NMFS Southwest Fisheries Science Center

Draft Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

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A. AGENCY OVERVIEW

The Southwest Fisheries Science Center (SWFSC) conducts fisheries and marine mammal research at three laboratories in California. Activities are primarily in support of the Pacific Fishery Management Council, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as a number of international fisheries commissions and conventions. The acting Science Director is Dr. Usha Varanashi, and the Deputy Director is Kristen Koch. All three SWFSC laboratories have supported the essential needs of the NMFS and the Pacific Fishery Management Council (PFMC) for groundfish, including as active members of the PFMC's Scientific and Statistical Committee (SSC), the Groundfish Management Team, and other management teams and advisory bodies.

The Center is headquartered in La Jolla, which hosts three divisions that conduct research on a wide range of Pacific and Antarctic fish, marine mammals, sea turtles, and marine habitats; the Antarctic Ecosystem Research Division (led by Dr. George Watters), the Protected Resources Division (led by Dr. Lisa Ballance), and the Fisheries Resources Division (led by Dr. Russ Vetter). The Fisheries Resources Division (FRD) conducts research on groundfish, large pelagic fishes (tunas, billfish and sharks), and small coastal pelagic fishes (anchovy, sardine and mackerel), and is the primary source of groundfish-related research at the La Jolla Laboratory. The La Jolla laboratory is also the primary source of federal support for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys that have taken place along much of the California coast since 1951. Researchers at the La Jolla lab have primary responsibility for ichthyoplankton collections, studies of species abundance and distribution (including responses to climate variability), systematics, and the application of early life history information to stock assessments.

The Fisheries Ecology Division (FED), located in Santa Cruz and directed by Dr. Churchill Grimes, comprises two research branches. The Fisheries Branch (led by Dr. Stephen Ralston) conducts research and stock assessments in salmon population analysis, economics, groundfish, and fishery oceanography. The Ecology branch (led by Dr. Susan Sogard) conducts research on the early life history of fishes, salmonid ocean and estuarine ecology, habitat ecology, and molecular ecology of fishes. Specific objectives of the FED groundfish programs include: (1) collecting and developing information useful in assessing and managing groundfish stocks; (2) conducting stock assessments and improving upon stock assessment methods to provide a basis for harvest management decisions at the PFMC; (3) characterizing and mapping biotic and abiotic components of groundfish habitats, including structure-forming invertebrates; (4) disseminating information, research findings and advice to the fishery management and scientific communities; and (5) providing professional services (many of which fall into the above categories) at all levels, including inter-agency, state, national and international working groups.

The Environmental Research Division (ERD), directed by Dr. Franklin Schwing, is located at the Pacific Fisheries Environmental Laboratory (PFEL) in Pacific Grove. The ERD is a primary source of environmental information to fisheries researchers and managers along the west coast, and provides science-based analyses, products, and information on environmental variability to meet the agency's research and management needs. The objectives of ERD are to: (1) provide appropriate science-based environmental analyses, products, and knowledge to the SWFSC and its fishery scientists and managers; (2) enhance the stewardship of marine populations in the California Current ecosystem, and other relevant marine ecosystems, by understanding and describing environmental variability, the processes driving this variability, and its effects on the production of living marine resources, ecosystem structure, and ecosystem function; and (3) provide science-based environmental data and products for fisheries research and management to a diverse customer base of researchers, decision-makers, and the public. The ERD also contributes oceanographic expertise to the groundfish programs within the SWFSC, including

planning surveys and sampling strategies, conducting analyses of oceanographic data, and cooperating in the development and testing of environmental and biological indices that can be useful in preparing stock assessments.

B. MULTISPECIES STUDIES

1. Research

Juvenile Surveys

The Fisheries Ecology Division (SWFSC) successfully completed the 27th year of its annual May-June survey of the distribution and abundance of pelagic juvenile rockfishes aboard the NOAA R/V Miller Freeman. This marked the first time the survey was completed on a vessel other than the NOAA R/V David Starr Jordan, which was retired in late 2008. Objectives of the survey include collecting data for use in estimating future recruitment to rockfish and other groundfish stocks, and otherwise monitoring the general state of the physical and biological environment (including krill, other forage fish, and physical oceanographic conditions). Results from the 2009 survey indicated a greater abundance of age-0 rockfish (*Sebastes*) relative to the preceding four years, which produced the lowest catch rates of young-of-the-year (YOY) in the history of the survey (Figure 1). Even so, the abundances of YOY rockfish, market squid, and YOY Pacific hake, were barely at their long-term average values, despite apparently greater production of krill and seemingly cool, productive ocean conditions. The trends observed in these four indicator groups are consistent with trends across a number of other taxa. Ongoing efforts will characterize these assemblages and their relationship to oceanographic conditions in the California Current.

Data from these surveys are used in rockfish and, in the past, Pacific hake stock assessments as indices of age-0 recruitment. Current assessments use an abbreviated time series of data developed from the period with full coastwide coverage (i.e., including data from a comparable midwater trawl survey of the northern portion of the US west coast that is conducted jointly by the NWFSC and the Pacific Whiting Conservation Cooperative). Indices from the coastwide survey were used in stock assessments of bocaccio, widow, and canary rockfish that were completed in 2009, and have been used for other species as well (chilipepper, shortbelly, and blue rockfish).

A spatial analysis of encounter rates of YOY groundfish has recently been completed using the combined SWFSC/NWFSC coastwide dataset, which is now being prepared for publication. Results show that the distribution of juvenile fish was highly unusual in 2005 and, to some degree, 2006 as well (Figure 2). Whereas the majority of species are typically encountered most often in the core region of the survey (i.e., 35-40°N lat.), in those years there was as a notable absence of fish in that area. Those two years were also years of greatly depressed total abundance (Figure 1). Conversely, encounter rates to the south and, especially to the north, were substantially elevated. Significantly, 2005 and 2006 were years that the Sacramento River fall run Chinook salmon stock collapsed and it is noteworthy that ocean entry occurs at 38°N during May-June. Thus, it is interesting to speculate that the failure of those salmon year-classes was due to a critical lack of forage at ocean entry. Ocean conditions in 2005 were very peculiar due to: (1) delayed onset of the spring transition to the upwelling season and (2) anomalous winter poleward geostrophic flow anomalies along the entire US west coast.

