-Horvath, J. Carlos Garza and V. Simon

Cowcod (*Sebastes levis*) is a temperate rockfish species managed as a single homogenous population, yet there are a combination of factors that, in concert, may produce population structure. These factors include a geographical distribution separated by a putative biogeographic boundary, Point Conception; severe declines in abundance which may have reduced effective population sizes and led to divergence driven by genetic drift; and dependence on patchily distributed habitat (i.e. rocky outcrops). Since 2004, the National Marine Fisheries Service has considered cowcod a "species of concern" due to its dramatic decline in abundance (3.4% - 16.3% of historical biomass). We address two questions: 1) Is there population subdivision within the species, specifically, between two marine biogeographic regions separated by Point Conception, and 2) Have cowcod populations experienced loss of genetic variation due to a reduction in population size? A combination of genetic (24 microsatellite loci and mitochondrial d-loop sequencing) and otolith microchemistry (based on trace elements) analyses were used to test these objectives. Coarse-scale analysis of sequence and microchemistry data indicated regional differences of fish separated at Point Conception, however, fine-scale analysis of microsatellites revealed cryptic, divergent lineages (F_{ST}=0.148, P<0.05) which were in contact south of Point Conception. Regional differences for cowcod include relatively faster somatic growth rate, higher genetic diversity, and greater structuring in the southern versus northern region. In general, cowcod is one of the least genetically diverse among other evaluated rockfishes. However, neither cowcod population appears to have suffered detectable loss in genetic variation, despite declines in abundance.

For more information please contact Paul Chittaro at Paul.Chittaro@noaa.gov

7. Acoustic Modeling and Research

a) Refinement of the EchoPro software package with inclusion of a geo-statistical technique (kriging) to process the 2011 Integrated Acoustic and Trawl Survey (IATS) data for hake biomass estimate

EchoPro software package developed in FY11 has been refined to increase the flexibility and reduce the complexity of the program. It reads the Nautical Area Scattering Coefficient exported from the EchoView (Myriax) and can provide length, age, and sex structured biomass estimate in a few minutes. The data processing is totally independent of Oracle database and the processing cycle is much shorter. In addition, the 2011 hake biomass estimate was obtained based on kriging, hence the coefficient of variance (CV) was provided at the same time. Kriging is a geostatistical method and a local estimator used to interpolate a spatially distributed quantity in an unobserved location and was considered to be suitable to estimate fish abundance and precision by an ICES Study Group. In addition, sensitivity analysis of the biomass estimates in terms of the stratification scheme and the kriging parameters was performed, indicating that the biomass estimate was robust.

For more information, contact Larry Hufnagle at Lawrence.C.Hufnagle@noaa.gov

b) Development of an age-1 hake index and analysis of historical data.

An age-1 index for Pacific hake is under development, with the preliminary analysis of 2003 to 2011 data concluded February 2011. This analysis included an overall index of abundance as well as a spatial component of age-1 echosign. This index of abundance was joined to the 1995-2001 historic AFSC data set of age-1 abundance. Initial results indicate that the age-1 index was consistent with major recruitment events; however, more years of data and a full spatial analysis are needed. Currently, work is proceeding on converting historic 1995-2001 echogram data, with hopes to get a full spatial component similar to that in spatial years. Also, as the current adult hake biomass estimate is currently calculated using kriging methods, but the age-1 index is calculated using simple linear interpolation, the age-1 index will also eventually move in the direction of kriging.

