# Northwest Fisheries Science Center

# National Marine Fisheries Service


# 2008 Agency Report to the Technical Subcommittee

# of the Canada-U.S. Groundfish Committee

**April 2008**

## 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. 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-U.S. 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 and ecology, 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; investigate the design, feasibility, function, and value of marine protected areas; and employ advanced technologies for new assessments.

During 2007, FRAMD continued to: implement a West Coast observer program; build a survey program that conducts West Coast groundfish acoustic and trawl surveys previously conducted by the AFSC; develop new technologies for surveying fish populations, particularly in untrawlable areas; and expand its stock assessment, economics, and ecosystem research. Significant progress continues in all programs.

For more information on FRAMD and groundfish investigations, contact the Division Director, Dr. M. Elizabeth Clarke at Elizabeth.Clarke@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. Usha Varanasi at Usha.Varanasi@noaa.gov, (206) 860-3200.

## B. Multi-species Studies

### 1. Research

#### a) Demersal fish abundance in relation to an offshore hypoxic zone along the U.S. West Coast

In August 2007, as part of the West Coast Groundfish Trawl Survey, FRAMD examined the abundance of benthic organisms in a known hypoxic area off the Oregon coast. Since 2002, seasonal hypoxia has been observed extending over an area greater than 700 $km^2$ offshore of Newport, Oregon. Although observed each summer, the intensity of hypoxia has varied with the greatest temporal and spatial extent noted in 2006. The Northwest Fisheries Science Center annually conducts the West Coast Groundfish Trawl Survey from Washington to California (55 to 1,280 m) using a stratified random design. A few stations generally fall within the hypoxic area and in 2006 FRAMD observed exceedingly low fish biomass here. Consequently in August 2007, FRAMD dedicated 2-days of the groundfish survey to examining the abundance of demersal fish and invertebrates within

the hypoxic zone in greater detail. Working collaboratively with colleagues from Oregon State University, we identified the geographic extent of the 2007 hypoxic zone. We sampled 17 stations along 2 depth contours (50 and 70 m) within the area. A Seabird SBE19-plus was attached to the trawl gear to monitor oxygen concentration during each tow. All catch was identified and weighed with stomach and tissue samples taken from selected species. Dungeness crabs from each tow were measured, weighed and assigned a condition code. During the 2-day survey, bottom oxygen concentrations at all stations were hypoxic with means along the tow tract ranging from 0.43 to 1.27 ml $l^{-1}$. Total CPUE (ln, kg $hectare^{-1}$) was significantly ($F = 6.56$, $P = 0.02$, $n = 17$) and positively related to oxygen concentration along the hypoxic gradient (Figure 1). In addition, CPUE (ln transformed) for 11 individual demersal fish species and 5 benthic invertebrate species were significantly ($P < 0.10$) and positively related to bottom oxygen concentration within the hypoxic region. Condition factors for 6 fish species, as well as Dungeness crab increased with increased bottom oxygen levels along the hypoxic gradient and preliminary results suggest the average weight of stomach contents for 4 fish species were lower at the lowest oxygen concentrations encountered.

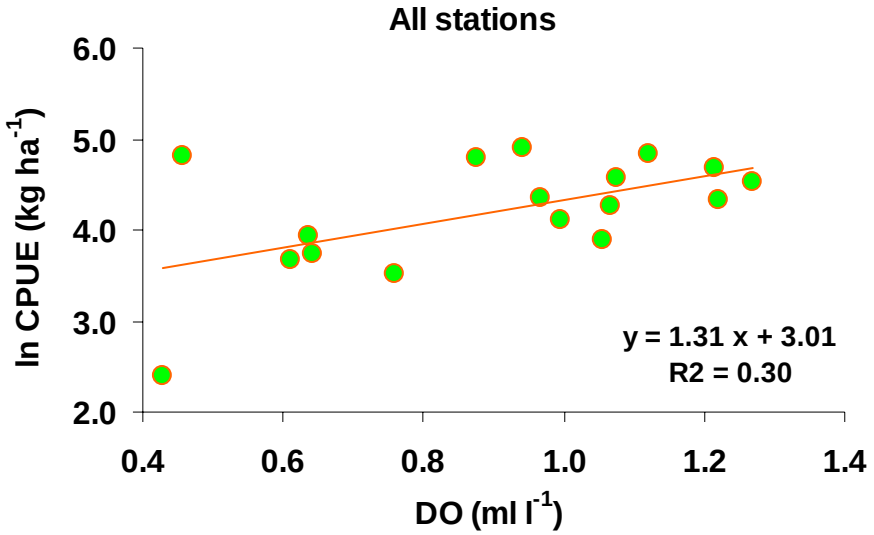


Figure 1. Relationship between catch per unit effort (CPUE, ln kg $hectare^{-1}$) and mean bottom oxygen concentration (ml $l^{-1}$) along the tow track within the hypoxic zone.

**b) The effects of temporal variation in fishing effort in the U.S. West Coast At-Sea hake fishery**

In 2007, FRAMD examined the effects of temporal variation in fishing effort on bycatch rate in the U.S. West Coast at-sea hake (*Merluccius productus*) fishery. Recent regulations limiting the bycatch of particular rockfish species in the at-sea Pacific hake fishery have resulted in several changes in the fishery, including documented changes in fishing depths. Concerns about rockfish bycatch have led to speculation that tows made during daytime hours have lower rockfish bycatch rates in comparison to nighttime tows.

For the 2006 and 2007 seasons, a voluntary agreement between the vessels was proposed to focus fishing primarily during daylight hours and minimize nighttime fishing when possible, in an effort to reduce widow rockfish (*Sebastes entomelas*) bycatch. Fishing during nighttime hours was still conducted, but the data indicate a distinct shift towards increased fishing effort during daylight hours. Bycatch in the hake fishery is highly variable, and rare tows with very high rates of bycatch can skew the data, but overall averages indicate the total bycatch rate increases around dawn and are slightly higher during daytime hours. However, the rate of hake catch drops off during the night and thus the perception of higher bycatch – in relation to hake caught – has led to the idea of limiting nighttime fishing to reduce bycatch. It does appear that the hours surrounding dawn might be a beneficial time to reduce effort in an attempt to lower bycatch overall.

Due to the sporadic nature of large widow rockfish catches, reduced nighttime fishing has not had a large impact on the total amount caught. Other means of bycatch reduction should be explored. Avoidance of the 1.5% of tows which have very high widow bycatch should be made the priority. If this could be done the widow bycatch rate could be cut in half. Bycatch is influenced by multiple variables and time of day is just one of those. Further investigations are needed to determine the extent of these influences.

For more information, please contact Vanessa Tuttle at Vanessa.Tuttle@noaa.gov

**c) Evaluating biomass reference points in a variable environment**

A simulation analysis was completed by Melissa Haltuch, FRAMD, as part of her Ph.D. thesis, to evaluate biomass reference points in a variable environment based on life-histories of three U.S. west coast groundfish species. There is strong evidence that low frequency inter-annual environmental variability, in addition to fishing, is able to impact fish population abundance via recruitment. However, scientific advice regarding harvest strategies is often based on control rules which depend upon the estimation of biomass reference points. These control rules typically do not explicitly consider the impact of trends in reference points that are caused by environmental variability. Sustainable harvest rates based on commonly-used biological reference points such as the level of unfished spawning biomass ($B_0$), and the current size of the stock in relation to $B_0$ under current environmental conditions may be unsustainable under different environmental conditions. Although several methods exist for estimating biomass reference points, it is unclear which methods are most robust to the impact of long term, low frequency, environmental variability. Therefore, simulation is used to evaluate alternative estimators, which differ in terms of whether a stock-recruitment relationship is estimated, for $B_0$, the steepness of the stock-recruitment relationship, and current spawning biomass relative to $B_0$. The simulations consider life histories of three U.S. west coast groundfish species: a long-lived unproductive rockfish, a moderately long-lived and productive flatfish, and a moderately long-lived and productive semi-pelagic gadid with highly variable recruitment.

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

**d) Feeding ecology of juvenile rockfish off Oregon and Washington as indicated by diet and stable isotope analysis**

In 2007, FRAMD, working with collaborators, examined the feeding ecology of juvenile rockfish off Oregon and Washington based on diet and stable isotope analysis. Early life history stages of marine fish suffer high mortality rates making this period a critical determinant of year-class strength. Despite this importance, few studies have looked at the feeding habits of co-occurring pelagic young-of-the-year rockfish (*Sebastes* spp.) off the west coast—information crucial to understanding how these fish may be influenced by bottom-up processes. We undertook a study of the feeding habits of juvenile rockfish collected off Oregon and Washington during GLOBEC (2002) and NOAA Predator (2006) surveys. The predominant species collected in both years were darkblotched (*S. crameri*), canary (*S. pinniger*), yellowtail (*S. flavidus*), and widow (*S. entomelas*) rockfishes. Analysis of gut contents (% number) from 2002 and 2006 revealed that darkblotched rockfish had a high degree of variation in their diets, consisting of gelatinous zooplankton (2002), several life-history stages of euphausiids (2006), as well as hyperiid amphipods and copepods (2002 and 2006). Canary, yellowtail, and widow rockfishes had a high degree of dietary overlap, because of common utilization of copepods and euphausiids. There was less overlap in diets between species when % wet weight was examined, with only canary and widow rockfish showing significant similarities (2006). Additionally, nitrogen stable isotopes confirmed that all fish from the same year were feeding at nearly the same trophic level while in both years darkblotched had enriched carbon values relative to all other species. Taken together, the stomach content and stable isotope data will advance our understanding of some of the important environmental factors that effect young-of-the-year rockfish during their pelagic phase.

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

**e) Using bioenergetics models to estimate responsiveness of California Current groundfish to temperature anomalies**

In 2007, FRAMD used bioenergetics models to estimate responsiveness of California Current groundfish to temperature anomalies. Temperature is known to affect fish feeding, growth, and reproductive rates, which in turn are related to numerous demographic and ecological variables. Bioenergetics models were developed for three groundfish (yelloweye rockfish *Sebastes ruberrimus*, sablefish *Anoploma fimbria*, and spiny dogfish *Squalus acanthias*) and used to estimate how each species responded to both long-term temperature change and temperature variability. Response variables were mass at age 1, maturation rate, maximum size, lifetime consumption and lifetime fecundity, all standardized relative to baseline scenarios at a fixed temperature of 8º C. As lifetime rearing temperature increased, most response variables increased non-linearly, peaked, and then declined precipitously. The most responsive species were yelloweye rockfish (age-1 mass, maturation rate) and spiny dogfish (maturation rate, maximum size, lifetime consumption, lifetime fecundity). When mean temperature was fixed at 8º C but allowed to vary (CV range = 5% to 20%), mean values of most response variables remained stable, with variability increasing in proportion to temperature CV.

The exception was maturation rate: increasing temperature variability slightly accelerated maturation for yelloweye rockfish and spiny dogfish. Of the remaining response variables, yelloweye rockfish were most responsive in terms of age-1 mass, and least responsive in all others. The chosen response variables are assumed proxies for key demographic and ecological properties, including first-year survival, reproductive potential and trophic impact, and may offer insight as to how these species population biology, distribution, and trophic ecology will be affected by climate anomalies and climate change.

For more information, Dr. Chris Harvey at Chris.Harvey@noaa.gov

**2. Stock Assessment**

**a) SS2 stock assessment model development**

Stock Synthesis 2 (SS2) is in the class of assessment models termed integrated analysis. SS2 incorporates a population sub-model operating by forward simulation, 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 randomly or across time blocks or can be specified as functions of environmental data. SS2 includes routines to estimate MSY and exploitation levels that correspond to various standard fishery management targets. A user-selected harvest policy is used to conduct a forecast in the final phase of running the model. The model is coded in AD_Model_Builder (Dave Fournier, Otter Research Ltd.). SS2 is included in the NOAA Fisheries Assessment Toolbox (http://nft.nefsc.noaa.gov/) incorporating a graphical user interface developed by Alan Seaver (NEFSC).

SS2 was first used for operational assessments in 2005. In 2007, SS2 was updated to version 2.00, which incorporated several enhancements including algorithms to define movement between assessment sub-areas and enhanced controls over processes for growth, selectivity, and recruitment. Its usage has expanded beyond west coast groundfish to include several groundfish stocks in Alaska and southeast Australia, west coast sardine and mackerel, and some tuna and billfish assessments. Further enhancements under development in 2008 include the capability to analyze tag-recapture data and weight frequency data.