Data from the SWFSC juvenile rockfish survey were also recently used to evaluate the consequences of fishing down adult rockfish stocks on seabirds that depend heavily on juvenile rockfish as a source of forage during the breeding season. This work tested the hypothesis that fishing has decreased juvenile rockfish availability and thereby limited seabird productivity. This was done by quantifying relationships between observed juvenile rockfish relative abundance and seabird productivity. The analysis used stock assessment models to estimate the relative abundance of juvenile rockfish in the absence of fishing and compared differences in seabird productivity that would have resulted without rockfish fisheries. Results show that while the relative abundance of juvenile rockfish has declined to approximately 50% of that expected in the absence of fishing, seabirds achieved 75% to 95% of the their un-impacted levels of productivity, depending upon the species of bird and other model assumptions (Field *et al*. In press). These results are consistent with the premise that the impacts of local rockfish fisheries on seabird productivity are less than impacts that have occurred to the prey resources themselves due to ocean climate and the ability of seabirds to buffer against changes in prey availability through prey-switching and other behavioral responses.

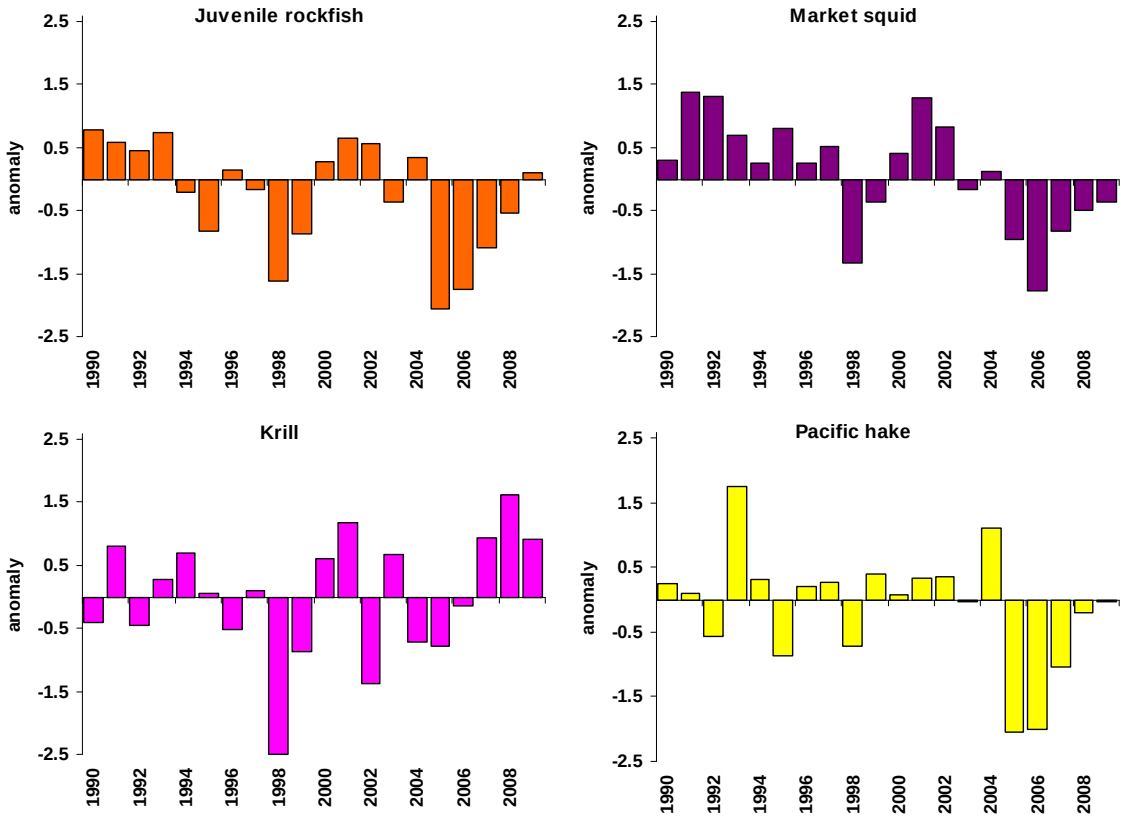

Figure 1: Standardized anomalies of the log of mean values by year for four key forage species that are well sampled in the SWFSC juvenile rockfish midwater trawl survey (figure reflects catches in the historical Central California core survey area from 1990-2009 only).

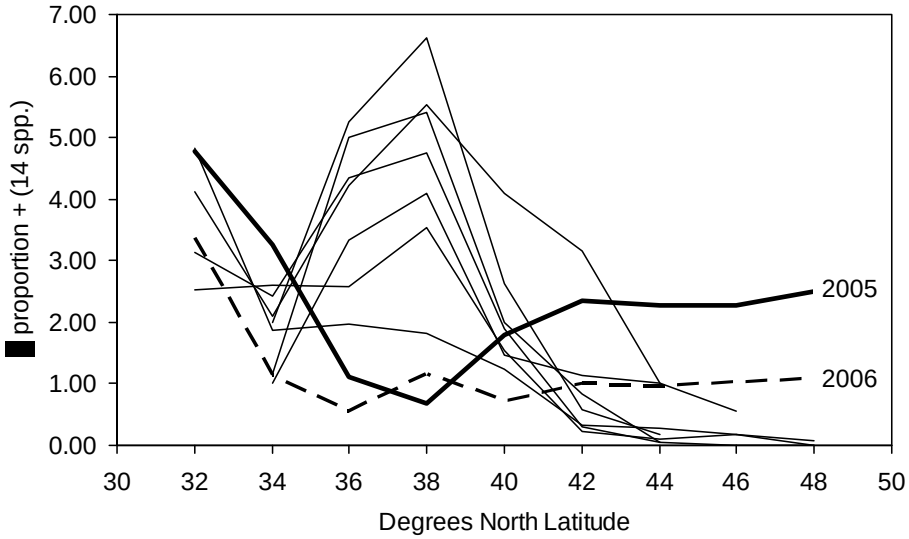

Figure 2: Encounter rates of YOY groundfish in the coastwide midwater trawl survey (2001-2009). Depicted is the proportion positive encounters, stratified by latitude and year, summed over 14 species.

