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Northwest Fisheries Science Center

National Marine Fisheries Service

2003 Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

March, 2004

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 focus for most of the research reported by the NWFSC to the Technical Subcommittee of the Canada-US Groundfish Committee. The FRAMD works in partnership with state and federal resource agencies, universities, and the groundfish industry to achieve a coordinated groundfish program for the West Coast.

FRAM consists of a multi-disciplinary team with expertise in fishery biology and ecology, stock assessment, mathematical modeling, statistics, computer science, and field sampling techniques. Additional members of this program are stationed at the NWFSC in Seattle. 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 multispecies fisheries; design programs to provide information on the extent and characteristics of bycatch in commercial fisheries, as they look at methods to reduce fisheries bycatch; characterize essential habitats for key groundfish species; and investigate the design, feasibility, function, and value of marine protected areas.
Research facilities in Newport on the Oregon coast are particularly important for groundfish research. The Newport location provides opportunities for staff to work with and share information and ideas with researchers from Oregon State University, the Oregon Department of Fish and Wildlife, Alaska Fisheries Science Center, U.S. Environmental Protection Agency, and the fishing industry.

During 2003, the FRAMD continued to: implement a West Coast observer program; build a survey program that will conduct West Coast groundfish hydroacoustic and trawl surveys previously conducted by the AFSC; and further augment 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.

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 biomonitoring 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 Center Director Dr. Usha Varanasi at (206) 860-3200, Usha.Varanasi@noaa.gov.

B. Multispecies Studies

1) Research

Historical foreign catch of rockfish (Sebastes and Sebastolobus sp.) off California, Oregon, and Washington was allocated to individual species by year and INPFC area. Allocation involved selecting 1965-1976 foreign catch estimates, separating that catch by fishing strategy, and finally applying species compositions specific to each strategy. Total foreign rockfish catch for 1965-1976 was estimated at 115,799 mt. Top ten species in the catch (in order of decreasing importance) were Pacific Ocean perch, shortbelly rockfish, widow rockfish, bocaccio, splitnose rockfish, darkblotched rockfish, yellowtail rockfish, shortspine thornyhead, chilipepper rockfish, and canary rockfish. Details of the allocation are available in the following 2003 NOAA Technical Memorandum:

Rogers, Jean Beyer. 2003. Species Allocation of Sebastes and Sebastolobus sp. caught by foreign countries from 1965 through 1976 off Washington, Oregon, and California, USA. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-57, 117 p.

This allocation provides a consistent approach for all rockfish and will be utilized in 2004 stock assessments. In the past, stock assessment authors for Pacific Ocean perch, darkblotched rockfish, yellowtail rockfish, and canary rockfish have used varying approaches, resulting in overlapping catch allocations. Stock assessment authors for the other rockfish species have assumed no foreign catch.

For more information, contact Dr. Jean Rogers at Jean.Rogers@noaa.gov, (541) 867-0535.

2) Stock Assessment

Unassessed Species

Quantitative assessments of many West Coast rockfish stocks of both major and minor importance to commercial fisheries have shown varying declines in abundances. The population sizes of less-abundant, co-occurring unassessed species may also be declining. However, determining stock status of the many non-targeted, minor species with high levels of certainty and quantifiable predictability may be prohibitively expensive and/or impractical because of the dearth of available data. Using a system of qualitative indicators may provide a cost-effective method to create preliminary assessments of the relative status of minor rockfish stocks and subsequently prioritize future studies. Therefore, this project used an array of indicators including catch-per-unit-effort, the proportion of positive hauls, and length composition data to detect population trends of minor West Coast rockfish species including *Sebastes aurora*, *S. babcocki*, *S. aleutianus*, *S. zacentrus*, *S. borealis*, *S. diploproa*, and *S. reedi*. Data were taken from three West Coast bottom trawl surveys conducted by the National Marine Fisheries Service. A ranking system of relative concern was created based on the generated trends in the indices using a modified categorical point-scoring approach. The interpretation of the health of the population projected by the indicators was compared to the population status based upon formal stock assessments for four species, *S. alutus*, *S. crameri*, *S. melanostomus*, and *S. rufus*.

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C. By Species, by Agency

1) Shelf Rockfish

West Coast

a) Research

Statistical methodology for bomb radiocarbon ageing validation. The use of the radiocarbon signal from atmospheric testing of nuclear weapons in the middle of the twentieth century has emerged, over the past decade, as a reliable method for ageing validation. The bomb radiocarbon method uses measured radiocarbon levels in otolith cores to validate the annulus

counts determined by break and burn or other ageing methodologies. We have developed a statistical method to rigorously compare reference radiocarbon data sets to each other and to compare test data sets to reference data sets. The statistical method evaluates assumptions inherent to radiocarbon validation and the degree of ageing bias. With this method, we combined time series from two studies that used known-age fish, haddock from the North Atlantic and Pacific halibut from the Northeast Pacific, to create a single robust reference for North American species. We tested six published data sets for various species from the published radiocarbon validation literature, showing fairly widespread evidence of under-ageing. Under-ageing is of particular concern for stock assessments in that, through biased age compositions, stock assessments can be overly optimistic about the productivity of a species.