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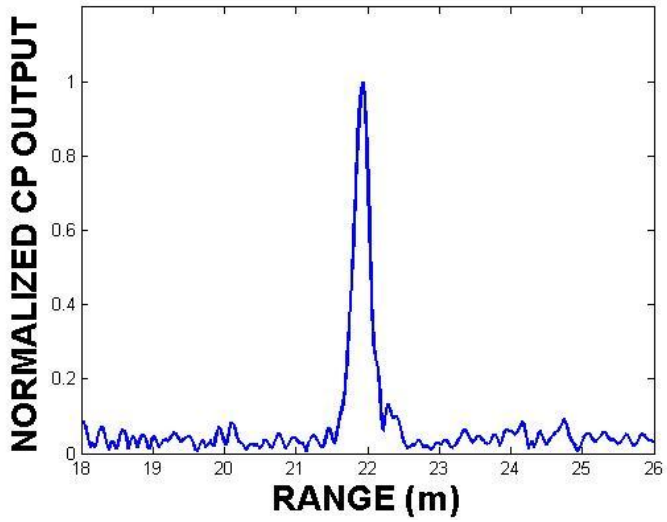
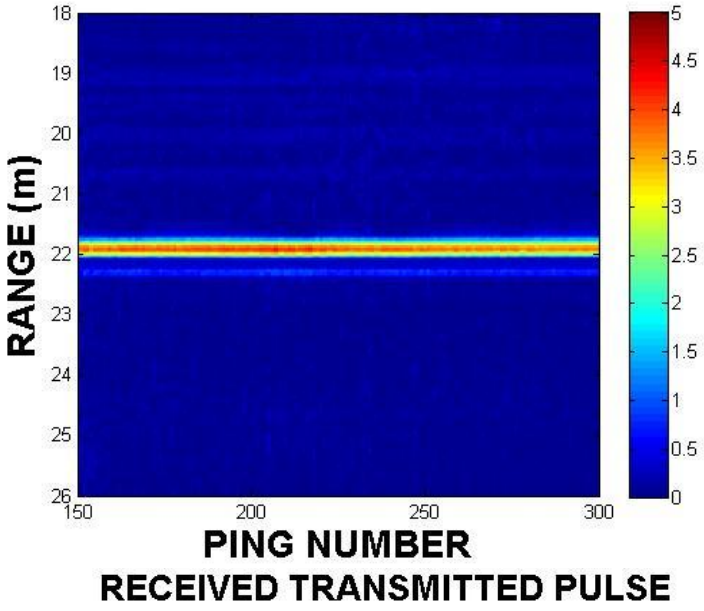
c) Application of low frequency broadband technology to fish characterization acoustically

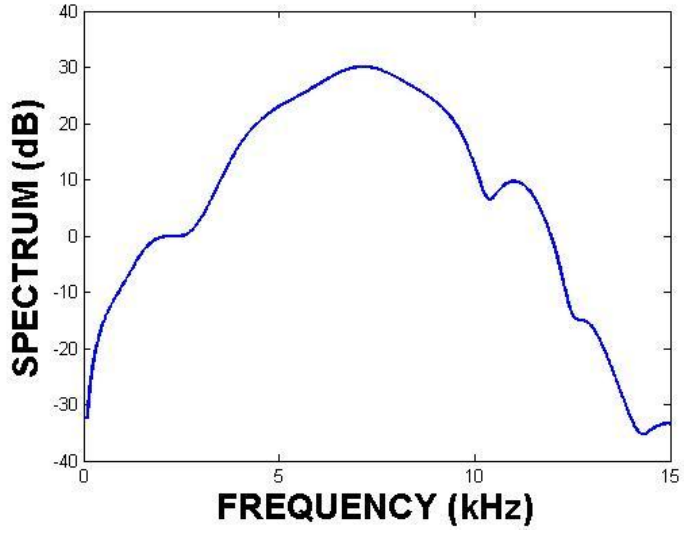
The goal of the proposed research is to develop a technology capable of discriminating Pacific hake from other marine species using a commercially available broadband echosounder system (EdgeTech XSTAR 512i (500 Hz to 12 kHz). The broadband system can provide much improved signal-to-noise ratio (SNR) and range resolution with pulse compression technique (Figure 27). Most importantly, it can provide a wide spectrum that covers a large range of acoustic resonance frequency for adult hake, a swimbladder-bearing fish species.