Adult Surveys

The Collaborative Optically-assisted Acoustical Survey Technique (COAST) was developed by the Advanced Survey Technologies Group to survey rockfish dispersions and abundances, by species, throughout the Southern California Bight (SCB). The technique uses historical fishing maps to initially define the survey sites; active-acoustics to map the distributions and estimate the abundances of rockfish, by species, using information about the proportions of rockfish species at each site and distributions of their lengths, estimated from video and still images. The cameras are deployed from a remotely operated vehicle (ROV). The physical oceanographic habitat is sampled using a CTD with a dissolved oxygen sensor and an ADCP; the seafloor is also imaged and classified using new multi-frequency biplanar interferometric techniques. COAST was used to survey rockfishes at 44 sites distributed throughout the SCB in 2004/5 and 2007/8. Data analysis was refined using new techniques in 2009. Terms of reference were drafted for a review of COAST by the Center for Independent Experts.

2. Stock Assessment Support

The Fisheries Ecology Division (FED) is currently the SWFSC lead for stock assessments of groundfish for the PFMC, and supports stock assessment science through the maintenance of data systems and the development of new analytical techniques. The FED works closely with the Pacific States Marine Fisheries Commission (PSMFC) and the California Department of Fish and Game (CDFG) to coordinate port sampling efforts and to maintain the CalCOM database, which serves as the source of the data provided to PacFIN by the State of California. The system provides port sampling biologists with Internet access to the database, so that data are entered directly in real time. In addition to maintaining the CalCOM database and supporting port sampling and landings estimation, the FED has participated in the PFMC process since its inception. FED staff scientists have been represented on the Groundfish Management Team (GMT) in every year since its establishment, and have also been active participants in the Scientific and Statistical Committee (SSC) for the PFMC.

New Methods for Assessing Data-Poor Stocks

MacCall (2009) developed a simple method for estimating sustainable yields called Depletion-Corrected Average Catch (DCAC). The method is applicable to data-poor stocks where little more than a catch history is available. Using an approach similar to DCAC, Dick and MacCall (In Prep.) developed an extension of the stochastic stock reduction analysis approach of Walters *et al*. (2006) called Depletion-Based Stock Reduction Analysis (DB-SRA). This method is suitable for assessment of data-poor stocks if approximate catches are known from the beginning of the fishery. DB-SRA was applied to 30 data-rich stocks to determine the effectiveness of the method (Figure 3).

DB-SRA was also applied to over 40 previously unassessed stocks (Dick and MacCall, In prep.) and was recommended by the Pacific Fishery Management Council's Scientific and Statistical Committee as the basis for setting overfishing levels and Annual Catch Limits for those stocks. Prior to application of this method, optimal yields for unassessed stocks were primarily based on average or maximum catch statistics.

A simulation study is also being conducted by FED staff to examine utilization of data from Marine Protected Areas (MPAs) to assess population status. The study is a cooperative research effort with Kristen Honey (a Ph.D. student at Stanford University) and intends to use dynamic SPR (spawning potential ratio) within MPAs and outside of MPAs to assess population status and to evaluate the effectiveness of MPAs for data-poor species management.

Quantifying Scientific Uncertainty in Groundfish Stock Assessments

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) as amended in 2007 requires the establishment of Annual Catch Limits (ACLs). An ACL represents a numerically specified upper limit on total fishing mortality that should not be exceeded and forms the basis for invoking accountability measures to rectify chronic overfishing. In addition, the Act requires that the Scientific and Statistical Committees (SSCs) of the regional Fishery Management Councils recommend Acceptable Biological Catch (ABCs) to their respective Councils that account for "scientific uncertainty" in estimates of overfishing limits (OFLs). This new requirement effectively adds a new step in setting catch levels. In particular, the application of F_{MSY} (or its proxy) to biomass values from a stock assessment now defines the OFL, which is functionally identical to the definition of ABC previously used at the Pacific Fishery Management Council (PFMC). As before, annual catches in excess of the OFL constitute overfishing. However, the new guidelines defines ABC as an annual catch amount that is reduced from the OFL in order to account for scientific uncertainty in the development of management advice by SSCs to their Councils. The expectation under the Guidelines is that scientific advice that is relatively uncertain will result in ABCs that are relatively lower, all other things being equal, i.e., a precautionary reduction in catch will occur due purely to scientific uncertainty.