We applied this method to canary rockfish by selecting and coring otoliths for radiocarbon analysis. To test two assumptions of the method, two sampling designs were used. A sampling design that controls for age-dependent ageing error allowed for testing the assumption of parallelism of the standardized rates of bomb radiocarbon increase for the validation and reference time series. A second sampling design that produces a linear relationship between the estimated age and birth year allowed for testing the assumption of ageing error consistency. Neither assumption was shown to be statistically invalid. Using the combined data sets, the similarity of the timing of increase in 14C levels in the canary otolith cores and the reference time series indicated that the canary rockfish ages determined using the break and burn method are reasonably precise, though with an average underaging bias of 2-3 years. We are currently working on validating the ageing of other species using this methodology.

Manuscripts describing this work have been submitted to the Canadian Journal of Fisheries and Aquatic Sciences.

For more information, contact Owen Hamel at (206) 860-3481, Owen.Hamel@noaa.gov, or John Wallace at (206) 860-3456, John.Wallace@noaa.gov.

b) Stock Assessment

Pacific ocean perch. In 2003, Pacific ocean perch (*Sebastes alutus*) (POP) were assessed for the combined US Vancouver and Columbia INPFC areas. The assessment uses a forward projection age-structured model. New data and changes to the data from that used in the 2000 assessment include updated (and reduced) estimates of historical foreign catch of Pacific ocean perch; biomass indices and age- or size-composition data (for some years) from the Alaska Fisheries Science Center (1992, 1996, 1997, 1999-2001), and Northwest Fisheries Science Center (1999-2002) slope surveys, and the most recent year of data from the triennial shelf survey (2001). Four years (1999-2002) of break-and-burn fishery age data were newly available and included when fitting the model. The inclusion of non-independent fishery age- and size-composition data for 13 years (1968-80) was removed, by omitting the size-composition data from the model fit. Two additional years of fishery catch data (2001-2), along with updated PacFin catch records for the years 1981-2000, were available and were included in the assessment. The reduction of the historical catch estimates had the greatest effect of the changes and additions to the data, resulting in lower estimates of both equilibrium unfished biomass and maximum sustainable

yield.

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 on alternative model structures / data set choices suggested 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 and the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of Pacific ocean perch.

For full documentation go to http://www.pcouncil.org/groundfish/gfsafe0803/gfsafe0803.html
For more information, contact Owen Hamel at (206) 860-3481, Owen.Hamel@noaa.gov.

Yellowtail Rockfish. The Pacific Fishery Management Council (PFMC) manages the U.S. fishery as two stocks separated at Cape Mendocino, California (40°30'N). This report presents the "coastwide" stock extending from Cape Mendocino to approximately 49°N. Traditionally, this coastwide stock is divided into three unit stocks: Southern Vancouver stock from Cape Elizabeth (47° 20'N) to approximately 49°N, Northern Columbia stock from Cape Falcon (45° 46'N) to Cape Elizabeth (47° 20'N), and Eureka/South Columbia stock from Cape Mendocino (40° 30'N) to Cape Falcon.

Due to redistribution of rockfish species composition and the new estimation algorithm, the catch data in the three stock areas were different from that reported in the last assessment. Based on the revised catch data, U.S. coastwide total catch reached a plateau at around 9,000 mt in 1978-1983 and then declined due to trip limits imposed in 1985. Annual U.S. landings decreased to 1,454 mt in 2002.

The following new information were included in the analysis: (i) 2001 NMFS survey abundance index and catch at age (sex-combined), (ii) the revised catch series by using new estimation methods, and (iii) catch at age and weight-at-age data by sex for 1999-2002. However, the domestic trawl CPUE index from 1988 to 1999 and the whiting fishery bycatch index from 1978 to 1999 were kept as they were assessed in 2000 because the changing fishery regulations make have altered the statistical properties of these abundance indices. Also, the area specific matureogive and age transition matrix were kept as they were assessed in 2000 due to insufficient new data. The stock assessment model is an age-structured model written with AD Model Builder software in 2000. The reference model is to fit the newly revised catch series of the coastwide stock.

There were concerns on usefulness of auxiliary abundance indices and their time-variant catchabilities as the stock was assessed in 2000. These concerns remain even if the whiting bycatch index and CPUE index were not updated and were treated to be non-informative. The survey indices fluctuated over the surveys, which may be the cause of flat trend in estimates of biomass. The effects of low age-4 recruitment in 1995-2002 on future management have yet to be evaluated. Concerns are also on low precision and potential bias for parameter estimation in

2002, especially the recruitment.

Assuming constant recruitment, equal to the average of 1967-2000 (13.0 million fish), the estimates of unfished biomass (B_0) is 115,493 mt, unfished spawning biomass (SPB_0) is 33,329 mt, target level spawning biomass ($SPB_{40\%}$) is 13,332 mt, overfishing threshold spawning biomass ($SPB_{25\%}$) is 8,332 mt and the recommended fishing mortality rate ($F_{50\%}$) is 0.091. The estimated coastwide biomass in year 2002 was 63,388 mt with a 26% CV. The estimated 2000 biomass was 66,933 mt in this assessment, compared with 69,400 mt estimated in the last assessment. In general, the trends of total biomass and population size in number of fish are declining. Total biomass in 2002 is 46% of the 1967. The spawning biomass is estimated to be 155% of the target spawning biomass ($SPB_{40\%}$).

Annual fishing mortality peaked in 1982 (F = 0.17). From 1983 to 1996, F fluctuated in the range of 0.06 to 0.17. However, F was in range of 0.04 to 0.09 after 1996, due to more restricted regulations on other overfished rockfishes.