NORMALIZED CP OUTPUT
RANGE (m)

(a)


RANGE (m)
PING NUMBER
RECEIVED TRANSMITTED PULSE

(b)


SPECTRUM (dB)
FREQUENCY (kHz)

(c)

Figure 27. Calibration outputs of a 30-cm aluminum sphere (AL300): a) echogram of the compressed pulse (CP, or matched filtered) output (top); b) time series of the CP output of the received echo from the calibration sphere (mid); c) averaged spectrum of the received

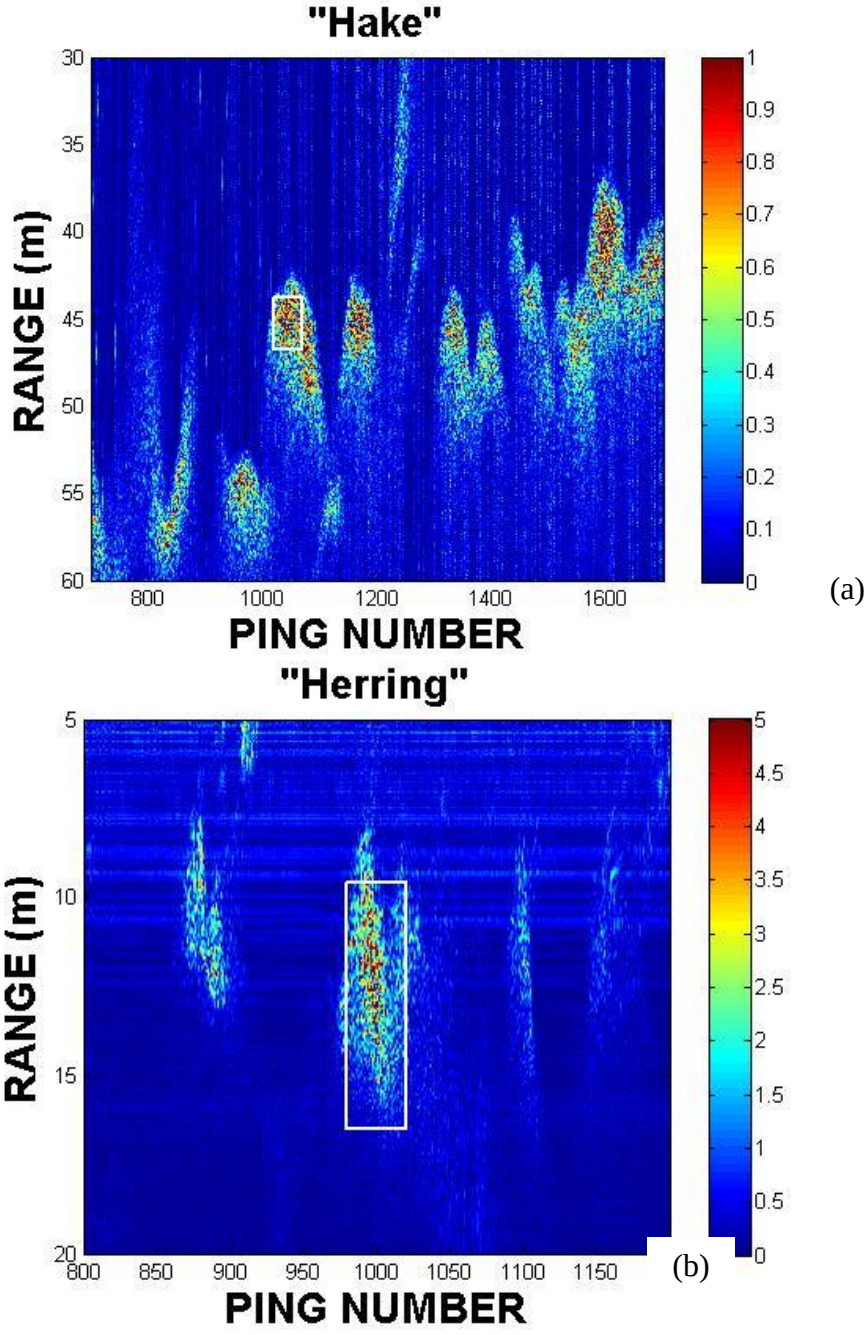


Figure 28. Examples of the Pulse-Compressed (PC) or match-filtered echograms recorded with the EdgeTech SB 512i broadband towed system for "hake" (a) and "herring" (b). The data within the white rectangular boxes were used for spectral analysis.