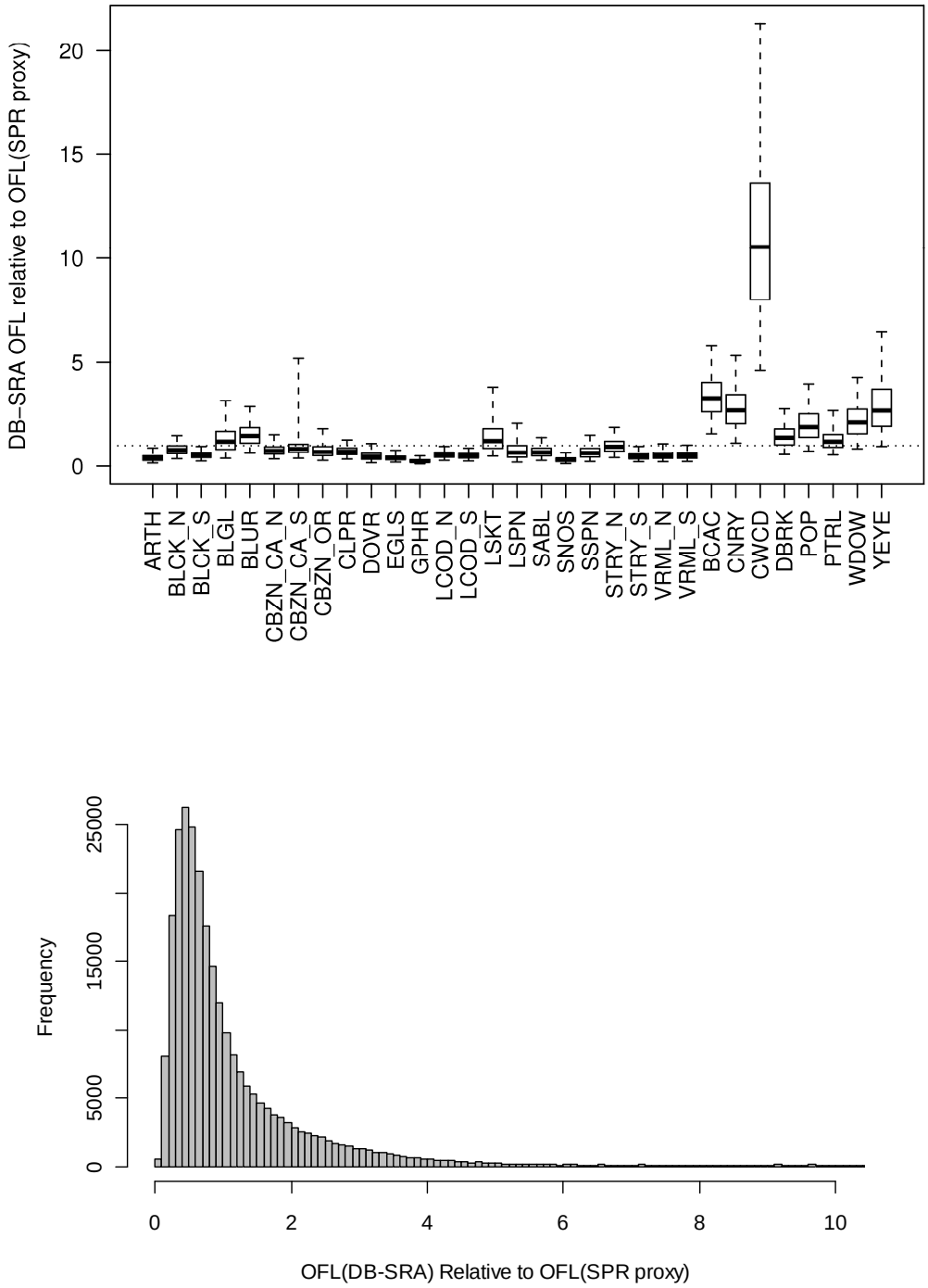

Figure 3. (Upper) DB-SRA estimates of OFL for 31 species, scaled relative to OFL(SPR proxy) estimates from the most recent assessment. Box-and-whisker plots characterize the median, IQR, and 95% intervals of the distributions. The reference line at unity represents agreement with the assessment's point estimate. Uncertainty in the assessment estimate of OFL is not considered. (Lower): Distribution of OFL from DB-SRA, integrated across 31 stocks and scaled relative to the assessment estimates for OFL (SPR proxy). The upper tail is not fully displayed to better illustrate the dominant values of the distribution.

Staff at the SWFSC FED have been involved in efforts within the SSC at the PFMC to quantify scientific uncertainty and to develop an ABC control rule that can be used as a basis for reducing harvest as a function of uncertainty and risk tolerance. There are a variety of uncertainties in developing an OFL, including: (1) biomass uncertainty, (2) harvest rate uncertainty, (3) stock projection uncertainty, and (4) ecosystem uncertainty. Given the short time frame required by the MSA to implement the required elements of the law, however, the PFMC SSC has focused exclusively on biomass uncertainty in the current management cycle, but is expected to incorporate additional variance components as these procedures mature. Those efforts have considered year-specific variation in biomass estimates derived from repeat assessments of the same stock as a composite measure of within assessment statistical variation, as well as model specification uncertainty, given the variation in analytical teams, models, reviewers, data sources, etc. that occurs when stock assessments are periodically repeated (see Figure 4). Biomass variability was estimated for 17 groundfish and coastal pelagic species (CPS) and, from a meta-analytic perspective, uncertainty (log-scale variance) was similar over four broad taxonomic groupings, i.e., rockfish, roundfish, flatfish, and CPS. Thus, the data were further pooled and a single lognormal distribution representing total biomass uncertainty was generated (mean=0.00, stdev=0.36). That distribution was then back-transformed to the arithmetic scale with associated cumulative probabilities. An ABC control rule for data-rich stocks was then tabulated, expressing the required reduction in ABC relative to OFL as a function of a policy decision pertaining to the risk of overfishing (P*). The PFMC adopted a maximum allowable P* of 0.45 for data-rich stocks and set 2011-12 ABCs based on that level of risk.