Under the Council's $F_{50\%}$ policy and assuming the constant recruitment (equal to the geometric mean of 1967-1997) the profile of 3-yr mean yield is 3,133 mt at 25-percentile, 3,971 mt at 50-percentile, and 5,034 mt at 75-percentile. The projected coastwide 3-yr average yield for 2004-2006 is 3,966 mt. The Council adopted ABC/OY for 2001-2003 was 3,146 mt. Council ABC and OY determinations need to account for the expected harvest by Canadian fishers.

Recommendations: (1) Increase sampling effort for age, length, weight, and maturity data; (2) Estimate new discard rate with the new observer data; (3) Investigate the effects of current low recruitment events on the future perspective of fisheries; (4) Include all landings in stock assessment; and (5) Assess the status of stock in area south of Cape Mendocino.

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2) Slope Rockfish

West Coast

b) Stock Assessment

Darkblotched Rockfish. Stock assessment and rebuilding analyses were updated for the population of darkblotched rockfish (*Sebastes crameri*) off the Pacific west coast United States between Mexico and Canada. This was the second update of the 2000 assessment, which used the length-based stock synthesis model. The first update was the basis of the 2001 rebuilding plan. The first update added data through the year 2000 and refit recruitments. This year's update added 2001 AFSC survey data and fishery data through 2002 and refit all parameters. Since the late 1990's, estimated biomass has increased and catch and exploitation rates decreased. Biomass (mt) of age 1+ fish at the start of the year declined until 1999 and then increased. Recent increase in biomass is partly due to high estimates for 2000 age 1 recruitments. Estimated catch has declined in recent years with increasing management

restrictions. The estimated exploitation rate (catch/biomass available to fishermen) has progressively dropped since 1998.

Although the model was extended through 2002**,** management was based on recruitments estimated only through 2000. This was viewed as a moderate choice, balancing a desire to use new information while recognizing risks from estimating recent recruitments using limited data. Allowable Biological Catch (ABC) and Optimum Yield (OY) for 2004 were higher than in 2003. ABC (Fmsy proxy at F50%) was lower than OY (80% probability of rebuilding to Bmsy by 2047) due to different time scales. The high 2000 age 1 recruitment would not greatly affect biomass available to the fishery in 2004, but would increase ability to rebuild the stock by 2047. Three sources of uncertainty affected fixed values or model structure and were therefore beyond the scope of an update. Age data produced for this update had different aging error and possibly aging bias than did earlier age data. Also, newly published indirect estimates suggest darkblotched rockfish natural mortality is higher than the value assumed in the model (Gunderson et al. 2003). Finally, NWFSC slope survey data from 1999-2002 were not included in this update. Those data were not combined with AFSC slope survey data because the two sources had different length compositions and trends for years with data from both sources. Exploratory models with either higher natural mortality or the NWFSC survey as a separate index increased spawning biomass relative to unfished levels. In both cases, however, the models fit extremely high 2000 recruitments and very low early recruitments.

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3) Sablefish

West Coast

a) Research

Depth Distribution of Sablefish. This year's main objective was to determine if the sablefish existed outside the usual range of the trawl survey. Specifically, we sought to investigate the areas of pinnacles and slopes that exist outside the first 700 fathom contour but would still be shallow enough to sample with standard trawl gear (700 fathom). If sablefish did exist on these pinnacles our goal would be to determine the relative densities of those fish and to further determine if those fish where different than those sampled by the trawl survey with respect to length, age, and sex ratio.

During Leg 1 (July 7-14, 2003) pot gear was set at 12 stations sampled by the trawl survey. Pot sets were made within 48 hours and between one quarter and one half miles from the trawl site. These stations are collectively referred to as "inside" stations. During Leg 2 (July 18-25, 2003) pot gear was set at 12 stations outside the usual range of the trawl survey (west of the first 700 fathom contour) at station located on the tops and slopes of topographic features that are referred to as pinnacles. These stations are collectively referred to as "outside" stations.

Station depths sampled by both gear types (inside) were similar to those sampled by only the pot gear (outside). As all stations were 700 fathom, in theory all should be trawlable gear. However, factors such as bottom hardness could render some outside stations untrawlable. Mean individual weight of sablefish was lower at the inside stations (1.83 kilograms) than at the outside stations (2.92 kilograms). Mean density of sablefish by numbers (mean number of fish-per-pot) was slightly higher at the inside station (14.4 fish-per-pot) than at the outside stations (10.0 fish-per-pot). Mean density of sablefish by weight (mean weight of fish-per-pot) was slightly higher at the inside station (25.4 kilograms-per-pot) than at the outside stations (23.1 kilograms-per-pot). Sex ratios by station departed from 50:50 much more so at the outside stations than at the inside stations. Sex ratio was not dependent on depth at the inside stations but highly dependent on depth at the outside stations. Caches tended to be biased towards males at the tops of the pinnacles while catches made on the adjoining slopes tended to biased towards females. Catches dominated by females were of lower density than those dominated by males. Sablefish densities at the inside stations were very similar to those at the outside stations. Sablefish caught at the outside stations were larger in size and more distributed by sex than those caught at the inside stations. While it is apparent that the trawl survey is missing this segment of the population, it has yet to be seen whether or not these fish remain unaccounted for in "virtual population" that is created in the assessment model. In Leg 3 we will again sample stations that the trawl gear samples (different stations than Leg 1). In Leg 4 we will sample the same stations as in Leg 2 in an effort to determine if the density of sablefish changes and whether or not the sex-based segregation remains in tact.