Due to the time constraint during the 2011 Integrated Acoustic and Trawl Survey (IATS), only one successful deployment and a system calibration were conducted off the NOAA Ship *Bell M. Shimada*. The classification of "hake" and "herring" was based on the experience and knowledge (Figure 28). The schools classified as "hake" was aggregated between 40 and 60 m from the towfish. The EdgeTech broadband system was towed at about 50 m at 2.5 knots, i.e., fish schools were at about 100 m depth. Echoes from the fish aggregations classified as "herring" were recorded during the calibration conducted on Aug 31, 2011 in Elliott Bay, WA. The fish aggregations were at about 15 to 20 meters from the surface.

The frequency response of S_v of the "hake" and "herring" aggregations are shown in Figure 29. Note that the frequencies corresponding to "peaks" of S_v for "hake" and "herring" are different, at 1.6 kHz and 2.05 kHz, respectively. The fact that the S_v spectra have peaks at lower frequency ($ka < 1$, where k is the acoustic wave number and a is the equivalent spherical radius of the swimbladder) and are peaked at different frequencies indicates that the two aggregations are swimbladdered fish with different (swimbladder) size. By taking into account the depth (pressure) difference between two fish, the average length of "hake" should be twice as that of 'herring", assuming they both have the similar body-to-swim bladder length ratio ($a_{esr} \propto \sqrt{1+0.1z} / f_{resonace}$, where a_{esr} is the equivalent spherical radius, z is the depth, and $f_{resonace}$ is the resonance frequency, Medwin & Clay, *Fundamentals of Acoustical Oceanography*, 1998, p294). This is a very important result, confirming the usefulness of a broadband acoustic system in classifying fish with different swim bladder sizes.

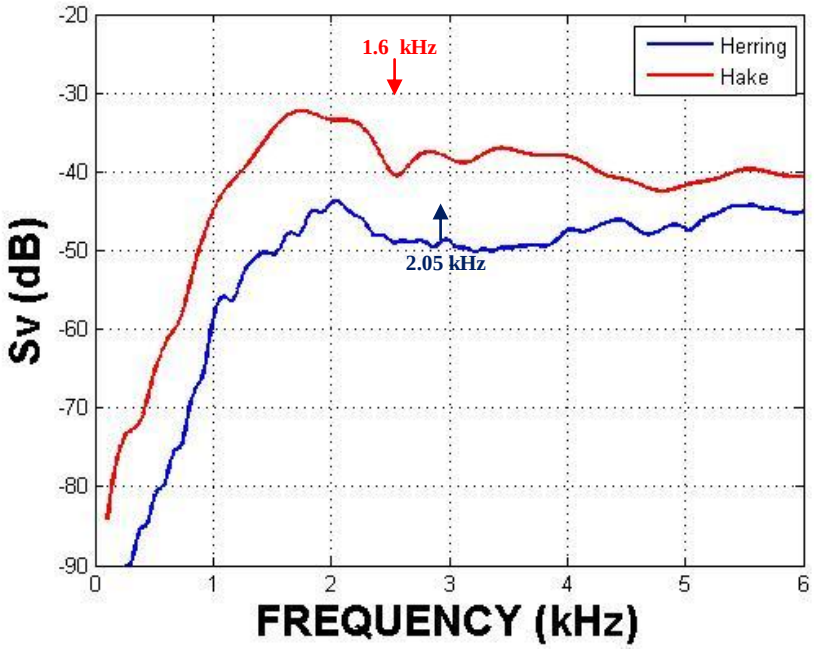


Figure 29. The Average Volume Backscattering Strength (Sv) as a function of frequency for "hake" and "herring". Note that resonance frequencies corresponding to the peaks of S_v for "hake" and "herring" are different, at 1.6 kHz and 2.05 kHz, respectively.