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

**b) Spatial stock structure and the performance of stock assessments: the revenge of SLOSS?**

The traditional approach to stock assessments on the U.S. west coast is to assume a unified population stock. This assumption is either based on direct evidence of perceived structure or, more commonly, the default assumption that there is no structure until

proven otherwise. Given increasing evidence of population structuring mechanisms in nearshore species and the potential structure-inducing effects of environmental change and fishing on metapopulations, the main question becomes: when does the assumption of stock unity break down? When assessing a population, is it better to assume more structure or less? This work explores the performance of stock assessments under varying assumptions of stock connectivity, life histories, and removal pressures. An operating model is used to simulate population dynamics under varying scenarios of stock connectivity and in turn sample data (i.e. indices of abundance and age compositions) commonly used to assess stocks. Each population is then assessed under varying stock structure hypotheses using Stock Synthesis 2, the primary assessment framework used for west coast groundfish assessments. Under an experimental simulation testing framework, absolute and relative errors between the true population model values and the derived assessment estimates of recruitment, biomass, spawning biomass, and stock depletion are compared to evaluate the performance of stock assessments under varying stock assumptions. As dry as this approach sounds, the results provide important insights into how assumptions of stock structure may or may not bias assessment outcomes and potential management advice. The above research was conducted by J. Cope as part of his Ph.D. thesis.

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

**c) Summary of the status of Pacific coast groundfish stocks**

Recent stock assessments for many Pacific coast groundfish species have shown substantial increases in biomass and rebuilding progress over the past few years. Today, the status of the stocks is a sharp contrast to where we were in 2000. FRAMD summarized the improvements in the status of Pacific coast groundfish from 2000 to 2007 for presentation at the 2008 Western Groundfish Conference in Santa Cruz, CA. Nine groundfish stocks were declared overfished along the West coast between 1999 and 2002, with spawning biomasses below 25% of unfished levels. Rebuilding plans were implemented that reduced fishing mortality for the overfished species as well as associated species throughout nearly all sectors of the groundfish fishery resulting in historically low allowable harvests and landings.

The reduction in fishing mortality combined with a stronger than average 1999 year class for many west coast groundfish species has resulted in increasing trends in biomass for the overfished species and the rebuilding of two stocks, Pacific hake (whiting) and lingcod, to target levels (40% of unfished spawning biomass). Rebuilding for some of the overfished rockfish stocks is expected to occur over a longer period of time, however, recent stock assessments and rebuilding analyses suggest four stocks, Pacific ocean perch, canary rockfish, bocaccio, and widow rockfish are rebuilding more quickly than previously estimated.

For more information, please contact Stacey Miller at Stacey.Miller@noaa.gov

**d) Deriving objective data weighting for age- and length-composition data in stock assessments using post-model and simulation results**

Integrated age-length structured stock assessment models derive estimates of management quantities by fitting to multiple sources of observed data, including indices of abundance, and age and length compositions. The relative weighting of these likelihood components is often an important contributor to uncertainty, but there is currently no clear objective approach to determine these weights. Model "tuning" is often applied, with the goal of achieving internal consistency between assumed data weighting and model fit. Tuning relies on reasonable starting values for input sample sizes to appropriately allocate lack of fit to process and observation error. Focusing on age- and length-composition observations from trawl survey data, we compare the effective sample sizes derived from assessment models fit to actual data in 2005 and 2007 with theoretical effective sample sizes based on simulation. We find that effective sample size is best represented as a function of both the number of fish and the number of hauls sampled. We develop guidelines for tuning of these data sources that should increase objectivity and reliability of stock assessment model results.

For more information, please contact Ian Stewart at Ian.Stewart@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 other than Pacific hake, conducted in 2007, is shown in Table 1.

Table 1. 2007 Review Schedule for Full Groundfish Assessments other than hake.

| STAR PANEL | STOCK | AUTHOR(S) | STAR PANEL DATES | STAR PANEL LOCATION |
|---|---|---|---|---|
| 1 | Longnose skate<br>Sablefish | Vladlena Gertseva<br>Michael Schirripa | May 7-11 | Hatfield Marine Science Center<br>Barry Fisher Bldg., Room 101,<br>2032 SE Oregon State University Drive, Newport, OR 97365 |
| 2 | Black rockfish (N&S)<br>Blue rockfish (Calif) | David Sampson & Farron Wallace<br>Meish Key | May 21-25 | Pacific States Marine Fisheries Commission<br>205 SE Spokane Street,<br>Portland, OR 97202 |
| 3 | Bocaccio<br>Chilipepper rockfish | Alec MacCall & Steve Ralston<br>John Field | June 25-29 | Southwest Fisheries Science Center<br>110 Shaffer Road<br>Santa Cruz, CA 95060 |
| 4 | Darkblotched rockfish | Owen Hamel | July 16-20 | NOAA Western Regional Center<br>Bldg 9. Conference Room,<br>7600 Sand Point Way NE,<br>Seattle, WA 98115 |
| 5 | Canary rockfish<br>Arrowtooth flounder | Ian Stewart<br>Isaac Kaplan & Tom Helser | July 30-Aug. 3 | NOAA Western Regional Center<br>Bldg 9. Conference Room,<br>7600 Sand Point Way NE,<br>Seattle, WA 98115 |

## 1. Shelf Rockfish - West Coast

### b) Stock Assessments

Shelf rockfish assessments conducted during 2007 included a full assessment of canary rockfish and an update of the 2006 yelloweye rockfish assessment.

**Canary rockfish:** This 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 2006. The resource is modeled as a single stock. 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 that there are distinct biological stocks of canary rockfish off the U.S. coast and very limited tagging data to describe adult movement, which may be significant across depth and latitude. Future efforts to specifically address regional management concerns will require a more spatially explicit model that likely includes the portion of the canary rockfish stock residing in Canadian waters off Vancouver Island. Since 1916 annual catch has ranged from 46.5 mt in 2004 to 5,544 in 1982. Canary rockfish have been primarily caught by trawl fleets, on average comprising ~85% of the annual catches, with the Oregon fleet removing as much as 3,941 mt in 1982. Historically, just 10% of the catches have come from non-trawl commercial fisheries, although this proportion reached 24% and 358 mt in 1997. Recreational removals have averaged just 6% of the total catch, historically, but have become relatively more important as commercial landings have been substantially reduced in recent years. Recreational catches reached 59% of the total with 30 mt caught in 2003. Total catches after 1999 have been reduced by an order of magnitude in an attempt to rebuild a stock determined to be overfished on the basis of the 1999 assessment.

Canary rockfish spawning stock biomass, as estimated in 2007, has grown steadily since the mid-1990s in response to reductions in overall harvest and above-average recruitment in the preceding decade. The best estimate is that spawning biomass has doubled since 1997; however, the magnitude of this increase is subject to considerable uncertainty. The size of the current spawning stock is estimated at roughly 32% of the unfished level. Recent year-class strength has generally been low. As the larger recruitments from the late 1980s and early 1990s move through the population in future projections, the effects of recent poor recruitment will tend to slow the rate of recovery. Canary rockfish is currently managed under a rebuilding plan. Recent recruitment and levels of depletion are presented in Figure 2.

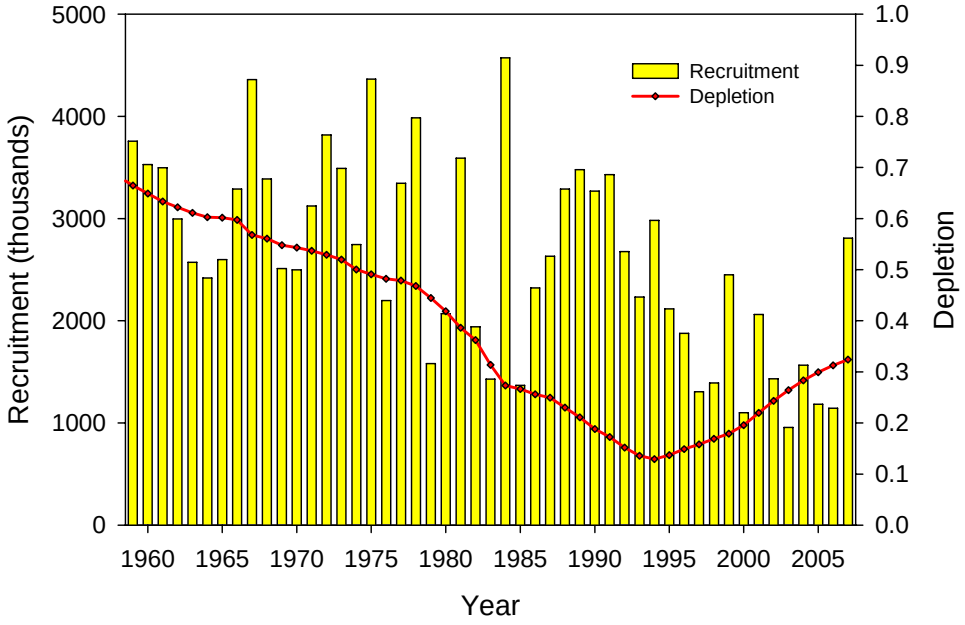

Figure 2. Level of depletion and recruitment for canary rockfish, 1966-2008.

**Canary rockfish:** The complete version of: Status of the U.S. canary rockfish resource in 2007 can be viewed online at: http://www.pcouncil.org/groundfish/gfstocks.html

For more information on the canary rockfish assessment, contact Dr. Ian Stewart at Ian.Stewart@noaa.gov

**Yelloweye rockfish:** The last full assessment of the yelloweye rockfish (*Sebastes ruberrimus*) resource off the west coast of the United States was conducted in 2006 (Wallace, et al. 2006). That assessment included both a coast-wide model, from the Mexican border to the Canadian border, and area models for Washington, Oregon, and California. The 2007 assessment represents an update of the coast-wide model, upon which management in 2007-08 was based. Catch data were updated for the period 1983-2006, with catches prior to 1983 taken from Wallace, et al. (2006). Annual total catch of yelloweye rockfish peaked around 1980, and remained above 200 mt throughout the mid-1990s. Catch declined sharply between 1997 and 2001.

The most recent assessment for yelloweye rockfish was conducted using SS2, version 1.21 in 2006 by Wallace, et al. Fishery-independent data used in that assessment included a CPUE index and size-compositions from the longline survey conducted by the International Pacific Halibut Commission. Catch data, as well as age and size compositions, were included for commercial and recreational fisheries off Washington, Oregon, and California. CPUE indices were also constructed from recreational data from each state. In the process of refreshing data for use in this updated assessment, several problems were corrected in developing the 2007 base model. Since the corrected bin values were lower than those used in the previous assessment and the Washington trawl data contained a higher proportion of old fish, these corrections led to downward revisions in the amount of spawning biomass and the level of depletion, relative to the 2006 assessment. In converting the model to SS2, the prior assessment's old SS1 "super-year" approach for dealing with small sample sizes for age and size compositions in some years was updated using the recommended SS2 method. This change had little effect on model results.

Additionally, during the 2006 STAR Panel review, a representative from the Canadian Department of Fisheries and Oceans, who was present, reported that the estimated value for yelloweye natural mortality (M) off British Columbia was 0.033. This information led the Panel to recommend lowering the value of M in the U.S. model from 0.045 (as used in 2005) to 0.036. Subsequently, it has been discovered that the actual estimated value of M for the B.C. stock is 0.043 (for females). The Chair of the STAR Panel has conveyed that if the correct value had been available during the review, it would likely have been recommended for use, rather than the 0.036 value (Owen Hamel, personal communication). Additionally, sensitivity analysis conducted across a range of M values, as part of the current assessment, indicates a substantial degradation in model fit with M=0.036, relative to values of M in the 0.043-0.046 range. As a result, current and projected biomass and depletion levels for an alternative base case (with M=0.043) are also reported in this document.

The long-term biomass trajectory in this assessment is very similar to that in the 2006 assessment. Spawning biomass declined steadily and rather rapidly, beginning in the early-1970s, with no indication of increase until roughly 2001. The amount of spawning biomass in all years is lower in the current base model than in the previous assessment, due to the correction of data/input errors previously discussed. The current spawning biomass is estimated to be 422 mt with the base model and 485 mt with the alternative model, resulting in depletion estimates of 14.5% and 16.4%, respectively. Recent recruitment and levels of depletion are presented in Figure 3.