For more information, contact Dr. Michael Schirripa at (541) 867-0536, Michael.Schirripa@noaa.gov.

Changes in sablefish *(Anoplopoma fimbria*) recruitment in relation to oceanographic conditions. Sablefish (*Anoplopoma fimbria*) range from the southern west coast of the United States, north to Alaska, the Bering Sea, and west to Japan. The species supports substantial fisheries in both the east and west Pacific Ocean. Juvenile recruitment along the west coast of the continental United States has been highly variable over the past three decades. Examining the estimates of spawning stock biomass from extensive surveys made over this same period point to the fact that factors external to the sablefish population dynamics have significant effects on population level recruitment. Using a General Additive Model (GAM), we demonstrate that there are physical oceanographic variables that significantly interact with sablefish recruitment. Significant relations were found between juvenile recruitment and northward Ekman transport, eastward Ekman transport, and sea level during key times and at key locations within the habitat of this species. The overall model explains nearly 70 percent of the variability in sablefish recruitment between the years 1974 and 2000. Bootstrapping techniques were applied to the parameter estimates and the resulting distributions were found to support the modeling assumptions of normality. Given the above model, it is possible to draw preliminary conclusions concerning year class strength of cohorts not yet available to the survey gear as well as historic year class strengths.

For more information, contact Dr. Michael Schirripa at (541) 867-0536, Michael.Schirripa@noaa.gov.

4) Pacific Hake

West Coast

a) Research

US-Canada Hake/Whiting Working Group

In 2003, a joint U.S.-Canada acoustic survey of coastal Pacific hake was completed. Scientist teams from both the U.S. and Canada participated on all legs of the cruise that was conducted aboard the vessel CCGS W.E. Ricker from 29 June to 1 September 2003, covering the length of the west coast from south of Monterey California to the Dixon Entrance area. A total of 119 line transects were completed. During the acoustic survey, aggregations of hake were found along the continental shelf break from just north of San Francisco Bay to Queen Charlotte Sound. Peak concentrations of hake were observed north of Cape Mendocino, California, in the area spanning the US-Canadian border off Cape Flattery and La Perouse Bank, and in Queen Charlotte Sound. As revealed by the associated midwater and bottom trawl samples, the majority of the coastal stock is currently dominated by the 1999 year-class (age 4). Our understanding of the level of abundance of Pacific hake was changed by the 2003 biomass estimate and subsequent assessment. The previous hake assessment in 2002, estimated spawning stock size to be at 20% of unfished in 2001. Because the stock was estimated to be below B25%, Pacific hake were declared overfished in 2001. New information in the 2003 assessment includes fishery age composition in 2002 and 2003, but more importantly, the results of the 2003 acoustic survey. The increase in biomass in the 2003 acoustic survey and the dominance of the 1999 year class in both fishery and survey data suggest that the 1999 year class is even higher than previously estimated.

Also, on November 21, 2003, U.S. and Canada signed an agreement that allocates a set percentage of the Pacific whiting catch to American and Canadian fishermen over the next decade. In this agreement, a Joint Technical Committee (JTC) will be established, as well as a Scientific Review Group (SRG) to provide independent peer review of the work of the JTC. These technical working groups would replace the historical working and STAR/PSARC groups -- the agreement is now in review by each government for ratification.

For more information, contact Guy Fleischer at (206) 860-3289, Guy.Fleischer@noaa.gov.

Analysis of variable annual growth in Pacific hake, *Merluccius productus*. Past El Niño Southern Oscillation (ENSO) events have affected populations across tropic levels in the northeastern Pacific Ocean (Barber and Chavez 1983). Understanding these past environmental variations and their effect on the growth of Pacific hake is necessary for management to make informed decisions. Fish otoliths contain chronological records of environmental histories experienced at the individual level, and we assume that otolith growth increments can be used as a proxy for somatic growth. Therefore, otoliths can be used to correlate past environmental variations to fish growth. The 1983 ENSO event was very strong and was associated with

reduced otolith growth increments in Pacific hake (MacLellan and Saunders 1995). The objective of this study was to determine if a similar reduction in growth occurred during the 1997 ENSO event, which was comparable in strength and duration to the one of 1983.

b) Stock Assessment

The coastal population of Pacific hake (*Merluccius productus*, also called Pacific whiting) was assessed in February 2004 using an age-structured assessment model. The U.S. and Canadian fisheries were treated as distinct fisheries. The primary indicator of stock abundance is the acoustic survey, and a midwater trawl juvenile survey provides an indicator of recruitment. New data in this assessment included updated catch at age through 2003, recruitment indices from the juvenile survey in 2003, and results from the U.S./Canadian acoustic survey conducted in summer of 2003. Based on the new acoustic survey and updated data, the strength of the 1999 year class, and consequently mature female spawning biomass was greater than previously estimated in the 2002 assessment. The current assessment results reflect uncertainty that is represented by a range of biomass. The lower biomass end of the range is based upon the conventional assumption that the acoustic survey catchability coefficient, Q=1.0, while the higher end of the range represents the Q=0.6 assumption.