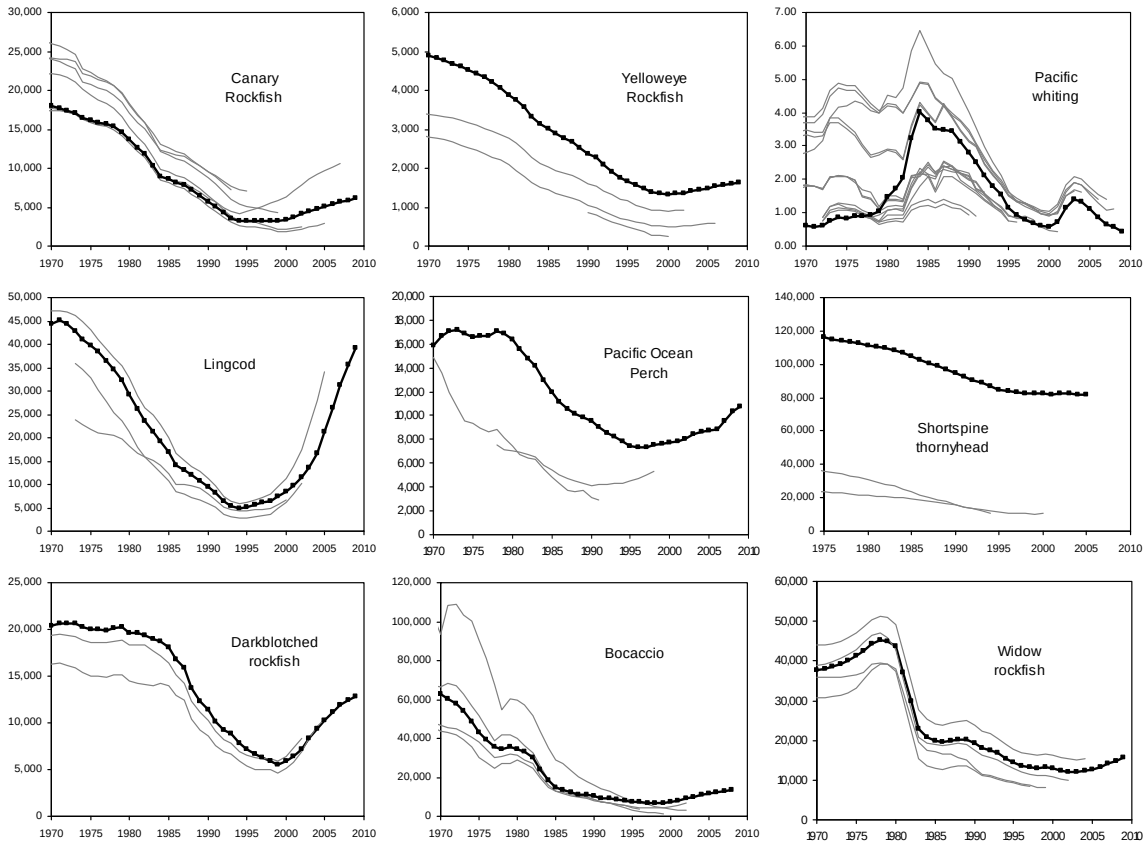

Figure 4. A comparison of biomass trajectories from repeat assessments of nine different groundfish stocks. The bold line is the most recent assessment completed.

Improved Access to Landings Data – Support of the California Cooperative Groundfish Survey

The FED has supported the California Cooperative Groundfish Survey since 1978. One of the key areas of support has been in the area of data management. FED staff recently completed a major overhaul of the website (http://calcomfish.ucsc.edu). The primary purpose of the website is to enable port samplers to enter data directly into the CALCOM database. A secondary purpose of the website is to allow end-users easy access to data. Recent improvements to the website include: (1) allowance for sablefish, whiting, and elasmobranch samples to be entered into the database, (2) allowance for Quota Species Monitoring (QSM) data to be entered and processed by the system, (3) increase in the amount and types of data available to end-users, (4) improved data quality and timeliness, and (5) reduction in work load for data managers. End-users can now download the following information from the website: (1) landing estimates from block summary, catch reconstruction, and commercial expansions, (2) age and length compositions, (3) access or inventory of otoliths, and (4) download all available documentation. In addition to accessing CALCOM through the website, users can request more complete access to sample data via ODBC connections to the database.

Digitization of Historical Landings Data and Catch Reconstruction Efforts

FED staff obtained funding from the NOAA Climate Data Modernization Project (CDMP) to support ongoing efforts at recovery of landings data. These funds have been used to convert microfiche and printed data into electronic format. To date the following data have been put into the database: (1) monthly block summary data from 1931 - 1968, (2) annual trawl log summary data from 1927 - 1957, and (3) landing receipts for the following years: 1951, 1955, 1957, 1960, 1965, 1967, and 1968 (1969 onwards have been available for many years). At the present rate of digitization, landing receipts for all years from 1951 to present should be available within three years.

Last year a variety of both full and update groundfish stock assessments were completed for the PFMC and a concerted effort was made to incorporate comprehensive catch reconstructions in the assessments when possible. To that end, staff at the SWFSC Fisheries Ecology Division completed a reconstruction of California commercial and recreational groundfish landings going back to 1935 and created a database to disseminate the information (Ralston *et al*. In press). Those results were used extensively in stock assessments of canary rockfish, yelloweye rockfish, bocaccio, splitnose rockfish, and others. In some instances incorporation of the historical catch data had a marked affect on estimates of stock status, in both favorable (bocaccio) and unfavorable (canary rockfish) directions. Staff will continue to improve the catch reconstruction estimates as more of the recovered data are keypunched under a grant from the NOAA CDMP.

Effects of Model Misspecification on Assessment Results

FED staff have completed a study using population simulations to examine effects of age-dependent mortality and selectivity on stock assessments. This study compares stock assessment results with simulated data with different assumptions concerning natural mortality and selectivity functions that are often used in west coast groundfish stock assessments. The study shows that mis-specified mortality and selectivity can have large effects on important assessment results, particularly OFL. A draft of this study has been completed and is to be submitted to an external journal for publication.

Influence of Climate on Productivity of Groundfish Populations

The FED is currently involved in efforts to evaluate climate effects on fish growth and productivity, with support from the FATE program and in collaboration with researchers at the NWFSC. The working hypothesis for this study is that poor feeding conditions during warm oceanographic regimes result in trade-offs affecting bioenergetic allocation patterns by females, leading to reduced growth and fecundity. Ongoing efforts include addressing these research questions by expanding on process studies relating environmental conditions to growth and fecundity (including collection of large amounts of age and fecundity data through fieldwork during the project years), by using these results to modify existing bioenergetics models, and by incorporating findings from these efforts into existing stock assessment models of west coast groundfish. The primary focus of these studies are chilipepper (*Sebastes goodei*), for which time-varying growth was modeled in the most recent assessment, yellowtail rockfish (*S. flavidus*), for which a subtantial amount of fecundity data over multiple time periods is available, and brown rockfish (*S. auriculatus*), a relatively data-poor nearshore species that can be subject to varying environmental "regimes" in aquaria. These refinements should improve future assessments by increasing precision and decreasing uncertainty, and improve on a greater mechanistic understanding of how climate drives changing productivity in marine resources.

C. BY SPECIES, BY AGENCY

3. Shelf Rockfish

i. Research

Modeling Rockfish Fecundity in Stock Assessments

A meta-analysis of rockfish fecundity was completed by members of the Groundfish Analysis Team (GAT) at the Fisheries Ecology Division (FED) to better characterize the reproductive output of exploited rockfish populations. Completed in early 2009, the results from this study have subsequently been incorporated into several rockfish stock assessments (*Sebastes paucispinis, S. elongatus, S. diploproa*, and *S. rubberimus*). General findings of the meta-analysis indicate that target harvest rates are sensitive to changes in relative fecundity with size and that Bayesian hierarchical models are a useful tool to inform predictions of fecundity at size, quantify uncertainty about those predictions, and provide predictive distributions of model parameters for unobserved species.