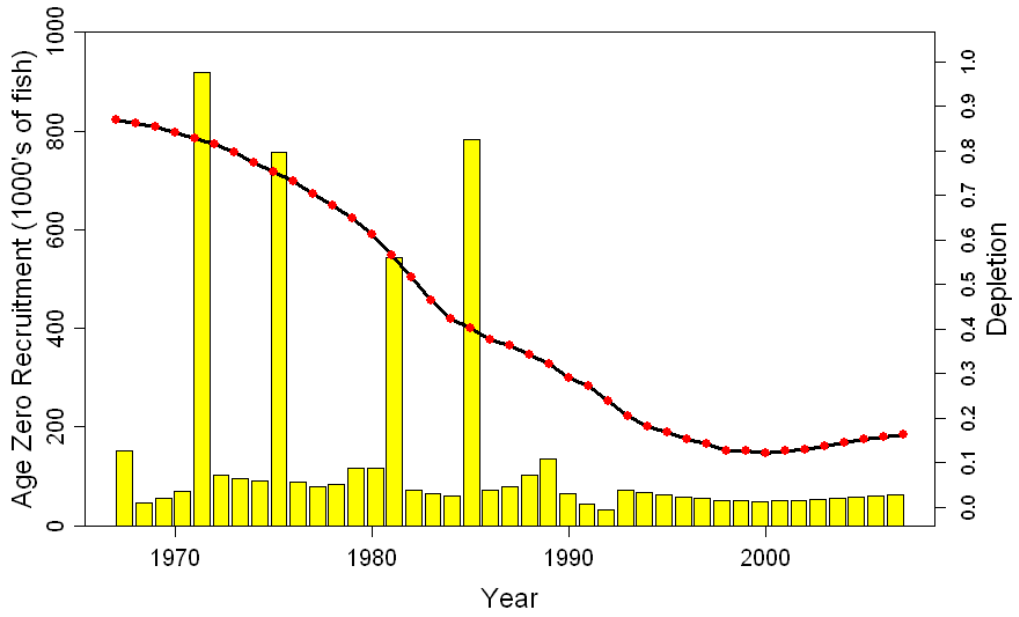


Figure 3. Level of depletion and recruitment for yelloweye rockfish, 1967-2007.

**Yelloweye rockfish:** The complete version of: Update to the status of yelloweye rockfish (*Sebastes ruberrimus*) off the U.S. West Coast in 2007 can be viewed online at: http://www.pcouncil.org/bb/2007/0607/Groundfish_Assessments_E6/Yelloweye_Update_2007_Final.pdf

For more information on the yelloweye rockfish assessment, contact John Wallace at John.Wallace@noaa.gov

**2. Slope Rockfish**

**b) Stock assessment**

Slope rockfish assessments conducted during 2007 included a full assessment of darkblotched rockfish and an update of the 2005 Pacific ocean perch assessment.

**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 mt) 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 assessment used the SS2 model, version 2.00 and data through 2006. Since 2001, overfishing occurred only once, with estimated catch exceeding the ABC by 14 mt (5.8%) 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.

Based on this assessment, darkblotched rockfish on the West Coast remain below the overfished threshold, but the spawning biomass appears to have increased steadily (and roughly doubled) over the past 6 or 7 years to 22% of the unfished level. 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 two of the four 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. 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 2%. This stock remains overfished and a rebuilding analysis was conducted. Recent recruitment and levels of depletion are presented in Figure 4.

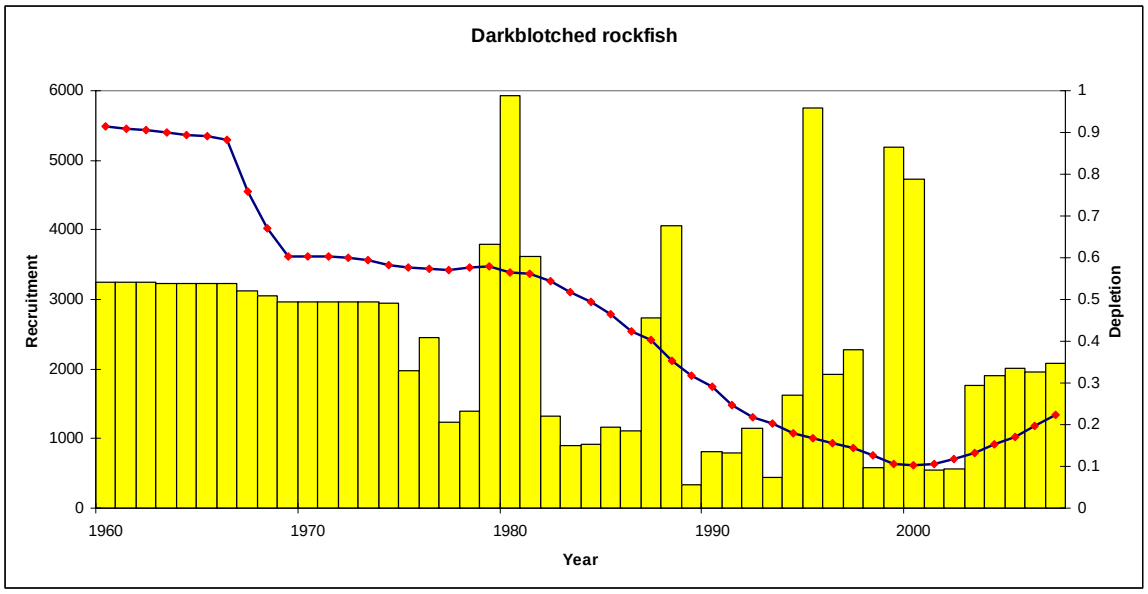


Figure 4. Level of depletion and recruitment for darkblotched rockfish, 1960-2007.

**Darkblotched rockfish:** The complete version of: Status and Future Prospects for the Darkblotched Rockfish Resource in Waters off Washington, Oregon, and California as Assessed in 2007 can be viewed online at:
http://www.pcouncil.org/groundfish/gfstocks.html

**Pacific ocean perch:** This assessment update applies to the Pacific ocean perch (*Sebastes alutus*) (POP) species of rockfish for the combined U.S. Vancouver and Columbia INPFC areas. Catches are characterized by large removals of between 5,000 and 20,000 mt during the mid-1960's, primarily by foreign vessels. The fishery proceeded with more moderate removals of between 1,100 and 2,200 mt per year from 1969 through 1994, with the foreign fishery ending in 1977. Management measures further reduced landings to below 900 metric tons by 1995, with subsequent landings falling steadily until reaching between 60 and 150 mt per year from 2002 through 2006. This assessment is an update and uses the same model as in the 2003 and 2005 assessments, a forward projection age-structured model (Hamel 2005, Hamel et al. 2003). New data and changes to the data used in the previous assessment are as follows. Catch data for 2003 and 2004 were updated, and new catch data were added for 2005 and 2006. Fishery age compositions from 1999-2004 were updated, with new 2005 and 2006 age compositions added. The 1999-2004 NWFSC slope survey biomass indices and age compositions were recalculated based upon changes in stratum area estimates and any updates in the database, with the 2005 and 2006 NWFSC slope survey biomass indices and age compositions added.

A number of sources of uncertainty are explicitly included in this assessment. For example, allowance is made for uncertainty in natural mortality, the parameters of the stock-recruitment relationship, and the survey catchability coefficients. However,

sensitivity analyses based upon alternative model structures / data set choices in the 2003 and 2005 assessments suggest that the overall uncertainty may be greater than that predicted by a single model specification. There are also other sources of uncertainty that are not included in the current model. These include the degree of connection between the stocks of Pacific ocean perch off British Columbia and those in PFMC waters; the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of Pacific ocean perch; gender differences in growth and survival; a possible nonlinear relationship between individual spawner biomass and effective spawning output and a more complicated relationship between age and maturity. A reference case was selected which adequately captures the range for those sources of uncertainty considered in the model. Bayesian posterior distributions based on the reference case were estimated for key management and rebuilding variables. These distributions best reflect the uncertainty in this analysis, and are suitable for probabilistic decision making.

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 30% of the unfished level; roughly 50% higher than the low of 20% reached in 1997. Despite the modest rate of increase over the last decade, POP is expected to reach the rebuilding target (40% of the unfished level) within the next 5 years, as the 1999 and 2000 year classes (two of the largest since the early 1960s) reach full maturity. 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 90s 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 recruitment and levels of depletion are presented in Figure 5.

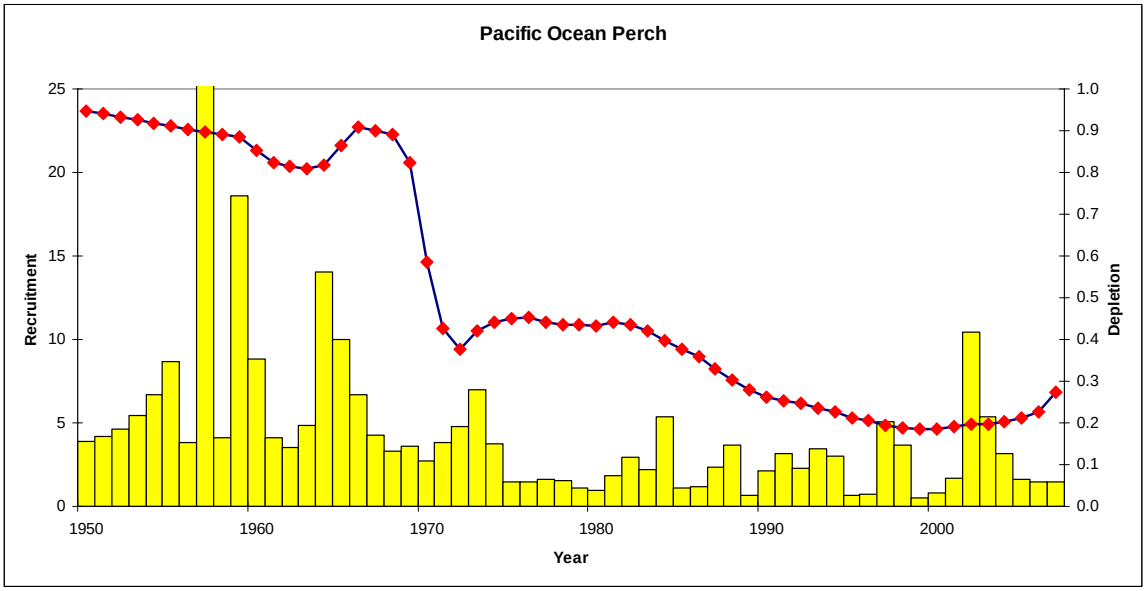


Figure 5. Level of depletion and recruitment for Pacific ocean perch, 1950-2007.

**Pacific ocean perch:** The complete version of: Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2007 can be viewed online at: http://www.pcouncil.org/groundfish/gfstocks.html

For more information on both of these assessments contact Dr. Owen Hamel at: Owen.Hamel@noaa.gov.

**3) Thornyheads**

**b) Stock Assessment**

No thornyhead assessments were conducted during 2007, and none are scheduled for 2008.

**4. Sablefish**

**b) Stock Assessment**

A full sablefish assessment was conducted in 2007.

In this assessment, the West Coast sablefish population was modeled as a single stock extending from the southern border of the Conception INPFC area through the northern border of the U.S. Vancouver INPFC area. Prior to 1967, catches varied between 1,000 and 3,600 mt. From that point, catches rose to over 24,000 mt in both 1976 and 1979. Catches have declined gradually since then to the 5,500-6,500 range in recent years. Data from several trawl surveys, along with landings, length and age data, and environmental indices were combined in a maximum likelihood statistical framework using Stock Synthesis 2 (SS2, version 2.00b, March 22, 2007). The major sources of uncertainty in this stock assessment were: (1) survey catchability ($Q$); (2) discard quantity and length composition; and 3) the mortality rate of discarded fish.

The West Coast sablefish spawning stock is estimated to be at roughly 38% of the unfished level. Improvements in the level of depletion and stock size since the 2005 assessment can be attributed primarily to the continued progression of the strong 1999 and 2000 year-classes into the population (Figure 6). However, erratic recruitment levels since 2001, combined with several poor year-classes prior to 1999, dampen expectations of stock increase over the next several years. Evidence continues to suggest that larval survival is modulated in part by annual fluctuations in the California Current System. A significant relation was observed between second quarter (April, May, and June) sea surface height in the northern coast (44-48 degrees latitude) and age-0 sablefish survivorship. A weaker, yet still significant, relationship was found between recruitment deviations and zooplankton species composition. Recent recruitment and levels of depletion are presented in Figure 6.

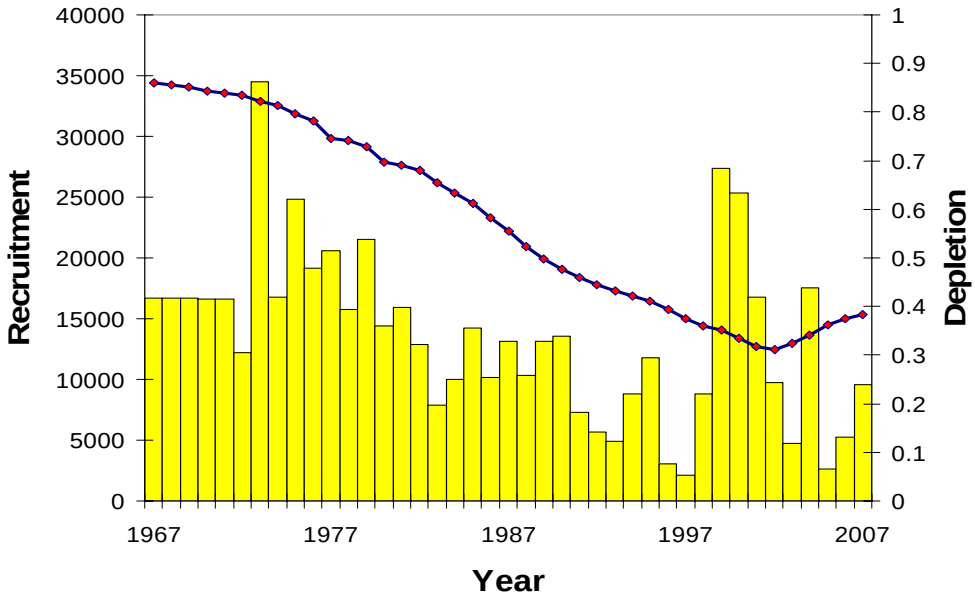


Figure 6. Level of depletion and recruitment for west coast sablefish, 1967-2007.