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8. Advance Technologies

a) Advance technologies for monitoring fish and their habitat on the U.S. west coast

Investigators: M.E. Clarke, E. Fruh, C.E. Whitmire and H. Singh

The Northwest and Pacific Islands Fisheries Science Centers have worked with researchers at Woods Hole Oceanographic Institution (WHOI) to redesign the Seabed AUV to overcome the difficulty of monitoring fish populations and habitat in rocky areas. Traditional fish monitoring techniques such as bottom trawl surveys have some limitations for assessing groundfish populations and their habitat throughout their range because of the abundance of rugged terrain. Hover-capable bottom tracking AUVs, on the other hand, offer a unique tool that is appropriate for work in such areas. In addition, this group is collaborating with other researchers to gather information to assess multiple technologies in a variety of habitats.

In 2011, the NWFSC conducted Autonomous Underwater Vehicle (AUV) operations funded by NOAA's Deep Sea Coral Program. In August 2011, scientists from the Northwest Fisheries Science Center and Cordell Bank National Marine Sanctuary a survey on the Sanctuary Vessel *Fulmar* at selected sites in Bodega Canyon off California. The scientists used an autonomous underwater vehicle (AUV) to take still photos to assess the abundance, distribution, and habitat associations of deep-sea corals and sponges, as well as associated fish and invertebrates. From these dives it was apparent that the Canyon habitat is primarily mud-draped rock with scattered outcrops of sedimentary rock. This primarily mud-draped area supported only a few Primnoid (likely *Plumarella longispina*) corals and scattered sponges. These data have been used to refine habitat maps of the region.

In September - October 2011 a collaborative study with the SWFSC was conducted to begin to assess the capability and efficiency of existing technologies to perform surveys of groundfish species in areas and habitats of the West Coast not surveyed adequately by bottom trawls. Underwater surveys of demersal fishes and habitats were conducted on two rocky seamounts off southern California using acoustics, the Nuytco *Dual DeepWorker* submersible, a SeaBED type AUV operated by the SWFSC, and a ROV operated by the SWFSC. The study site was located offshore of Santa Cruz Island, and includes two seamounts: the Piggy Bank and the Footprint Bank. The objectives were to collect data on counts and sizes for several rockfish species and estimate densities, total abundance and biomass for these species. Analyses of the data are underway.

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b) Developing the SeaBED AUV to monitor West Coast groundfish and their habitat

Investigators: M.E. Clarke, E. Fruh and C.E. Whitmire

Many of the commercially important species of demersal fish off the U.S. West Coast inhabit rocky habitats of varying relief that are not accessible with traditional survey gears such as bottom trawls. Due to the number and geographic extent of these habitats, and the number of fish stocks that must be assessed on a regular basis, there is a need for cost-effective tools to survey these areas. Over the past several years, we have been developing a SeaBED type AUV (Autonomous Underwater Vehicle) to survey various benthic habitats for fish and biogenic structure-forming invertebrates (e.g., deep-sea corals, sponges). The SeaBED AUV, developed by Hanumant Singh's lab at Woods Hole Oceanographic Institution, is a bottom tracking AUV that collects high-resolution digital still images of the seafloor and associated fauna. This AUV can be deployed from a variety of vessels ranging from fishing boats to larger oceanographic research vessels. The AUV is primarily an imaging platform that can provide high-resolution georeferenced images as well as associated oceanographic information such as temperature and salinity. We have configured the AUV with both orthogonal (vertical) and oblique (forward) perspective cameras to provide multiple views to aid in the identification of fish and invertebrates. Utilizing its very precise inertial navigation system, we have also employed the AUV to validate habitat information interpreted from high-resolution multibeam sonar imagery. Results from initial surveys show that many fish species can be identified from the images and that associations between fish and emergent fauna (e.g, deep-sea corals) can be quantified. The ability to collect precisely positioned still images has also facilitated photo-mosaicing techniques that show a broader view of the relationships between fauna and habitat than by individual images alone. Some limitations of this AUV relative to ROVs and manned submersibles are that samples cannot be collected and that there is more limited navigational control of the AUV during missions. This limits opportunistic adjustments while surveying, but also minimizes operator chosen diversions from the survey track. In general AUVs have the advantage of being untethered. This can allow the support vessel to conduct other operations in the vicinity thereby maximizing the data that can be collected per sea day. Furthermore, the complexity of operatingthe SeaBED AUV in relatively deep depths up to 1500 meters is generally less than those for tethered devices.