Sounds of Captive Rockfishes

Sound production by many fish species has been studied extensively, but little is known about sound production by rockfishes (genus *Sebastes*), and only a few species have been reported to be soniferous. To determine if additional rockfish species produce sounds, passive acoustic recordings were made during 2007/08 at Hubbs-SeaWorld Research Institute and Southwest Fisheries Science Center in tanks containing bocaccio (*S. paucispinis*), cowcod (*S. levis*), starry rockfish (*S. constellatus*), and sunset rockfish (*S. crocotulus*) (Širović and Demer 2009). Three distinct sounds were recorded in tanks containing only *S. paucispinis* and two of those sounds occurred at different rates during light and dark conditions. Their common characteristics were low frequency (below 800 Hz), short duration (4 s), and low source levels (103–113 dB re: 1 Pa at 1 m). Also, there was evidence that one or more other species

produced sounds. These findings indicate that more rockfishes produce sounds, and suggest passive acoustics could be a useful tool for remotely monitoring their populations.

Rockfish Sounds and Their Potential use for Population Monitoring in the Southern California Bight

The SWFSC is a leader in the development of non-lethal methods to assess and monitor rockfish stocks off Southern California. From August to October 2007, the ship-based COAST survey was augmented with two passive-acoustic moored recorders. One collected data at the 43-Fathom Bank for 46 days, while the other was serially deployed at 13 locations for shorter periods (1–8 d). Passive-acoustic data were analyzed for the presence of rockfish sounds. Potential sources of five pulsing sounds were identified from the optically estimated species compositions at each location, as well as from known rockfish recordings collected in aquaria. All sounds had a low frequency (<900 Hz). Some were short, individual pulses (_0.1 s), others were repetitive. A repetitive pulsing from bocaccio (*S. paucispinis*) was the most commonly recorded sound and it occurred mainly at night. The daily calling rates at each site were quantitatively compared with the rockfish abundance estimates obtained from the active-acoustic survey, and they were positively correlated. The feasibility of using passive-acoustic tools to efficiently monitor changes in rockfish abundance was explored (Širović *et al*., 2009). The principal challenges in using passive acoustics for population monitoring are determining which species make which sounds, and under which behavioral conditions these occur, and characterizing the large variations in these sounds. The bocaccio sounds might be a good signal for monitoring the recovery of this overfished stock in the SCB, because of its frequent occurrence and long-term persistence. In addition, the sounds from speckled rockfish (*S. ovalis*) may be a good indicator of their abundance, or species with which they aggregate.

A Statistical-Spectral Method for Echo Classification

The frequency dependence of sound-scatter intensity is commonly exploited to classify fish, zooplankton, and the seabed observed in acoustic surveys. Although less utilized, techniques based on the statistics of echo amplitudes can also be used to extract information. A hybrid, statistical-spectral method for target identification (SSID) was developed by the Advanced Survey Technologies Group, which incorporates information contained in both the signal amplitudes and phases (Demer *et al*. 2009). The SSID uses multi-frequency echo statistics from individual time-space intensities (pixels) to identify general scattering types, before applying model-based identification schemes for target identifications. The SSID is used for fine-scale separation of acoustic backscatter from demersal fish and the seabed and estimating seabed depth, within-beam slope, hardness and roughness, and the height of the dynamic acoustic dead zone. Using data from Collaborative Optically-assisted Acoustical Survey Technique (COAST) surveys, the SSID provides information about rockfish distributions, abundances, and their seabed habitats. New protocols for processing COAST survey data were developed and applied.

Concurrent Three-Dimensional Mapping of Demersal Fish and Their Seabed Habitat

The Advanced Survey Technologies Group has developed methods for concurrent three-dimensional mapping of demersal fish and their seabed habitat using the new Simrad ME70 echosounder. The Simrad ME70 multibeam echosounder was designed for quantitative fisheries research and is currently installed on each of the new, quiet, NOAA FSVs. The ME70 has configurable beams and transmits in the range 70–120 kHz to provide calibrated, acoustic-backscattering data throughout the detection range (fisheries mode, FM). With optional hardware and software, the ME70 can also collect soundings that potentially meet International Hydrographic Organization's S–44 Order 1 standards (bathymetric mode, BM). Furthermore, with custom algorithms and software, bathymetric data can be obtained from the ME70

operating in FM, and volume backscatter can be sampled from the ME70 operating in BM. This flexibility allows data to be concurrently collected on fish and their seabed habitat.

ii. Assessments

Bocaccio (*Sebastes paucispinis*)

The 2009 stock assessment of bocaccio (*S. paucispinis*) was the first full assessment conducted since 2003, and as with most west coast groundfish assessments, used the Stock Synthesis model framework (Field *et al*. 2009). The assessment included the southern subpopulation, from south of Cape Blanco to the U.S./Mexico border, only. As with bocaccio assessments done over the past 10 years, results indicate that spawning output fluctuated significantly through the 1960s and 1970s, and declined rapidly through the rest of the 1980s and 1990s. These declines were primarily a result of high exploitation rates, although a period of anomalously poor recruitment appears to have taken place throughout most of the 1990s that intensified the magnitude of the decline. Since that time, fishing mortality has declined tremendously due to management restrictions, and the stock has been increasing at a fairly rapid rate coincident with a series of several year classes (1999, 2003, 2005) that were strong relative to the stock size. One major change in the model was the revised historical catch history, based on a suite of ongoing catch history reconstruction efforts the catch of bocaccio prior to 1950 was estimated to be less than assumed in previous models, contributing to a more optimistic estimate of relative abundance and productivity. The final model estimated that the current spawning output was 28% of the unfished level in 2009, and the rebuilding analysis indicated that under the fishing rate adopted in the most recent rebuilding plan, the population would be expected to be rebuilt by 2021, two years earlier than the median time to rebuild (2023) under the last rebuilding analysis (Field and He 2009). A manuscript providing additional details on bocaccio recruitment and the application of recruitment indices in the stock assessment will also be published in CalCOFI reports (Field *et al*. In revision).

Widow Rockfish (*Sebastes entomelas*)

A full stock assessment for widow rockfish was conducted in 2009. Unlike previous assessments that used ADMB direct codes, the Stock Synthesis program (SS3) was used in this assessment. All data and model structures were reanalyzed and reexamined and the assessment was reviewed by a STAR panel. The revised version of the assessment was submitted to the Pacific Fishery Management Council in August 2009. Since the species was declared to be overfished in 2001 and the population status in 2009 was still below desired management level, a rebuilding analysis was also conducted and its results were submitted to the Council for determining catch limits for 2011 and 2012.