**Sablefish:** The complete version of: Status of the Sablefish Resource off the Continental U.S. Pacific Coasts in 2007 can be viewed online at:
http://www.pcouncil.org/groundfish/gfstocks.html

For more information, please contact Dr. Michael Schirripa at
Michael.Schirripa@noaa.gov

**5. Flatfish**

**b) Stock Assessment**

An update of the 2005 English sole assessment and a full assessment for arrowtooth flounder were conducted 2007.

**English sole:** The English sole (*Parophrys vetulus*) assessment updated the status of the resource off the coast of the United States from the Mexican border to the Canadian border. As in the 2005 assessment, data sources are treated separately for a southern (INPFC Conception and Monterey) and a northern (INPFC Eureka, Columbia and U.S. Vancouver) area, however the English sole population is modeled as a single stock. The biggest obstacle to modeling the English sole population in the southern and northern areas separately is a lack of data; specifically the length frequency of discarded fish (to reliably estimate selectivity separately for each fleet), current maturity observations and sufficient age data (mainly from the south) to allow estimation of the growth curve for each area as well as model changes in growth over time. Without these data and more spatially complex models, it is difficult to speculate on whether regional management is

appropriate for English sole, as relatively large historical catches of similar magnitude have been removed from both areas, albeit over different portions of the historical record.

The updated assessment uses historical landings reconstructed from a variety of sources for the 2005 assessment, to describe fishery removals over the period 1876 to 1980. Landings from 1981 to 2006 have been updated to reflect the best available estimates as of May, 2007. Peak landings from the southern area occurred in the 1920s with a maximum of 3,976 metric tons (mt) of English sole landed in 1929. Peak landings from the northern area occurred from the 1940s to the 1960s with a maximum of 4,008 mt landed in 1948. Landings in both areas have generally declined since the mid-1960s and have been at historical lows in recent years. Model estimates of discarding average 24% by weight over the time-series since 1940, with higher discards corresponding to periods of large recruitment and due to the associated increase in catch of smaller unmarketable English sole and modeled changes in selectivity and growth.

The most recent assessment for English sole was performed in 2005. The 2005 assessment used an early version (1.19) of the Stock Synthesis 2 modeling framework to estimate model parameters and management quantities. That assessment modeled the coast-wide English sole population (U.S. only), including both males and females. Fishery independent data included the NMFS triennial groundfish survey index of abundance (1980-2004), maturity observations, length-weight relationships as well as survey length-frequency and age-frequency data. Length and age data from commercial fishery landings are included from 1948-2004, as well as fishery discard information from three separate observer program periods, 1950-1961, 1985-1987 and 2001-2004. This document updates the 2005 assessment using the newest version of SS2 available, 2.00e (Methot 2007). The methods for summarizing the raw data and the modeling approach are maintained. The recent landings series have been updated for 1981-2006, and a large quantity of fishery length and age data (primarily from Washington) that was previously unavailable is now included. These new data provide substantially improved information regarding recent year class strengths and current stock status.

As in 2005, English sole spawning biomass was found to be increasing rapidly over the last 15 years after a period of poor recruitments from the mid-1970s to the early 1990s, which left the stock at nearly historically low levels. The spawning biomass at the beginning of 2007 was estimated to be 41,906 mt (~ 95% confidence interval: 31,046-52,766), which corresponds to 116% (83-149%) of the unexploited equilibrium level. This value reflects the accelerated maturity schedule estimated from the 1990's relative to historical conditions and therefore does not necessarily correspond to the same age structure in the population as implied by unexploited conditions. Historical depletion levels were estimated to have reached minima as low as 20% in 1953 and, more recently, 23% in 1992. Current (2006) total catches were estimated to be 1,078 mt, of which 886 mt were landed. These results are very similar to the 2005 assessment, although the recent trend shows a slightly larger increase in stock size.

Following two decades of low recruitments, strong year classes were estimated for 1995, 1998-2000, and 2002. The data indicate that the 1999 year class is the largest in the time-

series, and the magnitude of this event is now much more certain than in the 2005 assessment; the coefficient of variation (CV) of this estimate has dropped from 25% (in 2005) to 19%. This change is mainly due to the large quantity of age data now available through 2006. These large recent recruitment estimates are larger than those from the 2005 assessment, resulting in the estimate of relatively higher current stock size. The recruitment deviations for 2004 and later years are informed primarily by the stock recruitment function and this is reflected in the increased relative uncertainty of these estimates.

The estimated spawning potential ratio (SPR) for English sole fluctuated above and below the proxy target of 40% for flatfish from the late 1940s to the early 1990s. Since 1992 the intensity of exploitation has been less than that of the target, resulting in higher SPR levels. This corresponds to a relative exploitation rate (catch/biomass of age 3 and older fish) history that is high from the late 1940s to the early 1990s, and steadily declining to very low levels over the last 15 years. The stock appears to have never been exploited at the rate (0.27) that would reduce the stock to SPR levels estimated to produce *MSY*, 0.259, during the time-series. The fishery has exceeded the relative exploitation rate that results in fishing at the SPR target of 40% of 0.17 in only a few years of the historical series. Recent English sole landings and estimated discards have been below both the coast-wide ABC of 3,100 mt and the estimated *MSY* harvest level of 4,080 mt. Recent recruitment and levels of depletion are presented in Figure 7.

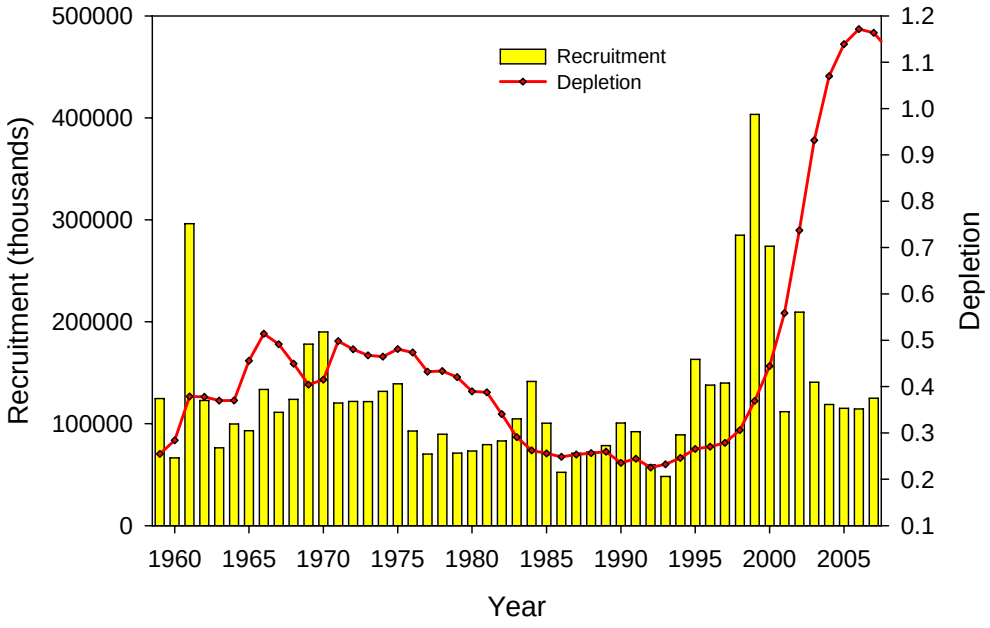


Figure 7. Level of depletion and recruitment for English sole, 1959-2007.

**English sole:** The complete version of: Updated U.S. English sole stock assessment: Status of the Resource in 2007 can be viewed online at:
http://www.pcouncil.org/groundfish/gfstocks.html

For more information on the English sole assessment, please contact Dr. Ian Stewart at Ian.Stewart@noaa.gov.

**Arrowtooth flounder:** This assessment reports the status of arrowtooth flounder (*Atheresthes stomias*) off the U.S. West Coast. Arrowtooth flounder are primarily found off Washington, Oregon, northern California, and north of the U.S.-Canada border. We assume a single mixed stock, using a model with one area. Arrowtooth are commonly caught by trawl fleets off Washington and Oregon, but they are frequently discarded due to low flesh quality. This is the first assessment of arrowtooth flounder off the U.S. West Coast since 1993, and the first to use a modern age-structured estimation framework (Stock Synthesis 2). We modeled both males and females, allowing for different growth between the sexes. We included catch data from 1928-2006. We obtained and incorporated ages (from otolith readings) for a subset of fish from the NWFSC Shelf-Slope Survey and commercial landings from 1986-1991, 1998, and 2003-2005. The model shows a period of moderate depletion through the 1950s and 1960s, followed by a rebuilding of the stock beginning in the late 1970's. Recent strong year classes, in particular the 1999 year class, have led to an increase in the stock since the late 1990s. We estimated unexploited equilibrium spawning biomass to be 80,313 mt (95% CI: 68,228-92,398). We estimate that the stock has never fallen below the overfished threshold. Since this stock is not overfished we have not reported any rebuilding parameters. Recent recruitment and levels of depletion are presented in Figure 8.

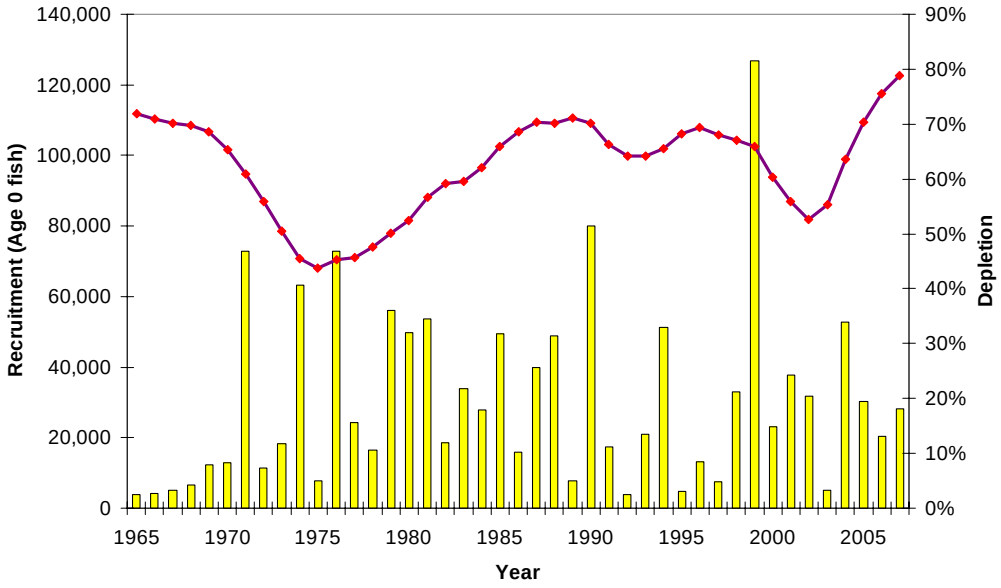


Figure 8. Level of depletion and recruitment for arrowtooth flounder, 1965-2007.

**Arrowtooth flounder:** The complete version of: Stock Assessment of the Arrowtooth flounder (*Atheresthes stomias*) Population off the West Coast of the United States in 2007 can be viewed online at: http://www.pcouncil.org/groundfish/gfstocks.html.

For more information on the arrowtooth flounder assessment, please contact Isaac Kaplan at Isaac.Kaplan@noaa.gov.

**6. Pacific Hake**

**b) Stock Assessment**

The status of Pacific hake was assessed in early 2007 and 2008. In both years, the assessments and reviews were conducted with representation from the U.S. and Canada. The coastal stock of Pacific hake is currently the most abundant groundfish population in the California Current system. Smaller populations of hake occur in the major inlets of the north Pacific Ocean, including the Strait of Georgia, Puget Sound, and the Gulf of California. However, the coastal stock is distinguished from the inshore populations by larger body size, seasonal migratory behavior, and a pattern of low median recruitment punctuated by extremely large year classes. The population is modeled as a single stock throughout U.S. and Canadian coastal waters, however fishing fleets from each country are treated separately in order to capture some of the spatial variability in Pacific hake distribution.