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c) Report of the National Marine Fisheries Service automated image processing workshop, September 2010, Seattle, WA

Investigators: K. Williams, C.N. Rooper and J.H. Harms

This report is a summary of presentations and discussions from a workshop on automated image processing conducted in Seattle, Washington from September 4-7, 2010. The objective of the workshop was to examine current and future applications of automated image processing for fisheries and marine ecology research. The workshop provided a

platform for representatives from all six NOAA centers to present image–based sampling systems that are being used and developed for a wide range of purposes, including essential fish habitat research, target identification for acoustic biomass surveys, verifying commercial fisheries catches through video observing systems, and fish behavior studies.

Experts in the field of image processing presented their past and current projects that incorporate automated processing in various stages, showing what can be achieved through automation and where the challenges lie. The majority of the projects presented by computer vision experts dealt with marine ecology or fisheries applications, even though the analytical methodology is general to the field of computer vision. Their examples illustrate the possibilities for future collaborations as automated processing solutions for image-based sampling programs continue to expand. We hope this publication will serve as a networking tool for biologists and computer vision experts and provide concrete examples of working projects, as well as guidance for developing future automated image processing projects.

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9. Observer Data Collection and Analysis

The FRAM Observer Program continued collecting fishery-dependent data during 2011 on groundfish fleets along the entire U.S. west coast. On January 11, 2011 the West Coast Trawl Catch Share program was implemented. Simply stated, this program divides the total allowable catch in the groundfish trawl fishery into shares controlled by individual fishermen or into cooperatives. A key component of the catch share program is 100% mandatory monitoring of catch at-sea since all catch (not just retained catch) is counted towards quota attainment. The observer program was restructured and enlarged to successfully meet this data collection requirement.

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.

In response to additional data needs under the new catch share program, observer sampling/data collection protocols were updated and expanded as necessary. Since the end of 2010 and through 2011, the program conducted 7 observer trainings, an increase

of around 70% over previous years. The number of observer sea days increased dramatically in this sector between 2011 and 2010, with 9574 observed sea days in 2011, compared to 3418 in 2010. The table below provides further information on observer coverage in the catch share fishery.

Table 2. Summary of observer coverage in the catch share fishery

Description	SS IFQ Trawl	SS IFQ Fixed Gear	SS Hake	MSCV	A-SHOP
Number of vessels	72	26	27	18	14
Number of trips	1164	320	927	49	47
Number of hauls	9406	2182	1716	1256	1315

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 continued to collect data in other west coast fisheries that are not part of the catch share program. The program observed 10 distinct fishery sectors in 2011, including state-managed nearshore and pink shrimp fisheries and federally managed fixed gear fisheries. The program had 2102 sea days in the non-catch share fisheries in 2011 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.

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.

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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. Several fleet-specific reports, which are detailed below, were completed during

2011 - 2012. All reports can be obtained through the links included in the report descriptions.

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Table 3. Recent summaries of data collected on observed trips

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

For more information, please contact Janell Majewski at Janell.Majewski@noaa.gov

d) Implementation of West Coast groundfish trawl catch hares program

The NOAA NMFS Northwest Fisheries Science Center is responsible for at-sea monitoring under the trawl catch share program. In 2010, the observer program, in conjunction with the NOAA Northwest Regional Office, the Pacific Fisheries Management Council, NOAA Office of Law Enforcement, and NOAA General Counsel, completed the necessary regulation to implement the program in 2011.

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e) Multivariate analyses to predict and avoid bycatch events

Investigators: J.E. Jannot and D. Holland

Fisheries managers need to find effective and efficient approaches to managing bycatch of unmarketable fish species. Bycatch of unmarketable species occurs because target species and bycatch species overlap in time and space. Thus, the best management response depends on a number of factors including understanding the interacting physical, ecological, environmental, and temporal factors that influence bycatch. However, bycatch can be highly variable in space and time and therefore difficult for managers and fishers to predict. Abnormally large bycatch events, although rare, do occur, often account for a large proportion of annual species bycatch, and can have serious negative impacts on both the bycatch species population and the fishery. Rare events, such as abnormally large bycatch events, require special modeling techniques. To