The coastal stock of Pacific hake in 2003 was estimated to range from 2.6 to 4.0 million mt (age 3+ biomass) for the Q=1.0 and Q=0.6 model scenarios, respectively. Stock biomass increased to a historical high in 1987 due to exceptionally large 1980 and 1984 year classes, and then it declined as these year classes passed through the population and were replaced by more moderate year classes. Stock size stabilized briefly from 1995-1997, but then it declined continuously to its lowest point in 2001. Since 2001, stock biomass has increased substantially as the strong 1999 year class has entered the population. The mature female biomass in 2003 was estimated to range from 47% to 49% (Q=1.0 and Q=0.6) of an unfished stock. Thus the stock can be considered to be rebuilt to the target level of abundance only 3 years after reaching a low level that resulted in the depleted (overfished) determination. The hindcast estimation of biomass in 2001 remains near, but slightly above, the depleted level (25% of the unfished level). The coastwide ABC and OY for 2004 are estimated to be 501,000 mt and 740,000 mt (Q=1.0 and Q=0.6) based upon a F40% harvest rate and 416,000 mt and 630,000 mt (Q=1.0 and Q=0.6) based upon the F45% harvest rate. With biomass above 40% unfished biomass level, the 40:10 OY adjustment would not be applied. Projections beyond 2004 are for a decline in stock biomass and ABC-OY as the 1999 year class passes through its age of peak abundance. At this time there is no evidence of sufficiently large recruitments after 1999 to maintain the stock at a high abundance level. By 2006, the spawning stock biomass is projected to again decline to near the depleted threshold (25% unfished). Such a rapid increase and subsequent decrease in stock abundance and potential yield is to be expected for a stock with such extreme fluctuations in recruitment. A new examination of the harvest policy that takes into account this variability is recommended for this highly fluctuating stock.

The hake assessment is highly dependent on acoustic survey estimates of abundance. Since 1993, the assessment has relied primarily on an absolute biomass estimate from the joint US-Canadian acoustic survey. The acoustic target strength of Pacific hake, used to scale acoustic

data to biomass, is based on a small number of *in situ* observations. While the fit to the acoustic survey time series has improved with revision of the survey biomass estimates (1977-1992) these are still uncertain with poor fits in some years. Large fluctuations in the most recent estimates of recruitment and biomass (2001) are not entirely unexpected given the high uncertainty in terminal year estimates. This is because the information content regarding the 1999 year class, in particular, was only present as age 2 fish in the 2001 fishery and acoustic survey age compositions, and coupled with the relatively low acoustic survey biomass in 2001 produced lower estimates. The addition of new information regarding fishery and survey age compositions, along with the 2003 survey biomass estimate, decreases the level of uncertainty about this year class.

Uncertainty in the assessment result is characterized in terms of variability in model parameters and in terms of the assumption regarding the acoustic survey catchability coefficient, Q. All past assessment results and recommendations have been based upon fixing the acoustic survey Q=1.0; thus asserting that the acoustic survey estimate of biomass is an absolute measure of biomass and not just a relative measure. The past several assessments have explored relaxation of this assumption, but final results have been based upon the Q=1.0 scenario. The ability to relax the Q=1.0 assumption in this year's assessment is based upon: 1) continued lengthening of the acoustic survey time series, thus allowing the survey to be treated as an index of relative abundance in the model; 2) relatively better model fits to the data when Q is less than 1.0; and 3) high quality of expertise in the STAR Panel to allow critical examination of the Q=1.0 assertion. Uncertainty in the final model result is therefore represented by a range of biomass. The lower biomass end of the range is based upon the conventional assumption that the acoustic survey catchability coefficient, Q=1.0, while the higher end of the range represents the Q=0.6 assumption. Even lower Q values are indicated by some model runs, but these are considered by the STAT team and STAR panel to be implausibly low. Future assessments may be able to explore alternative model configurations that could provide more insight on which aspect of the data lead to the low Q estimates.

The relative probability of the range of plausible Q levels was discussed extensively at the STAR. The two endpoints are considered as less likely than intermediate points and an equal blending of results from the two endpoints is not unreasonable.

Acoustic Survey Recommendations:

1. a) Determine whether there are differences in survey performance between the WE Ricker & Miller Freeman. These include differences in mid-water and bottom trawl efficiency as well as differences in acoustic capabilities between the vessels. Analyze the available data to determine if we can continue to accept the null hypothesis that there is no difference in survey performance between these vessels;
   b) Perform a detailed meta-analysis across all survey years: compare spatial distributions of hake across all years and between bottom trawl and acoustic surveys to estimate changes in catchability/availability across years;
   c) Generate appropriate estimates of variability for every survey year; and
   d) Review the methods used to estimate proportions at age for the acoustic survey with
2. Estimation of Target Strength

a) Evaluate the current target strength for possible biases, particularly the use of nighttime experiments which are applied to daytime survey transects. Explore alternative methods for estimating target strength;
b) Assess the value of the recent Canadian hake target strength observations and, if these are assessed to be useable, add these into the target strength model; and
c) Commission the acquisition of additional in-situ observations to increase the model sample size.

For more information, contact Thomas Helser at (206) 302-2435, Thomas.Helser@noaa.gov.