Coastwide fishery landings from 1966 to 2007 have averaged 219,000 mt, with a low of 90,000 mt in 1980 and a peak harvest of 364,000 mt in 2006. Catches in 2006 and 2007 (276,000 mt) were above the long term average. Catches in both of these years were predominately comprised by fish from the large 1999 year class. The United States has averaged 163,000 mt, or 74.6% of the total landings over the time series, with Canadian catch averaging 56,000 mt. The 2006 and 2007 landings had similar distributions, with 74% and 72%, respectively, harvested by the United States fishery. The current model assumes no discarding mortality of Pacific hake.

The acoustic survey catchability coefficient ($q$) has been, and continues to be, one of the major sources of uncertainty in the model. From 2003 to 2007, assessments have presented two models (which have been assumed to be equally likely) in an attempt to bracket the range of uncertainty in the acoustic survey $q$. In the 2008 assessment, also conducted in SS2 (version 2.00n), an effort was made to include the uncertainty in $q$, as well as additional uncertainty regarding the acoustic survey selectivity and the natural mortality rate of older fish within a single model. As a result, a broader range of uncertainty is presented via probability distributions and risk profiles using Markov Chain Monte Carlo simulation. Further refinements include, for the first time, incorporation of an age-reading error matrix.

Pacific hake spawning biomass declined rapidly after 1984 (6,450,000 mt) to the lowest point in the time series in 2000 (880,000 mt). This long period of decline was followed by a brief increase to 1,890,000 mt in 2003 as the 1999 year class matured. In 2008

(beginning of year), spawning biomass is estimated to be 1.10 million mt and approximately 42.9% of the unfished spawning biomass ($SB_{zero}$). Estimates of uncertainty in relative depletion range from 21.9%-53.9% of unfished biomass, based on asymptotic confidence intervals. It should be pointed out that the 2008 estimates of spawning biomass are lower and depletion level higher compared to last year's assessment result for 2007. The reason is that survey *q* was freely estimated and the assessment incorporated an age-reading error matrix that lowered estimates of $SB_{zero}$ (through a reduction in mean log recruitment) and increased the size of the 1999 year class. As such, spawning biomass for the most recent years, while generally lower than predicted in the 2007 assessment, is greater relative to the estimate of $SB_{zero}$. Recent spawning biomass levels and depletion relative to $B_{zero}$ are presented in Figure 9.

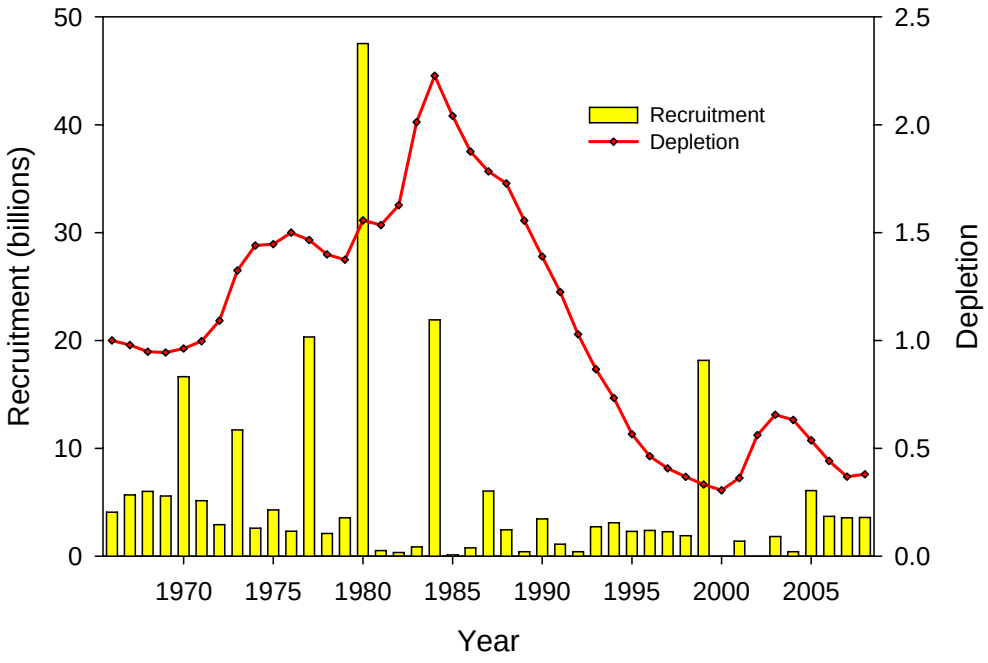


Figure 9. Level of depletion and recruitment for Pacific hake, 1966-2008.

The 2007 assessment for Pacific hake is available online at: ftp://ftp.pcouncil.org/pub/Hake07. The 2008 assessment is available online at: http://www.pcouncil.org/groundfish/gfstocks.html.

For more information, please contact Dr. Thomas Helser at Thomas.Helser@noaa.gov

**7. Other species**

**b) Stock Assessment**

An assessment of longnose skate was conducted during 2007.

**Longnose skate:** Longnose skates (*Raja rhina*) are found from Navarin Canyon in the Bering Sea and Unalaska Island in Alaska to Cedros Island, Baja California in Mexico. This assessment is for the population occupying the waters off California, Oregon and Washington, bounded by Canada in the north and Mexico in the south. Within this study area, the longnose skate population is treated as one fishery stock, due to the lack of biological and genetic data supporting the presence of multiple stocks.

The longnose skate is not a commercially important target species. It is caught primarily as bycatch in trawl fisheries, where most are discarded. Although the landed catch of skates is documented through fish tickets, most records are for a combined-skate category. There are also apparent reporting inconsistencies with regard to the condition of landed skates (e.g., as whole fish or as wings). The extent to which landings in the combined-skate category were comprised by longnose skate is informed by limited periods of species-composition sampling in Oregon and Washington. Historical landed catch was reconstructed from a variety of sources. Over the last 57 years, longnose skate landings ranged between 35 and 1,721 mt. Landings peaked in the mid-1990s, due to increased demand from Asian markets. Discard rates were estimated at 93% prior to 1995 and 53% after 1995, which corresponds to changes in skate markets in the mid- 1990s. This is the first assessment for longnose skate on the U.S. West Coast. The Stock Synthesis 2 (version 2.00e) modeling program was used to conduct the analysis and to estimate model parameters and management quantities. Since there are no apparent differences in biological and life history parameters as well as length and age frequencies between females and males, the assessment uses a single-sex model. The model starts in 1916, assuming an unfished equilibrium state of the stock in 1915. The assessment model includes one fishery that operates within the entire area of assessment. Fishery dependent data used in the assessment include combined-skate landings (1950-2006), fishery length compositions (1995-2006) and limited age data (2003-2004). Fishery independent data include biomass estimates (1980-2006) and length compositions (1997-2006) from four NMFS surveys conducted on the continental shelf and slope, as well as age data from one of the surveys (2003). The model uses discard data from Rogers and Pikitch's study (1986-1987), the Enhanced Data Collection Project (1996-1998), and the NMFS West Coast Groundfish Observer Program (2004-2005).

This assessment uses a single-sex model; therefore, spawning biomass is the sum of the mature biomasses of both sexes. Using the base model, the unexploited level of spawning stock biomass for longnose skate is estimated to be 14,069 mt. At the beginning of 2007, the spawning stock biomass is estimated to be 9,268 mt, which represents 66% of the unfished stock level. The assessment shows that the stock of the longnose skate in the U.S. West Coast is not overfished. Currently, the stock is at 66% of its unfished level. Historically, the exploitation rate for the longnose skate has been low. It reached its maximum level of 4.02% in 1981. Currently, it is at the level of 1.25%.

**Longnose skate:** The Status of the Longnose Skate (*Raja rhina*) off the continental U.S. Pacific Coast in 2007 can be viewed online at:
http://www.pcouncil.org/bb/2007/0607/Groundfish_Assessments_E6/LongnoseSkate_AssessmentReport.pdf

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

**D. Other Related Studies**

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

The PaCOOS Marine Habitat Data Portal was 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 in 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 COAS 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. Currently, this portal houses geological and geophysical data including 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://nwioos.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.

For more information, contact Elizabeth.Clarke@noaa.gov (206-860-3381) or Chris Goldfinger at gold@coas.oregonstate.edu (541-737-5214)

**2. West Coast bycatch reduction research: fish behavior during interactions with bottom trawls**

Since 2004, the NWFSC has collaborated with the Oregon Department of Fish and Wildlife (ODFW) on a bycatch reduction research project to obtain baseline information on the behavior of demersal fishes when overtaken by a bottom trawl. *In situ* information of this nature is critical to the future development of species-selective trawls and bycatch reduction devices for West Coast groundfish fisheries. In this project, a conventional low-light video was used in conjunction with a DIDSON ultrasonic imaging sonar (Dual-frequency IDentification SONar) to document and categorize fish behavior in response to interaction with a selective flatfish bottom trawl (Figure 10). A complementary project seeks to build a catalog of enzyme activities as an indicator of species-specific, burst-swimming abilities for many groundfish species.

The summer of 2007 marked the third field season for this research project. This project represents the first successful application of a DIDSON sonar in bottom-tending mobile fishing gear, which produced dual observations of fish-trawl interaction vis-à-vis video and DIDSON imaging. A novel set of mounting frames provided a stable platform for

sonically imaging all areas in front and in the mouth of the trawl (e.g., footrope, headrope, wings, and footropes mud cloud form). DIDSON imaging of Pacific halibut, lingcod, Pacific hake, skates, and flatfish will help assess methods to reduce bycatch. Information was gathered on trawl performance, in the form of observational data on the speed and direction of fish movement, herding behavior, wing interactions, and footrope and headrope effects.

The 2007 field season focused on deploying the DIDSON sonar system to obtain information on diel differences in response to contact with the trawl foot rope in the absence of artificial light. The use of lights may confound observations of fish behavior in the proximity of fishing gear, submersibles, or ROVs. DIDSON imaging sonar uses only ultrasound to form images of fish, as well as the gear, surrounding structures and the seafloor. We used DIDSON to examine diel behavior differences in roundfish along a 12-meter section of the footrope on a starboard wing of a selective flatfish trawl. The DIDSON was mounted looking forward along the starboard wing of the net, giving a view of the footrope and the seafloor ahead of it. We used a lightmeter on the net to measure light levels at the trawl mouth. As the DIDSON image does not allow species identification where the seafloor is also in view, all fish captured in the trawl were counted and weighed: roundfish and halibut were measured for length. We tracked the movements of individual fish, continuously measuring the distance from the footrope. Analysis of fish tracks revealed that during the day, roundfish remained farther from the footrope, maintained a relatively constant distance, and showed less variation in direction. At night, fish approached the footrope at a sharper angle and displayed a more abrupt change in direction and velocity. These behavioral differences suggest that herding efficiency and gear selectivity is different in darkness. They emphasize the importance of monitoring environmental factors during surveys where constant selectivity is applied. Data from both the 2006 and 2007 field seasons are currently being analyzed. Preliminary results were presented at the 2007 American Fisheries Society Annual Meeting symposium entitled: "Developing Tools for Ecosystem-Based Fishery Management: Incentive Programs, Bycatch Quantification, and Gear Technology" and the 2008 Western Groundfish Conference.

Figure 10. DIDSON ultrasonic imaging sonar system.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov, (541) 867-0542 or Bob Hannah at Bob.W.Hannah@state.or.us, (541) 867-0300 or Keith Matteson at keith.m.matteson@state.or.us (541) 867-0300.

**3. Cooperative Ageing Unit**

The Cooperative Ageing Project (CAP) provides direct support for U.S. West Coast groundfish stock assessments by providing ages derived primarily from otoliths. In 2007, CAP aged the following species: canary rockfish, Pacific ocean perch, darkblotched rockfish, Pacific hake, sablefish, arrowtooth flounder, and English sole.

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

**4. Cooperative Resource Surveys**

**a) West Coast Slope and Shelf Groundfish Survey**

The NWFSC conducted its tenth annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2007 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 the third week of October. Each vessel was chartered for eight weeks with the *Ms Julie* and *Noah's Ark* surveying the coast during the initial pass from May to July. The *Excalibur,* and *Raven* operating in tandem, surveyed the coast during the 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 2007, 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) Establishing a DNA sequence database for the marine fish fauna of California- Scripps Institution of Oceanography; 3) Life history of the white-spotted ratfish, *Hydrolagus colliei* - Moss Landing Marine Laboratories; 4) Feeding ecology of the roughtail skate, *Bathyraja trachura*.; 5) Collection of all unusual or unidentifiable skates, sharks, or chimaeras - Moss Landing Marine Laboratories; 6) Collection of biological data and specimens of the deepsea skates, *Bathyraja abyssicola*, and broad skates, *Amblyraja badia* - Moss Landing Marine Laboratories; 7) Collection of *Raja stellulata* - Moss Landing Marine Laboratories.