date few studies have compared the efficacy of alternative modeling methods for predicting rare bycatch events. The goal of this study is to compare the ability of three models (logistic regression, zero-inflated models, and choice-based sampling models) to predict the probability of bycatch events using multiple spatial, temporal and environmental variables. To facilitate this comparison, analyses were presented of the relationship between environmental variability and bycatch variability of rebuilding fish species in the U.S. Pacific limited entry trawl groundfish fishery. Utilizing data collected by the West Coast Groundfish Observer Program, this work will provide insight into the predictability and rarity of bycatch distribution and events, inform management tools for reducing bycatch, and provide a basis for understanding preferred modeling approaches for rare bycatch events.

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f) Discarding and total fishing mortality trends in the U.S. Pacific west coast groundfish demersal trawl fishery

Investigators M. Bellman and E. Heery

Discarded catch is a major concern in mixed-stock fisheries and enumeration of discard has been a challenge in marine fishery management. We provide estimates of discarded and total catch in the U.S. Pacific west coast groundfish demersal trawl fishery from 2002 through 2009, under trip limit management. Discarded-catch data from the West Coast Groundfish Observer Program (WCGOP) were expanded to the fleet-level using a ratio estimator. Total estimated discard in the fishery declined by 54% across the study period and represented 33% of the annual average groundfish catch. Fishing effort (landings and tow hours) with a high proportion of discard was observed at the beginning of the study period, and then fishing effort subsequently increased but overall discard decreased. The largest components of discard (by weight) were Pacific hake (*Merluccius productus*), arrowtooth flounder (*Atheresthes stomias*), skates (*Rajidae* sp.) and spiny dogfish (*Squalus suckleyi*). For species managed under rebuilding plans, total catch estimates fluctuated but the discarded proportion of catch increased (39%). For non-rebuilding groundfish species, the discarded proportion of catch decreased (21%). This study provides the first reference of total mortality trends in the west coast demersal trawl fishery and will serve as a baseline for future comparisons as the fishery shifts from trip limit management to an Individual Transferable Quota (ITQ) program in 2011.

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g) Observed and estimated bycatch of green sturgeon and Pacific eulachon in U.S. west coast fisheries (2002-2010)

Investigators: A. Al-Humaidhi and M.A. Bellman.

The West Coast Groundfish Observer Program (WCGOP) is tasked with quantifying bycatch estimates in U.S. west coast groundfish fisheries as prescribed under the Magnuson-Stevens Act. This also includes providing bycatch estimates of non-salmonid fish species protected under the Endangered Species Act (ESA) in observed U.S. west coast fisheries. WCGOP provides important information to fisheries managers regarding

rates and estimates of protected species encounters in these fisheries. We present observer bycatch ratios and estimated bycatch for two species listed as threatened under the ESA: green sturgeon (*Acipenser medirostris*) and Pacific eulachon (*Thaleichthys pacificus*). Bycatch estimates were provided for 2002 through 2010 for all fishery sectors observed by the WCGOP. The coast-wide green sturgeon bycatch estimate for 2010 was the lowest estimate of all observed years. The largest estimates of green sturgeon bycatch were in the limited entry sector of the California halibut trawl fishery. Overall, green sturgeon bycatch estimates from 2003 through 2006 were higher, in contrast with bycatch estimates from 2007 through 2010, with the exception of 2009. The Pacific eulachon bycatch estimates for 2009 and 2010 were the highest estimates of all observed years. The pink shrimp (*Pandalus jordani*) trawl fishery constituted the largest source of eulachon bycatch coast-wide. Observer coverage of the pink shrimp fishery increased in 2010 with increased coverage in California and the initiation of coverage in Washington. Protected species bycatch estimates produced by the WCGOP inform managers regarding the level of risk and impact of the various fisheries, allowing for well-informed and focused efforts to preserve protected species.

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10. Recent Publications

Andrews, K.S., Quinn, T.P. in press. Combining fishing and acoustic monitoring data to evaluate the distribution and movements of spotted ratfish *Hydrolagus colliei*. Marine Biology. DOI 10.1007/s00227-011-1853-x.

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