5) Estimates of Pacific Halibut Bycatch and Mortality in IPHC Area 2A in 2002

West Coast

a) Research

The estimate of Pacific halibut bycatch and mortality in the bottom trawl fishery was updated through the calendar year 2002. The estimate of halibut bycatch and mortality in the bottom trawl fishery is based upon the method developed in the report for 1999 (Wallace, 2000). The 2002 analysis uses halibut bycatch rates observed from 31 August 2001 thru 28 August 2002 in the West Coast Groundfish Observer Program. These rates are stratified by season, depth, latitude, and level of arrowtooth flounder catch, and then multiplied by the amount of trawl effort in each stratum determined from Oregon and Washington trawl logbooks in 2002. Estimated halibut bycatch and mortality in other gear types was not updated for 2002.

For more information, contact John Wallace at (206) 860-3456, John.Wallace@noaa.gov.

6) Pacific Mackerel and Sardines

West Coast

a) Research

Pacific mackerel, jack mackerel, and Pacific sardine are seasonally abundant off Oregon and Washington. Sardines presently support a purse-seine fishery off N Oregon/SW Washington and spawn off the Northwest in summer. Presently, fish catches from the NOAA Fisheries/BPA Columbia River Plume surface trawling surveys and Predator/Baitfish surveys off the Columbia River are being used as annual relative indices of abundance. Ocean temperatures and currents appear to play an important role in sardine and mackerel distribution and abundance. The Fish Ecology (FE) division is working with the SWFSC to develop a coast-wide estimate of Pacific sardine abundance.

Pelagic trawl surveys off Oregon/Washington indicate that northern anchovy are now relatively

abundant and there have been commercial landings. The increased abundance appears to be linked to cooler ocean conditions that started in 1999. The abundance of northern anchovy and other forage fishes may be partly responsible for the recent increases in the salmonid marine survival and subsequent improved adult runs.

For more information, contact Robert Emmett at Robert.Emmett@noaa.gov, (541) 867-0109.

D. Other Related Studies

1) Age, Growth and Maturity of Longnose Skate, *Raja rhina,* from the U.S. West Coast.

The two greatest accomplishments made since September include the optimization of an ageing technique and finding a reliable source for monthly samples of longnose skates. In order to arrive at a satisfactory procedure, several different methodologies were tested on centra which had been collected during the summer of 2002, on the West Coast slope survey. All of these methods were used to age vertebral centra of other elasmobranch species in the past. The preparation tests varied in several of the following respects: 1) the chemical(s) used to stain the age structure (which helps clarify the bands), 2) the part of the centrum which is stained (half-section, thin-section, or exterior of a whole centrum), 3) soak time in the stain, and 4) concentration of stain solution. Also tested were the difference between thin-sections, which were soaked in ethanol before being stained, and thin-sections which were not. Soaking in ethanol has been shown to help clarify the growth bands in otolith age structures, and is a common practice.

The results of these tests were presented in a poster at the Western Groundfish Conference, attended during the week of February 9-13, 2004 in Victoria, B.C At the conference, I was able to meet with a few more of the skate species experts from Moss Landing Marine Lab (MLML), as well as a few people studying skate species found off the coast of Canada and in the Bering Sea.

Living in Newport has also facilitated the collection of monthly samples (25 individuals per month) from the docks, which are needed for the age validation portion of my research. The employees at Pacific Shrimp seafood plant trust me, and have been willing to give me full access to their skates. Since I do not do any damage to the pectoral fins in my sampling, which is the only meat from the animal that is used, I simply put the skates back on ice when I am done with them. I have now collected samples for the months of November, January, February and March. Therefore, it looks as though I will be collecting these samples through October 2003.

For further information, contact Josie Thompson at (541) 867-0520, Josie.Thompson@noaa.gov.

2) At-sea Hake Observer Program

The at-sea hake observer program continued to deploy observers to collect total catch and species composition data on the at-sea hake motherships and catcher-processors. The vessels fish

in waters from the Canadian border to Northern California. A class of 22 observers was briefed from May 7th to 9th. All participating vessels in the 2003 fishery carried two observers and fished from May 15th to October. Over 98% of all the hauls were sampled by observers.

The observer program is run entirely by NWFSC FRAM D staff. However, as all of these vessels also participate in the Alaskan fisheries, they already have an observer data transmission system (ATLAS) on board. Also, the data collection protocols followed by the observers are those utilized by the North Pacific Groundfish Observer Program. Therefore, because of the assistance provided by the North Pacific Groundfish Observer Program, the collected data is stored on AFSC's computer system (NORPac) and observers use the gear similar to that issued to observers deployed in the North Pacific.

The goals of the program are to collect:
1) Total catch data,
2) Species composition of the catch,
3) Biological samples of hake, rockfish bycatch, prohibited species and protected species.

The Northwest Regional Office uses the observer catch data for in-season management of the at-sea hake fishery. In addition, stock assessment scientists use the collected hake biological samples for use in hake assessments.

For more information, contact Vanessa Tuttle at (206) 860-3479, Vanessa.Tuttle@noaa.gov.

3) Bycatch Modeling

In 2001, a model was developed within FRAM for purposes of projecting groundfish trawl catch of target species, and associated bycatch of several groundfish species that have been listed as overfished and are subject to rebuilding plans. During 2003, data collected from the trawl fleet during the first year of observation by the WCGOP were incorporated into the model. Bycatch rates were calculated for species under rebuilding plans, relative to the retention of target species. These rates were then applied to projected target species landings within the model in order to calculate bycatch mortality. Additionally, for pre-season modeling management options for the 2004 fishery, discard rates for major target species were also derived from the observer data and integrated into the model. The availability of WCGOP data represents a major step forward in the ability to accurately estimate total mortalities for both bycatch and target species, under the current management regime.