Cowcod (*Sebastes levis*)

FED staff completed an updated assessment of cowcod (*S. levis*) in the Southern California Bight. The model was developed in Stock Synthesis II (SS2), and incorporated a revised time series of historical recreational landings (1928-1980). The final model estimated the 2009 spawning biomass to be approximately 4.5% of the unfished level (Dick *et al*. 2009a). For this stock in particular, there is an urgent need for an informative abundance index that can monitor the recovery of this stock, as past relative abundance information was derived from recreational CPUE time series that are now truncated due to a ban on retention and the establishment of the Cowcod Conservation Areas (CCAs) to rebuild the stock. A rebuilding analysis based on the updated stock assessment was also completed by FED staff (Dick *et al*. 2009b), estimating a median time to rebuild of 62 years (achieving target biomass with 50% probability in 2072).

Greenspotted Rockfish (*Sebastes chlorostictus*)

Staff at the SWFSC FED worked on developing a "data-moderate" approach to assessing a number of rockfish stocks in California. The approach relies on three types of input data: (1) catch (landings + discard), (2) life history information (natural mortality, growth, and reproductive parameters), and (3) length frequency data from the fishery. Because no trend indices are involved, the approach requires there to be a signal of the exploitation history in the length composition data. To test the method length composition data were simulated under an exploitation history similar to that which occurred in California over the last 30 years. The simulated data were then inputted to a stock assessment model that was implemented in the SS3 framework. Results of this feasibility study showed that under a variety of simulation conditions the approach is very capable of accurately estimating population trend, status, and abundance.

The method was then applied to the California greenspotted rockfish (*S. chlorostictus*) stock and findings were reviewed by a stock assessment review panel last year (Dick *et al*. In prep.). This species is important in both sport and commercial fisheries and has produced more landings than any California rockfish that has not been assessed. While clear patterns in the length-frequency data demonstrate a reduction in mean size and truncation of larger size fish during the 1980s and 1990s, with stabilization and recovery over the last 10 years, two factors prevented completion of a successful review. First, it was shown that growth of greenspotted rockfish varies spatially, with fish north of Point Conception being larger for their age than southern fish. There is also a suggestion that growth has changed over the last 30 years. Thus, to account for these factors a two-area model with time-varying growth is being developed. In addition, the size-at-entry to the fishery appears to have shifted to smaller fish as the population was fished. Whether due to changing size selectivity or retention, this aspect also requires further exploration and resolution before the assessment will be ready for use by management.

Bronzespotted Rockfish (*Sebastes gilli*)

Although not conducted as a part of the PFMC management cycle, the SWFSC FED developed a stock assessment for bronzespotted rockfish (*S. gilli*) in California waters, which underwent an independent review process that included a reviewer from the Center for Independent Experts (CIE) in September 2009. The bronzespotted rockfish is a rarely encountered, long-lived and slow growing species found primarily in southern California waters, and the assessment differs from most west coast groundfish assessments due to the lack of independent, informative indices of abundance. Insights into population status were largely gained by evaluating the relationship between the bronzespotted rockfish and cowcod (*S. levis*) fisheries, using a suite of data-poor modeling methods. It appears that the current abundance of bronzespotted rockfish is well below target levels, most likely on the order of 5% to 10% of the historical unfished abundance (MacCall *et al*. In revision). Management actions that have been implemented by the Pacific Fishery Management Council since 2000 to protect cowcod and other Southern California rebuilding species (including a specific ban on retaining bronzespotted rockfish based on conservation concerns), offer a feasible path to the conservation and rebuilding of this low productivity stock.

D. OTHER RELATED STUDIES

2. Molecular Genetics

Staff from the Fisheries Resources Division and academic collaborators have begun development of genetic markers linked to functional metabolic genes for use in studies of rockfish species. Recent work in cod and other fishes has shown that markers linked to such genes under environmental selection can better define regional populations than traditional neutral microsatellite markers. As several environmental compartments are present along the west coast of North America we hypothesize that regional selective pressures on *Sebastes* spp. exist, particularly at early life stages. Marker development has proceeded well and initial application to studies on bocaccio is planned for later this year.

Work on the redefined vermilion rockfish (*S. miniatus*) was completed that examined gene flow between populations and calculated larval dispersal values using 782 bp of DNA sequence data from the mitochondrial cytochrome b gene of 681 vermilion rockfish sampled from 16 sites between Kyuquot Sound, Canada and San Quintin, Mexico. Significant genetic heterogeneity was found among sample sites ($FST = 0.0742$, $p < 0.001$). Isolation by distance analysis produced a strong and significant correlation, suggesting that average larval dispersal distance is on the order of 10's of kilometers (Hyde and Vetter 2009). Analysis of molecular variance showed strong and significant partitioning of genetic variance across the biogeographic boundary at Point Conception ($FCT = 0.0923$, $p < 0.001$). Additional genetic barriers were found across Cape Mendocino, Punta Colnett, Santa Monica Bay, and along the coast of Washington. These genetic barriers conform to oceanographic compartments previously proposed for the California Current ecological geography province and suggest natural management units for this species at Cape Mendocino and Point Conception.

Staff from the Fisheries Ecology Division have also been investigating population structure of several species of *Sebastes* - shortbelly, kelp, widow, blue and black rockfish - in the California Current using data from 14-17 microsatellite markers per species. These studies have revealed a general lack of population structure in the Central/Northern California portion of this ecosystem (Gilbert-Horvath et al. 2007; Petersen *et al*. in prep). However, in blue rockfish a substantial signal of population structure was confirmed to be due to the presence of two cryptic groups of blue rockfish with little gene flow between them. These groups have tentatively been referred to as incipient species and assigned the interim names blue-sided and blue-blotched rockfish. These two fishes were found to be broadly sympatric, with separation between them not geographically-based (Petersen *et al*. In revision).

3. SWFSC Current Habitat Activities

SWFSC/FED Habitat Ecology Team conducts research in response to the mandates of the Magnuson-Stevens Reauthorization Act of 2006, with a focus on deep-water California demersal communities. Our goal is to provide sound scientific information to ensure the sustainability of marine fisheries and the effective management of marine ecosystems, with objectives to: (1) improve stock assessments, especially of overfished rockfish species in complex habitats; (2) characterize fish and habitat associations to improve EFH identification; (3) contribute to MPA design & monitoring and to Marine Spatial Planning; and (4) understand the significance of deep-sea coral habitats.