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) collection of samples from spiny dogfish to aid stock assessment and demographic analysis; 3) fin clip collection for various shelf rockfish species; 4) collection of stomachs for selected species including: Pacific hake, bocaccio and chilipepper; 5) identification and density-estimation of seabirds along the U.S. West Coast; 6) collection and identification of cold water corals; 7) Food habits studies of jumbo squid, *Dosidicus gigas*, in the California Current; 8) Comparison of skate total length with disc width for California skate *Raja inornata*, starry skate *Raja stellulata*. longnose skate *Raja rhina*, and big skate *Raja binoculata*; and 9) a preliminary determination of sexual parasitism of crabs (carcinophily) in the northeast Pacific Ocean.

The Northwest Fisheries Science Center's Fishery Resource Analysis and Monitoring Division (FRAMD) also investigated the composition and abundance of benthic marine debris collected during the 2007 West Coast Groundfish Trawl Survey from May 14 to October 23, 2007. Marine debris was recorded in 198 tows; 86 tows during pass 1 and 112 tows during pass 2. Total debris recorded from all tows weighed 3,574 kg (range 0.01–2,200 kg $tow^{-1}$). The largest item taken during the survey was a fishing net (2,200 kg) retrieved by the F/V *Ms. Julie* off CA. Debris was subdivided into 6 categories (plastic, metal, clothing, glass, toxic and other). Plastic and metal debris were encountered most frequently with 502 kg of plastic taken in 108 tows and 406 kg of metal taken in 94 tows. Clothing (134 kg) was present in 54 tows while glass debris (47 kg) was present in 56 tows. Preliminary results indicate that marine benthic debris is more frequently encountered in the southern portion of the survey, occurring in 65% of the southernmost tows versus 25% overall.

For more information, contact Aimee Keller at (206) 795-5860, Aimee.Keller@noaa.gov.

**b) Research Related to Improving Bottom Trawl Surveys**

**1) Methods for standardizing the U.S. West Coast Groundfish Trawl Survey**

The Northwest Fisheries Science Center presented information on the gear and methods used to standardize the annual West Coast Groundfish Trawl Survey at the 16th annual PICES (North Pacific Marine Science Organization) meeting in October 2007. PICES is an intergovernmental scientific organization, established in 1992 to promote and coordinate marine research in the northern North Pacific and adjacent seas. Its present members are Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States of America. The 16th annual meeting focused on the changing North Pacific: previous patterns, future projections, and ecosystem impacts with a workshop devoted to trawl standardization. Standardization of both gear and methods for bottom trawl surveys is essential to correctly interpret catch per unit effort as a measure of relative abundance. In the United States, standardization problems stemming from inaccurate measurement of the towing warps on a NOAA survey vessel resulted in a thorough review of standardization methodology and the development of the National Bottom Trawl Survey Protocols governing the operation of all NOAA-sponsored surveys. The PICES workshop attended by FRAM reviewed the various pelagic and bottom trawl surveys conducted by PICES member countries, with a focus on the operational protocols used to ensure that survey catchability remains constant over time. The history, design, and trawl standardization protocols for the West Coast Groundfish Trawl Survey were described at the meeting. Operation protocols include: net diagrams, construction, repair methodology and certification procedures; warp standardization and measurement; tow duration, distance-fished and speed over ground; and use of trawl mensuration instrumentation. On each haul wingspread, headrope height, trawl depth, temperature and bottom contact are measured using trawl-mounted sensors. Trawl operations are mediated and reviewed by field staff via a series of custom software applications. The applications display real-time sensor data and include trawl annotations and environmental conditions.

Additional applications provide graphical displays of all sensor time series for evaluation and review; require entry of a tow quality judgment at the conclusion of each trawl operation and allow at sea data checking and verification. Software applications promote data quality by guiding field staff workflow, minimizing data entry errors and providing for as much immediacy in operation evaluation and corrective action as possible during and following trawling. Variation in net mensuration data for acceptable tows was also described and discussed.

For more information, contact Aimee Keller at (206) 795-5860, Aimee.Keller@noaa.gov.

**2) When Do Adverse Conditions Dictate a Weather Day?**

As weather conditions deteriorate, the effectiveness of trawl survey gear may be reduced well before safety considerations force the cessation of sampling activity. Through comparison of 1,754 hauls completed as part of the West Coast Groundfish Trawl Survey between 2003 and 2005 on the shelf and slope using chartered fishing vessels, we show a significant reduction in catch rates of bottom dwelling fish and invertebrates as a function of visually-estimated wave height. Comparing randomly located trawl sets that occurred fortuitously close to one another, we conclude that to reduce the estimated impact of elevated wave height on catch of benthic species (and potentially relative biomass estimates) survey trawl activities on these vessels should be halted when wave heights reach six feet. Only 41 hauls from the 2003-2005 data were conducted when wave heights exceeded six feet, however their exclusion reduces the maximum expected bias in any single tow due to wave height by ~31%. Selecting a lower maximum wave height for routine sampling may begin to exclude geographic areas of the survey (i.e. those characterized by elevated winds) and introduce new bias to the randomized sampling design.

For more information, contact Aimee Keller at (206) 795-5860, Aimee.Keller@noaa.gov.

**c) Development of Survey Techniques for Use in Untrawlable Habitats**

The Northwest Fisheries Science Center (NWFSC), in collaboration with researchers at Woods Hole Oceanographic Institution (WHOI), is developing the SeaBED AUV to overcome the difficulty of monitoring fish populations in rocky areas. Rocky, untrawlable areas are not well surveyed by traditional trawl gear, yet these areas are important habitat for a variety of commercially important fish stocks including rockfish.

Traditional fish monitoring techniques, such as trawl surveys and ship borne acoustics, are of limited applicability in these areas due to the rugged nature of the terrain. Thus, to enhance our ability to adequately assess fishery species that use these habitats alternate technologies must be identified and evaluated for augmenting current fishery-independent assessment techniques. Hover-capable AUVs offer a unique tool that is appropriate for work in these types of habitat. In addition, AUVs allow other simultaneous shipboard data collections that will greatly enhance the data available for integrated ecosystem assessments.

The Seabed AUV (Figure 11) is a multi-hull, hover capable vehicle, which unlike traditional torpedo shaped AUVs, is capable of working extremely close to the seafloor while maintaining very precise altitude (3 $\pm$ 0.05 m) and navigation control. Its small footprint coupled with its 2000 m working depth makes it an ideal platform for conducting surveys off the continental shelf on ships ranging from standard NOAA oceanographic vessels to smaller fishing vessels of opportunity.

Figure 11. The Seabed - a hover capable AUV developed by Hanu Singh at WHOI

The suite of sensors onboard the AUV include a 12 bit 1.2 Megapixel high dynamic range camera and associated strobe, a 230 kHz Delta-T multibeam imaging system, a 1.2 MHz RDI Acoustic Doppler Current Profiler, fluorometers and a pumped CTD. Typical mission durations for the current vehicle allow it to run with its suite of sensors for 6-8 hours covering distances of up to 10-15 km on a single dive.

The sensors, the AUV, and its associated systems are all vertically integrated. Thus the imagery can be easily color corrected, merged with the navigation and attitude data, photo-mosaiked and then analyzed for species counts, sizes and distributions with easy to use, web accessible GUIs. Example mosaics of photos taken using the downward-looking camera during the 2006 cruise are shown in Figure 12.

Enhancements of the Seabed AUV are being developed to improve our ability to identify rockfish. These will include addition of higher resolution forward-looking as well as downward-looking camera configurations. In Spring 2007 in collaboration with DFO Canada mapping of rockfish and their habitat off Vancouver Island, B. C. was conducted off CCGS Vector using both the DFO Canada ROV and the Seabed AUV. A comparison of the results is underway.

For more information, contact Dr. Elizabeth Clarke at Elizabeth.Clarke@noaa.gov

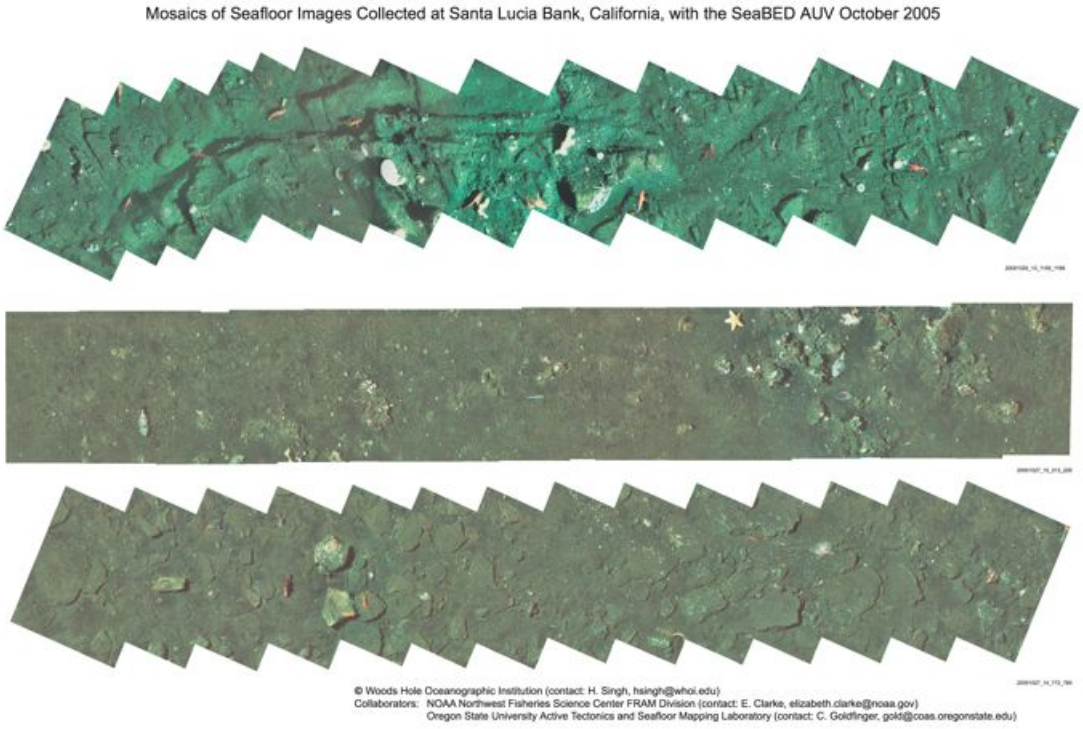


Figure 12. Photomosaics of some of the images collected with the AUV in a rocky untrawlable habitat.

**d) Southern California hook-and-line survey**

In early Fall 2007, FRAM personnel conducted the fourth 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) aimed at developing an annual time series of catch rate data and other biological information for structure-associated species of rockfish (genus *Sebastes*) such as bocaccio (*S. paucispinis*) and vermilion rockfish (*S. miniatus*) within the SCB.

The F/V *Aggressor* (Newport Beach, CA) and F/V *Mirage* (Port Hueneme, CA) were each chartered for 11 days, with nine biologists participating throughout the course of the survey. The two vessels sampled a total of 101 sites ranging from Point Arguello in the north to 60 Mile Bank in the south. Approximately 2,500 lengths, weights, fin clips, and otolith pairs were taken representing 35 different species of fish.

Several ancillary projects were also conducted during the course of the survey. This includes the deployment of non-lethal genetic tagging hooks. designed by FRAM personnel. These hooks remove a small piece of tissue from a fish's mouth during a strike without bringing the animal to the surface, limiting mortality associated with barotrauma stress. Genetic microsatellite analysis uniquely "tags" each fish which can

then be "recaptured" during subsequent deployments of the tagging hooks. In 2007, 382 of these hooks were used during the course of the survey. An underwater video system was deployed at four sites to gather imagery of the seafloor for future analyses correlating catch rates of key species with specific habitat types. Other projects included the testing and networking of a data-logging anemometer and the preservation of several rockfish and flatfish specimens for a genetic voucher program conducted by the University of Washington and for species identification training for the West Coast Observer Program.

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

**e) Joint U.S.-Canada acoustic survey**

The joint U.S./Canada integrated acoustic and trawl survey was conducted from 20 June to 24 August 2007 to estimate 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 approximately 35º N to 55º N with acoustic transects spaced 10-20 nm apart. With the unexpected sidelining of the CCGS W.E. *Ricker*, the NOAA ship *Miller Freeman* completed the entire survey by combining survey time with inter-vessel (NOAA ship *Oscar Dyson*) calibration time. The survey resulted in 132 transects with over 12,000 miles of fishing and other operations. Pacific hake were observed from approximately 36.5º N (Pt. Sur) to 55º N (Dixon Entrance), the northern extent of the survey. Data were collected on 18-, 38-, 70-, 120-, and 200-kHz EK60 echo sounder. Midwater and bottom trawls were conducted to verify size distribution and species composition and to obtain biological information (i.e. age composition, sex). A total of 92 successful trawls resulted in a total catch of 47,571.3 kg (90.3% hake by weight). Additionally 277 CTD casts were completed. The estimated total biomass of Pacific hake was 0.88 million metric tons. The stock was dominated by hake in the 45-50 cm length range. Additionally, there was a strong showing of one and two year old hake, which appeared further north relative to previous years.