For more information, contact Dr. Jim Hastie at (206) 860-3412, Jim.Hastie@noaa.gov.

4) Comparison of Submersible Surveys on Heceta Bank, Oregon: Changes in Groundfish Populations after a Decade

This project is part of a larger ongoing study of groundfish habitat on Heceta Bank. This has been an interdisciplinary project involving Waldo Wakefield (NWFSC FRAM Division), Brian

Tissot (Washington State University Vancouver), Mark Hixon (Oregon State University), David Stein (NOAA OAR), William Barss (ODFW Newport), Mary Yoklavich (SWFSC Santa Cruz), and Julia Clemons (NWFSC FRAM Division).

During Fall 2002, a major submersible dive series was completed on Heceta Bank, Oregon with the Delta submersible. The purpose of this project was to conduct a comparison of habitat-specific densities for groundfish inhabiting the Bank between surveys completed in the late 1980's and the present (2002). Considerable effort was employed to duplicate the original survey to reduce bias. The survey followed the historical methodologies, utilized the same submersible, took place during the same season (September), shared some of the original pilots, and was restricted to the original observers (Hixon, Stein, and Barss). These data were worked up in 2003 and are being incorporated into posters and talks that will be presented at conferences in 2004. Following is a brief overview of some results from that work.

The density of numerically dominant and commercially important fishes within different habitat types was examined for statistically significant changes between periods to determine long-term trends. The abundance of many species in 2002 fell within the range of interannual variation displayed in 1988-1990. However, a few species declined and other species increased in abundance in 2002 relative to earlier surveys. These abundance patterns will be examined in relation to the spatially explicit intensity of fishing on and near our survey sites derived from trawling records and with the AFSC and NWFSC trawl surveys.

For more information, contact Waldo Wakefield at (541) 867-0542, Waldo.Wakefield@noaa.gov, or Brian Tissot at tissot@vancouver.wsu.edu.

5) Cooperative Ageing Unit

The NWFSC continues its collaborative effort with Oregon Department of Fish and Wildlife and the Pacific States Marine Fisheries Commission to maintain a laboratory dedicated to the ageing of west coast groundfish. In 2003, Oregon Department of Fish and Wildlife withdrew from the role of officially supervising the lab and the vacancy was filled by Mr. Patrick McDonald of Pacific States Marine Fisheries Commission. From August 2003 to January 2004 12,561 otoliths were aged by the Cooperate Ageing Project. The species and number of associated otoliths aged for this reporting period include; Pacific hake Merluccius productus (5759), darkblotched rockfish Sebastes crameri (1996), sablefish Anoplopoma fimbria (1933), Dover sole Microstomus pacificus (1841), Pacific Ocean perch S. alutus (723), Canary rockfish S. pinniger (291) and blackgill rockfish S. melanostomus (18). The total number of otoliths aged includes production (7795), training (1400), double read (2842) and research related ageing (724).

The only stock assessment for which production ageing directly supported for this reporting period was for Pacific hake (whiting). The otoliths aged for this assessment account for 45.8% of the total (12,561) otoliths aged. An otolith exchange with the ageing lab in Naniamo Canada was completed and analyzed. An interlab workshop is planned to take place in the upcoming 2004 Committee of Age Reading Experts conference to further increase precision and reduce bias between the two labs. Darkblotched rockfish otoliths from the 1995, 1998 and 2001 federal

shelf surveys were re-examined and re-aged. It was determined that the 1995 and 1998 surveys were aged using an inconsistent criteria compared to the 2001 survey.

Production age reading has been lower than normal due to several factors: 1) Non-assessment year has allowed for individuals to perform age related research in collaboration with NMFS personnel. Research performed will contribute to future stock assessments; 2) Re-ageing of darkblotched rockfish from three federal surveys was very time consuming for our darkblotched rockfish lead ager; 3) Our four newest age readers are continuing to learn and gain experience in age reading. This means that more time than normal has been allowed for training purposes; and 4) The Pacific hake (whiting) ageing manual that is to be incorporated into the Committee of Age Reading Experts groundfish-ageing manual was not completed. The completion date has been pushed back. There are two reasons for this: 1) The individual responsible for completing the Pacific hake (whiting) ageing manual was promoted to supervisor and has had less time to commit to the project, and 2) The collaborating author in Canada has had additional priorities that have precluded her from committing the time necessary to finish as well.

Titles of presented work not mentioned previously in this document include:
1. The Percentage of Misidentified Blackgill Rockfish Otoliths in Darkblotched Rockfish Otolith Collections for Years 2000, 2001 and 2002.
2. Difficulty of Age Determination of Pacific hake (Merluccius productus), Pacific Ocean perch (Sebastes alutus) and Sablefish (Anoplopoma fimbria).
3. Using Marginal Increment Analysis to Validate the Periodicity of Annulus Formation in Dover sole, Microstomus pacificus. Poster presentation (2004 Western Groundfish Conference).

For further information, contact Michael Schirripa at (541) 867-0536, Michael.Schirripa@noaa.gov, or Patrick McDonald at (541) 867-0513, Patrick.J.McDonald@noaa.gov.

6) Cooperative Resource Surveys

The NWFSC conducted its sixth annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2003 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*, *Blue Horizon*, and *Captain Jack* were contracted to survey the area from Cape Flattery, WA to the Mexican border in Southern California, beginning in the later part of June and continuing through the third week of October.