Monitoring MPAs off Central California.

With funds from California Ocean Protection Council and collaboration of academic partners, we are collecting baseline data on demersal communities (fishes, invertebrates, habitats) in deep portions of new MPAs and reference sites. Deep-water habitats comprise 75% of the seafloor in state waters off central CA, and yet far less is known about these habitats than in shallow water. We couple seafloor habitat maps with visual surveys conducted from the manned submersible *Delta* (Figure 5). These quantitative, non-destructive survey methods are necessary for an ecosystem approach to the management of diverse communities on rocky areas of shelf and slope. Long-term monitoring is needed to fully evaluate the benefits of these MPAs.

Improving Stock Assessments.

Using these same techniques, we have developed an extensive database of habitat-specific fish abundance for over 100 species of demersal fishes off CA. We have produced the first-ever fishery-independent stock assessment for cowcod, and will do so for several other rockfish species. These surveys will need to be repeated periodically to improve the assessments.

We also are using these data to evaluate the performance of two underwater survey vehicles (the *Delta* submersible and Phantom DS4 ROV). We compare habitat-specific densities estimated from the survey cameras of both vehicles and we determine changes in fish behavior as potential reaction to the survey tools. Similar species were seen in the visual surveys using each vehicle, but identification of species was more difficult using the ROV than using the submersible. Although fishes reacted to both vehicles, more fishes reacted to the ROV (51%) than to the submersible (18%). In general, fishes that occur higher off the bottom had a greater reaction to either vehicle than those fishes on the seafloor. Understanding survey biases, such as the ability to detect and identify various species and the behavioral response of the fishes to each vehicle, will result in improved survey design and interpretation, more accurate abundance estimates, and can help in selection of appropriate survey tools for specific species.

Predicting Distribution of Benthic Macro-invertebrates.

As part of the California Seafloor Mapping Project (CSMP), the FED Habitat Ecology team has been collaborating with USGS and others to create a suite of maps detailing seafloor morphology and geology, and characterizing potential benthic habitats derived from high-resolution multibeam sonar data. We are using a towed camera sled to groundtruth these data and to survey biological components of the habitats. From presence/absence of macro-invertebrates associated with specific sediment types, depth, and latitude, we have developed multivariate models using logistic regression to predict the distribution of various species. Coupling these results with spatial information on bottom type and depth, we have created maps of probability of occurrence of these important components of seafloor communities. These maps will provide managers, policy

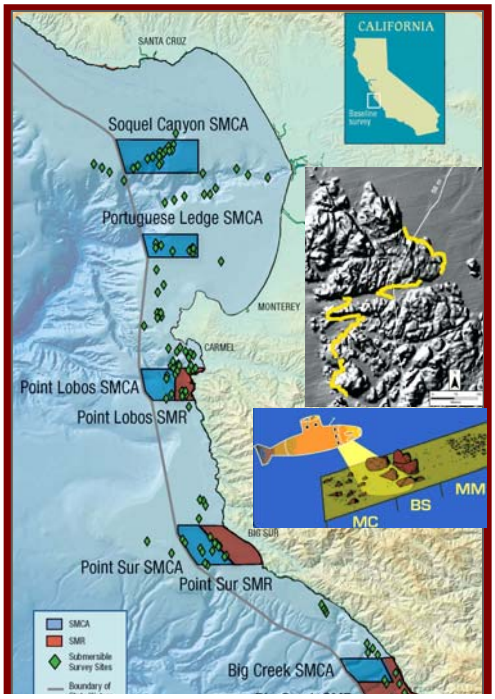

Figure 5: Survey sites in and out of MPAs off central CA. Top inset: Submersible transect over map of rock outcrop. Bottom inset: Schematic of habitat patches (mud, boulder, cobble, sand) along submersible transect.

makers, and the public with information that can be used in the conservation and management of sustainable marine resources.

NMFS' Marine Fisheries Habitat Assessment Improvement Plan (HAIP).

The FED Habitat Ecology group is leading a group of NMFS' scientists to develop the first nationally coordinated plan focused on marine fisheries aspects of habitat science. NMFS and all of its partners will benefit from and contribute to the success of the HAIP. This Plan will help to improve stock assessments and identification of EFH, and contribute to ecosystem-based management (EBM) and integrated ecosystem assessments (IEAs).

4. Economic Studies

The FED's Economics Team is developing a model of fishery dynamics using 1981-2007 vessel-and trip-specific data for all Pacific coast commercial fisheries (including groundfish). This model is intended to: (1) analyze patterns of fishing behavior across space and time, (2) identify biological, economic, regulatory and environmental factors underlying these behavioral changes, and (3) evaluate the cumulative effects of these changes on fishing communities. A shift-share model is being used to evaluate the extent to which port-level changes in fishing activity are related to regional changes in all fisheries and changes in the particular fisheries active in that port. A paper is in preparation that describes model results.

The Economics Team is also conducting an analysis of the effect of the 2003 vessel buyback program on technical efficiency in the Pacific coast groundfish trawl fishery. A Bayesian approach to estimating technical efficiency is being used in this analysis.

The Economics Team is working in collaboration with the Environmental Research Division (ERD) on an analysis of the economic effects of the Rockfish Conservation Areas (RCAs) on California's groundfish trawl fleet. Using 1997-2005 trawl logbook data, landings receipt data, and regulatory information, ERD has created maps depicting the spatial distribution of trawl effort and harvest (pounds and ex-vessel value) before and after the RCAs were established. For each year after RCA implementation (2003), the maps also include layers that depict the particular RCA boundaries that applied in that year. The Economics Team is collaborating with ERD on research pertaining to adaptations by California groundfish trawlers to the RCAs in terms of spatial redistribution of effort and changes in fishing strategies. A paper on this topic is currently in preparation.

The Economics Team has completed separate economic surveys of southern and northern California recreational anglers. Both surveys involve collection of data on angler fishing patterns, preferences, expenditures and demographics. In addition, conjoint methods are being used in the southern California survey to determine angler preferences for rockfish versus other species, and in the northern California survey to determine angler preferences for differing combinations of groundfish regulations (bag limits, area and season closures); the survey was completed in 2009 and data analysis will occur in 2010.

GROUNDFISH PUBLICATIONS OF THE SWFSC, 2008 – PRESENT

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