Also on the joint U.S./Canadian survey, the NWFSC Digital Video Plankton Recorder (DVPR) was used 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. The DVPR is shown in Figure 13.

Figure 13. NWFSC Digital Video Plankton Recorder

For more information, contact Dr. Dezhang Chu at Dezhang.Chu@noaa.gov

**f) Joint PWCC-NMFS hake pre-recruit survey**

A joint Pacific Whiting Conservation Cooperative and FRAMD pre-recruit survey was conducted in 2007 to determine the spatial distribution and abundance of young-of-year (YOY) Pacific hake along the U.S. West Coast. The survey occurred in May-June 2007 and covered the area from 34º 30' N to 48º N at 30 nm intervals. 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. 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. YOY Pacific hake numbers were found to be low, suggesting a relatively weaker year class than in recent years. Additionally, spawning appears to have returned to a more southerly distribution.

For more information, contact Dr. Dezhang Chu at Dezhang.Chu@noaa.gov

**g) 2008 Inter-vessel calibration (IVC) cruise**

We are planning to conduct an Inter-Vessel Calibration cruise in August 2008. There will be three research vessels participating in the cruise including the NOAA ship FSV *Miller Freeman* and *Oscar Dyson*, as well as the Canadian ship CCGS. *W. E. Ricker*. The purpose of the IVC cruise is to quantitatively compare the difference among the ships in terms of their acoustic estimates of Pacific hake (*Merluccius productus*) biomass, or more precisely, acoustic indices. This is a crucial step towards a smooth transition from conducting hake surveys on the old generation of fisheries research vessels such as *Miller Freeman* to a new generation of fisheries research vessels such as *Oscar Dyson*.

For more information, contact Dr. Dezhang Chu at Dezhang.Chu@noaa.gov

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

**Project Title:** Improving Stock Assessments by Explicitly Including Environmental Indicators and other FATE Products

**Investigators:** Michael J. Schirripa, Richard M. Methot, C. Phillip Goodyear

The goal of this investigation is to construct an environment of computer programs that will: (1) enable the user to create a virtual fish population whose reproductive success is explicitly driven by a predetermined annual environmental and/or oceanographic event; (2) efficiently output a sample of data from this virtual population and create a file suitable for input into the stock assessment software program SS2; (3) evaluate the efficacy of the methods employed via the SS2 program to successfully capture and characterize the known environmental effect that emerges via the resulting observed and estimated population dynamics.

The FSIM program suite is a flexible software tool for simulating the response of fish populations to exploitation under many combinations of exploitation patterns and biological features of the species. It provides a convenient method to simulate many forms of fisheries data routinely collected from real fisheries. Analyses of these "known" simulated datasets facilitate studies of the robustness of alternative assessment methodologies. The model is also useful for exploring the implications of uncertainty about the dynamics of fish populations, forecasting consequences of management alternatives, and predicting future trends in population sizes and catches for a wide assortment of possible biological attributes under different management alternatives.
Annual stochastic variability can be added to the recruitment time series by specifying a value for the coefficient of variation of recruitment greater than zero. This is accomplished by multiplying the predicted (mean) recruitment from the stock-recruitment relationship by exp(R*CV – 0.5*CV 2), where R is a random normal deviate with mean of zero and a variance of 1.0; and CV is the coefficient of variation of the log of the random multiplier and is read from an input file. Longer term temporal trends may

be incorporated in the simulations by reading a time series of deviations from mean survival. These are incorporated in the simulation by multiplying the predicted (mean) recruitment from the stock-recruitment relationship by exp(D), where D is an empirically derived, or assumed deviation from the expected recruitment in log units (i.e. D = log(O/E) where O ="observed" recruitment, and E = expected recruitment). The program assumes the cyclic pattern persists throughout the simulation, and accomplishes this by concatenating the pattern for the period of the simulation. The beginning point of the cycle may be randomized. The annual stochastic and longer term cyclic survival patterns may be combined during a simulation by specifying non-zero values for both options.

The simulation tool set produced from this work was used to carry out investigations in conjunction with the Groundfish Harvest Policy Workshop held December 18-21, 2006 in La Jolla, California. A presentation was given entitled, "The potential effects of including/excluding environmental factors into stock assessments". A simulation-estimation framework was developed specifically for sablefish using FSIM, a population and fishery simulator. The estimation model was the SS2 model from the sablefish assessment. Environmental forcing on recruitment was modeled using an actual time series of sea surface height data to drive recruitment variability around the mean stock-recruitment relationship. A random component was also included to model residual variability not associated with sea surface height. A number of scenarios were considered, including those with and without environmental forcing on recruitment, and assessment models that attempted to estimate the environmental forcing and those that did not. All results are for scenarios in which the data used in the assessment are nearly perfect, i.e., there is minimal sampling error. To develop recommendations based on this work, the analyses need to be repeated for more realistic data-moderate and/or data-poor situations.

An alternative approach of using environmental data as a survey-like data input was discussed briefly at the workshop. We are currently comparing the two different approaches on parameter estimates and overall perception of stock status.

For more information, contact Dr. Michael Schirripa at Michael.Schirripa@noaa.gov

**6. Ecosystem Studies**

**a) Impact of fishing on marine community structure.**

Using food web models, we are examining a range of marine communities, varying in species richness, productivity, and fishing intensity, to determine how fishing has affected community structure and some basic ecosystem parameters. Our initial work suggests that incompatibilities exist between managing for sustainable fisheries and managing for the health of coast ecosystems—two of NMFS' mission goals. We are developing indices of "ecologically sustainable yield" based, not on single-species fish population dynamics, but on systemic dynamics and NMFS ecosystem goals.

For more information Dr. Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov

**b) Groundfish bioenergetics.**

Bioenergetics models provide an excellent tool to estimate the energetic demands of fishes and, thereby, better understand the amount of prey required by fish populations. Bioenergetics models are also useful for explaining fish growth trajectories as they relate to prey quality, temperature, fish size, and species- and sex-specific differences. We developed bioenergetics models for *Sebastes* species to examine various issues such as per capita prey demand of different species, the influence of temperature anomalies (e.g., PDO shifts, El Niño) on fish growth and reproductive potential, and habitat-specific prey allocation across different life history stages of rockfish (i.e., Do adult and juvenile rockfish share common habitats and common prey, and if so, do the predatory demands of one age group constrain the success of the other?).

For more information, Dr. Chris Harvey at (206) 860-3228, Chris.Harvey@noaa.gov.

**c) Fish movement and MPA design**.

Rational design of networks of MPAs requires an understanding of the relationship between the spatial extent of a reserve, home ranges of fish, and the distribution of resources. As a result, understanding movement patterns of fishes is of central importance to measuring MPA effectiveness. There are two potentially conflicting objectives of MPAs: (1) to conserve a breeding stock adult, movement out of MPAs should be minimal, but (2) to augment local fisheries, some flux outside the MPAs to harvested areas is desirable. However, very little is known about the short-term movement of most economically and ecologically important temperate fish species. Here, we propose: (1) to determine the degree to which habitat structure and food resources affect movement by rockfishes; and (2) to apply these data to models that can ascertain effectiveness of existing MPAs and develop guidelines for designing future MPAs. Our approach involves first documenting the movement of rockfishes on rocky reefs using sonic telemetry. We will then use the information gathered during the empirical phase of our project to model MPA effectiveness as a function of fish motility and habitat-structure food availability.

For more information, contact Dr. Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov

**d) Development of a spatially explicit ecosystem model to examine effects of fisheries management alternatives in the Northern California Current**

Decision analysis is intimately associated with the analysis of uncertainty: Given uncertainty about future behavior of a system, what policies are most robust over the full suite of alternative future conditions? Classic fisheries science, which relies on single-species population models, has been criticized by some as inadequate for fisheries decision analysis because it considers one possible effect of fisheries policy (i.e., fishing affects abundance and age structure which, in turn, affects yield). In contrast, ecosystem-based management recognizes a broader suite of system responses, and it explicitly recognizes that fish stocks respond to underlying yet unpredictable ecosystem dynamics (e.g., irreducible uncertainties) and that fishing itself can induce ecosystem changes.

Thus, decision analysis frameworks ideally explore responses of populations to fishing under alternative scenarios of ecosystem forcing and fishing-mediated ecosystem change.

Do we presently have the tools to predict all elements of marine ecosystems? Absolutely not, and it is unlikely that such a case will ever arise. Do we presently have the tools to identify potential ecosystem responses and behaviors? Fortunately, we have considerable and expanding expertise. Our knowledge of food web processes in marine ecosystems continues to grow, building a strong conceptual framework of the types of food web relationships that are common, rare, and, most importantly, dangerous in the context of fisheries management. What is presently lacking, however, is an integrated modeling framework that can be used to 1) synthesize this information; 2) analyze possible ecosystem responses; and 3) identify key processes that govern ecosystem condition.

We are developing such a modeling framework for the Northern California Current Ecosystem (NCCE). Our approach explicitly estimates the ecosystem and population-level consequences of various fisheries management alternatives in the face of a varying environment. ATLANTIS, a modeling approach developed by CSIRO scientists in Australia, achieves the crucial goal of integrating physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain. In ATLANTIS, marine ecosystem dynamics are represented by spatially-explicit sub-models that simulate hydrographic processes (light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, and food web relations among functional groups. The ATLANTIS model represents key exploited species at the level of detail necessary to evaluate the direct effects of fishing. The model is thus ideally suited for ecosystem-based decision analysis.

The overarching goal of this project is to develop a model that allows users to examine the effects of large-scale management efforts against a backdrop of environmental variability resulting from climate events, seasonal changes, oceanographic dynamics, food web interactions, and fisheries. To achieve this goal, we are (1) collating data for the processes and functional groups included in the model; (2) defining the spatial structure of the NCCE; and (3) simulating behavior of the NCCE under alternate fisheries management policies and environmental regimes.

For more information, contact Dr. Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov

**e) Home range and patterns of space use for lingcod, copper rockfish and quillback rockfish in Puget Sound**

For marine fishes the estimation of home range size has received attention recently because of its application to the design of marine reserves. How individuals use space may also be important to the management of the species or for understanding behavioral processes like optimal foraging or territoriality. We used an acoustic tracking system (VRAP) to examine patterns in home range size and movement behavior for three demersal fishes in Puget Sound: lingcod *Ophiodon elongatus*, copper rockfish *Sebastes*

*caurinus* and quillback rockfish *S. maliger*. Data were collected over eight weeks in the summer of 2006.

Home ranges were relatively small (~1500 to 2500 $m^2$) and did not differ among species. However, lingcod had larger home ranges during the day than at night. Movement in all three species was in some way related to diel and tidal cycles, although individuals within species differed, and there was no general pattern. For example, about half of the lingcod used particular portions of their home ranges only during the day and on the flood tide. In contrast, other individuals used particular portions of their home ranges on the ebb tide. Some copper rockfish moved to specific areas of their home range on the day ebb tide, while others moved on the night flood tide and still others showed no movement pattern. Similar results were seen for quillback rockfish. The individual variation in movement behavior is the most interesting aspect of the results. Failure to incorporate this variation into ecological models ignores the individual level variability upon which natural selection operates.

For more information, contact Dr. Nick Tolimieri at Nick.Tolimieri@noaa.gov

**f) Quillback otolith chemistry: life-history information obtained from opportunistic sampling**

Ascertaining ecological information about species of concern is often difficult given their low abundance and conservation status. Using opportunistically collected quillback rockfish (*Sebastes maliger*) from sites throughout Puget Sound and the Strait of Juan de Fuca we investigated: a) the ability to differentiate fish based on the elemental concentrations found in their otoliths; and b) similarities in their life-histories as inferred from individual profiles of otolith chemistry. Our analyses indicate that the spatial patterns of otolith elemental concentrations were sufficiently unique to differentiate individuals among sites and to identify individuals that shared similar environments throughout their entire lives, compared with those that likely utilized different habitats at specific times in their lives. This study highlights the usefulness of opportunistically collected specimens and the application of techniques such as otolith chemistry to further our ecological understanding of species of concern.

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

**g) Developing an *in situ* index of nutritional status in lingcod: implications for evaluating management strategies such as marine reserves**

For most fish species, it is difficult to measure *in situ* growth or feeding rates non-lethally. In this project, we use the endocrine system, which plays an integral role in regulating cell division and growth in all vertebrates, to develop an index of nutritional status for lingcod *Ophiodon elongatus*. One of the principal hormones regulating growth is insulin-like growth factor-1 (IGF-I). Levels of blood plasma IGF-I are related to feeding and growth rates of Pacific salmon and several other marine teleosts. First, we characterize the relationship between levels of IGF-I and growth rates in a controlled

laboratory experiment. Growth rates of lingcod in the laboratory varied from -0.96 – 1.56 g $day^{-1}$ over two feeding periods lasting a total of 62 days. After characterizing the relationship between IGF and growth in the laboratory, we use this index to quantify relative differences in the nutritional status or growth of lingcod in the field by collecting blood samples at different fishing sites. The differences in this index among lingcod are compared with densities of lingcod and other groundfish species at each fishing site to investigate whether nutritional status (or growth) is density-dependent among sites. Understanding whether processes, such as density-dependent growth, occur will have considerable impacts on the overall success of specific management strategies.

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

**h) Patterns of movement in sixgill sharks: does small scale behavior predict large scale patterns?**

While patterns of density are ultimately produced by the interaction of births, deaths and movement, far more attention has been paid to the processes of births and deaths than to movement. The manner in which organisms move through their environment is crucial to the success of individuals and individual patterns of movement can generate observed spatial patterns of the population. We have been examining patterns of movement in sixgill sharks as a means to better predict the consequences of environmental change and/or human perturbation on this species. In 2005-2007, we acoustically tagged >40 sixgill sharks with pressure sensor transmitters and monitored their movement patterns. Acoustic monitoring suggests that sharks occupy core areas during late fall-early spring and move away from these core areas in warmer months. Active tracking revealed that sharks are responding to habitat attributes at the scale of 100's of meters. Analysis of 24h movement paths indicated that sharks tend to move much less than would be predicted by a random walk model on scales of days-weeks. The limited movement of these large predators suggests their local ecological impact may be substantial, and that they are at risk of local depletion if a fishery develops for them.

For more information, contact Dr. Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov

**7. Acoustic Modeling**

**a) Acoustic Scattering Modeling Workshop**

From Jan. 14 - 18 2007, Drs. Rebecca Thomas and Dezhang Chu from the FRAM division attended the Acoustic Backscatter Modeling Workshop in Friday Harbor, WA. The workshop, funded by the NOAA/NMFS ASTWG for domestic participants and the NOPP for international participants, reviewed and compared the currently used fish/zooplankton scattering models that widely are used in the fisheries acoustics community. There were 16 participants, representing scattering modeling experts from six countries. The workshop was very successful in that it strengthened the collaborations and provided a direct and much more efficient communication channel among scientists

from different organizations and countries. In addition, it established a convenient platform for future developments.

For more information, contact Dr. Dezhang Chu at Dezhang.Chu@noaa.gov

**b) Fish Acoustics Science Review**

A meeting of Fish Acoustic Science Review was held from 1 - 2 Nov. in Plymouth, MA. It brought together approximately 25 scientists, along with ONR program managers from Biological Oceanography, Ocean Acoustics, and Signal Processing, spanning several disciplines. The review covered the areas of biology, acoustics, and signal processing. Each scientist gave a presentation of the state-of-the-art in their respective area. Dr. Dezhang Chu from FRAM division gave a presentation on acoustic modeling of scattering by swimbladder-bearing fish. After the plenary-style presentations were given, small focus groups were formed to identify issues. The initial outlines for an ONR Departmental Research Initiatives (DRI) proposal entitle Multiscale Bioacoustics, which was a collaborative and multi-disciplinary research project, were presented by Dr. Jim Eckman (ONR program manager - Biological Oceanography) at the end of the review.

For more information, contact Dr. Dezhang Chu at Dezhang.Chu@noaa.gov

**8. Economic Data Collection and Analysis**

**a) Commercial Fishing Economic Cost-Earnings Data**

Development, implementation, and fielding of the West Coast open access groundfish and salmon economic cost earnings survey was completed during 2007. Economic cost earnings data were collected from the owners of over 300 fishing vessels through the use of in-person, telephone, and mail questionnaires. When combined with data from the limited entry cost earnings survey completed during 2006, this open access groundfish and salmon survey provides representative economic data on all vessel types which provide shoreside landings in the federally managed groundfish and salmon fisheries.

Cost earnings data collected from the limited entry trawl fleet (during 2006) were used during 2007 to model the impact of implementing a limited access privilege (LAP) regulatory regime on limited entry trawl fleet size and harvesting costs. This analysis indicates that fleet size is likely to be reduced by about 50% after implementation of a LAP regulatory regime, with a substantial reduction in annual harvesting costs.

The Center's first cost earnings survey of seafood processors was developed during 2007. Meetings were held with industry representatives to develop a survey questionnaire and OMB approval for survey fielding has been received. The survey will be fielded during 2008.

For more information, contact Dr. Carl Lian at Carl.Lian@noaa.gov

**b) Survey of the Economic Value of Sport Fishing**

An economic valuation survey was developed and implemented during several 2-month waves of recreational angling in Oregon and Washington during 2006. An original and innovative survey format was used to elicit the effect of regulations on angler valuations and participation rates. Extensive testing of the survey instrument and outside reviews were conducted to improve the quality for responses for use in future research.

For more information, contact Dr. Todd Lee at Todd.Lee@noaa.gov

**c) Economic Survey of West Coast Charter Fishing Vessels**

The economic survey of West Coast recreational Charter Boat operators has been developed over the past year and is currently being fielded in Oregon and Washington. The survey is designed to determine the state of the industry and to determine the regional economic impacts of the sector on the respective coastal communities. This survey will compliment the survey of the commercial fishing vessels which is also currently being fielded and the processor survey which has been developed and is under review of industry representatives. Upon completion we will be able to build a comprehensive regional economic model of the West Coast that incorporates commercial, recreational, and processors.

For more information, contact Dr. Todd Lee at Todd.Lee@noaa.gov

**d) Regional Economic Impact Analysis**

A three step research program has also initiated to investigate how coastal communities interface with marine resources. In Phase 1 a Social Accounting Matrix (SAM) will be developed for selected communities. This phase will utilize federal, state, and local secondary data sources and some limited "ground truthing". Presently, Westport, Washington and Newport, Oregon have been selected for inclusion in this project, and one or two communities in California may also be included. Significant progress was made during 2007 on Phase 1 of this project.

Phase 2 will involve surveying businesses and households in Westport, Newport, and at leaset six other communities. These interviews will be used to improve the data obtained from the secondary data sources and examine important issues such as location of expenditures by businesses and households, household income from marine related endeavors, extent of income from non-labor sources, and additional sociological questions about people's preferences and values for the marine resources. Phase 3 will focus on estimating visitor usage and visitor expenditure profiles. Completion of these two phases will rely upon future availability of funding. Survey design for phases 2 and 3 of this project has been completed, and fielding will begin after Paperwork Reduction Act clearance is received from OMB.

For more information, contact Dr. Carl Lian at Carl.Lian@noaa.gov

## 9. Observer Data Collection and Analysis

The FRAM division's At-Sea Hake and West Coast Groundfish Observer Programs continued collecting fishery-dependent data during 2007 on groundfish fleets along the entire west coast.

### a) At-Sea Hake Observer Program

The At-Sea Hake Observer Program deployed two fisheries observers on each of sixteen at-sea Pacific hake processing vessels for every fishing day during the 2007 season, exceeding 1,400 observer days at sea. Due to low total catch limits on some bycatch species in this fishery, observer data are crucial to the successful management of the fishery. Beginning in 2005, program staff has taken an active role in conducting pre-cruise meetings between vessel crew and the observers. These meetings provide an opportunity to outline observer duties, expectations, and identify solutions to meet both the needs of the observer program and the vessel, through increased communication and cooperation. The observers sample nearly 100% of the hauls in this fishery. Through the hard work of the observers and vessel cooperation, the average sample size of each haul has increased from roughly 30% to around 50% during recent seasons.

### b) West Coast Groundfish Observer Program (WCGOP)

During 2007, the West Coast Groundfish Observer Program deployed observers on the bottom trawl and various fixed-gear fleets along the entire U.S. West Coast, exceeding 2,900 observer days at sea on over 300 vessels. The program also deployed electronic monitoring technology on the entire shore-based Pacific hake fleet and developed a cost sharing arrangement between the shore-based hake fleet and NOAA Fisheries for the 2007 season. The observer program currently conducts observations aboard vessels ranging in size from skiffs to large trawlers, which fish in depths ranging from less than 20 fm to more than 500 fm. Due to its unique data collection circumstances, the program continues to stress safety and data quality. The program's safety focus and unique sampling methodology was exemplified by its high profile at the International Fisheries Observer Conference held in May in Victoria, British Columbia.

### c) Data and analytical reports

The WCGOP collects at-sea data from limited-entry trawl and fixed-gear fisheries as well as from open access nearshore, prawn/shrimp, California halibut, and deep water fisheries. The WCGOP's goal is to improve total catch estimates by collecting information on the discarded catch (fish returned overboard at-sea) of west coast groundfish species. The data are used in assessing and managing a variety of groundfish species.

Summaries of data collected on observed trips are routinely published on the NWFSC web site. Several fleet-specific reports were completed during the fall and winter of

2007. The limited-entry trawl fleet report summarizes discarded catch data collected by the West Coast Groundfish Observer Program (WCGOP) from the limited-entry trawl fleet from January 1, 2006 through April 30, 2007. The non-sablefish report summarizes discarded catch data collected by the WCGOP from the limited-entry non-sablefish-endorsed fixed-gear fishery from January 1, 2006 through April 30, 2007. The sablefish report summarizes discarded catch data collected by the WCGOP from the limited-entry sablefish-endorsed fixed-gear fishery from January 1, 2006 through December 31, 2006. The nearshore report summarizes discarded catch data collected by the WCGOP from the open access fixed-gear fisheries in shallow water (average of start and end depths < 50 fathoms) from September 1, 2004 through April 30, 2006. FRAMD also prepares an evaluation of total annual fishing mortality. The most recent report is for the year 2006. All reports can be obtained at:
http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/index.cfm.

For more information, please contact Jonathan Cusick at Jonathan.Cusick@noaa.gov

**d) Recent trends in bycatch and discard in the U.S. West Coast groundfish trawl fishery**

The West Coast Groundfish Observer Program was initiated by NOAA Fisheries' Northwest Fisheries Science Center in the fall of 2001. Since that time, the Pacific Management Council has initiated numerous measures, such as closed areas, gear restrictions, and explicit modeling of bycatch, which have been intended to constrain the catch of species for which rebuilding plans have been developed. In 2007, FRAMD examined the trends in the trawl fleet's discard and overall bycatch of these rebuilding species since 2002, and related these changes to the evolution of groundfish management and its effect on the magnitude and distribution of fishing effort over this period. In addition to rebuilding species, FRAMD also reviewed changes in trawl discard species since 2002. Improved understanding of how bycatch and discard in this fishery have responded to recent management actions will enhance the ability to identify future groundfish management approaches that are effective with respect to achieving bycatch and economic objectives.

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

**Publications**

Andrews, K. S., P. S. Levin, S. L. Katz, D. Farrer, V. Gallucci, G. Bargmann. 2007. Acoustic monitoring of sixgill shark movements in Puget Sound: evidence for localized movement. Canadian Journal of Zoology, 85(11):1136-1143.

Berntson, E. A., P. S. Levin, P. Moran. 2007. Conservation of North Pacific rockfishes: Ecological genetics and stock structure. Proceedings of the workshop March 2-3, 2004, Seattle, Washington. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC 80, 80 p.

Brand, E. J., I. C. Kaplan, C. J. Harvey, P. S. Levin, E. A. Fulton, A. J. Hermann, J. C. Field. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-84, 145 p.

Francis, R. C., M. A. Hixon, M. E. Clarke, S. Murawski, S. Ralston. 2007. Ten Commandments for Ecosystem-Based Fisheries Scientists. Fisheries, 32:217-233.

Helser, T. E., I. J. Stewart, H. Lai. 2007. A Bayesian Hierarchical Meta-analysis of growth for the genus Sebastes in the Eastern Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences.

Helser, T. E., I. J. Stewart, C. Whitmire, B. H. Horness. 2007. Model-based estimates of abundance for 11 species from the NMFS slope surveys. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-82, 145 p.

Keller, A. A., V. H. Simon, B. H. Horness, J. R. Wallace, V. J. Tuttle, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. C. Buchanan. 2007. The 2003 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-86, 130 p.

Keller, A. A., B. H. Horness, V. H. Simon, V. J. Tuttle, J. R. Wallace, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. C. Buchanan. 2007. The 2004 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-87, 134 p.

Methot, R. D. 2007. User manual for the integrated analysis program Stock Synthesis 2 (SS2): Model version 2.00a.

Stewart, I. J. 2007. Defining plausible migration rates based on historical tagging data: a Bayesian mark-recapture model applied to English sole. Fishery Bulletin, 105:470-484.

Tolimieri, N. 2007. Patterns in richness and evenness in groundfish assemblages on the continental slope of the US Pacific coast. Environmental Biology of Fishes, 78:241-256.

Whitmire, C.E. and M.E. Clarke. 2007. State of deep coral ecosystems of the US Pacific Coast: California to Washington. pp. 109-154. In: S.S. Lunsden, Hourigan, T.F., Bruckner, A.W., and Dorr, G. (eds.). The state of deep coral ecosystems of the United States. NOAA Technical Memorandum CRCP-3. Silver Springs, MD 365 pp.