Each vessel was chartered for eight weeks with vessels operating in pairs, along the coast. The survey followed a stratified random sampling scheme with 15-minute tows at randomly selected depths. The depth strata were: shallow (30-100 fms), middle (100-300 fms), and deep (300-700 fms). The sample design consisted of 620 sampling locations, with 170 on the shelf (30-100 fms) and 450 on the slope (100-700 fms). Each of the four vessels occupied a different subset of 155 cell sites.

In 2003, we also converted to a new data collection system, using new software applications, new hardware, and wireless networking. Newly 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.

For more information, contact Aimee Keller at (206) 860-3460, Aimee.Keller@noaa.gov.

7) Economics Research Program

During 2003, the NWFSC economics program focused on providing economic analyses related to developing and implementing of fisheries management regimes that comply with the Sustainable Fisheries Act (SFA). The program also provided technical support for the National Marine Fisheries Service's Northwest Region office and the Pacific Fishery Management Council. The program also addresses requirements of the Regulatory Flexibility Act, including community impact analyses of proposed and alternative management options. During 2003, the NWFSC began an effort to collect data that will be used to estimate the economic value of recreational, groundfish fishing off the Pacific Coast. The data will be collected in 2004-2005 and the results of the study are expected to be completed in 2005. Additionally plans were initiated during 2003 for the development of a new survey to collect cost and earnings information from several components of the commercial fishing fleet operating off the Pacific Coast. A major focus of this effort will be the groundfish trawl fleet. Collection of data and development of models during 2004-2005 are expected to improve the ability to quantify the status of, and changes to, the economic health of the trawl fleet. These data will provide an important benchmark, revealing conditions existing prior to the implementation of a permit buyback in late 2003.

For more information, contact Dr. Jim Hastie at Jim.Hastie@noaa.gov, (206) 860-3412.

8) Fish/Habitat Associations

Over the past decade a number of regional interdisciplinary groups have come together to apply innovative approaches to the study of fish habitats. The formation of these interdisciplinary groups was a bottom-up phenomenon encouraged by technological advances, and funded and facilitated by NOAA's National Undersea Research Program and parallel support in Canada. In general, these groups have linked the fields of marine geology and fisheries science to study the habitat ecology of commercially-important species of fish.

The NWFSC FRAM Division has formed an interdisciplinary team with the Southwest Fisheries Science Center Santa Cruz Lab, Pacific Marine Environmental Laboratory, Oregon State University, Washington State University Vancouver, and a host of other government, academic, and private institutions. Heceta Bank, Oregon has been the focus for this group's research, although recently the team has expanded the geographic boundaries to include a larger portion of the shelf break off central Oregon.

Heceta Bank is the largest of the heavily fished rocky banks on the outer continental shelf off Oregon. Since the late 1980's this bank has been a primary focus of groundfish habitat investigations. The first phase (1987-90) used submersible transects to establish relationships between seafloor habitats and the distribution of rockfish (genus *Sebastes*) and other populations of demersal fishes and epibenthic invertebrates. A second phase began after a comprehensive multibeam survey was completed in 1998. The data from the 1980's submersible dives were retrofitted onto the multibeam grid using GIS techniques and extrapolated to broader areas of the bank using the new imagery. This work was completed in the spring of 2000 (OSU Masters Thesis completed by Nicole Nasby, and manuscript published in 2002 in Fishery Bulletin, Nasby et al., Fish. Bull., 100:739-751). The third phase of the study represents an on-going NOAA NURP program with additional support from NOAA's Office of Ocean Exploration to conduct an interdisciplinary and comprehensive study of the Bank's habitats using state-of-the-art survey strategies, instrumentation, and data analysis.

The project focuses on the following questions:

1) At what scales are there quantifiable relationships between groundfish populations and morphology/texture?
2) What are the factors that control these relationships?
3) What changes have occurred in the fish populations and habitat after a decade? and
4) What is the likelihood of the existence of natural refugia on the Bank?

During the summer of 2000 and 2001 a diverse team of marine geologists, fisheries scientists, invertebrate biologists and ecologists, conservation biologists, commercial fisherman and educators participated in two cruises at Heceta Bank aboard the R/V Ronald Brown with the ROPOS remotely operated vehicle (ROV) and two-person submersible Delta (in 2000 only). The ROV and submersible were used to explore and intensively sample five of the original six transect stations in addition to extensive transects over new areas identified on the seafloor imagery.

ROPOS completed twenty-one line transects, covering ~150 km of distance, to assess fish, invertebrate and habitat relationships and to ground-truth the multibeam topography and backscatter imagery data collected in 1998. The NWFSC FRAM Division and the Heceta Bank Project's research team completed the extraction of all of the fish and invertebrate counts from the extensive ROPOS ROV video in 2003. Habitat associations, the distribution of habitat types, and habitat-specific densities were determined for non-schooling species of demersal fishes for all primary habitat types observed. Preliminary results from this study show: (1) Juvenile rockfish dominated the observed fish assemblages in rock ridge and boulder habitats with

densities of ~1350 fish/ha. Cobble habitats were dominated by sharpchin rockfish (~2000 fish/ha) and fish densities in mud habitats were the lowest of all habitats with observed counts of flatfish (~400 fish/ha) and greenstriped rockfish (45 fish/ha) comprising the largest portion of those assemblages.

In a related effort, four demersal fish habitats were mapped across the entire extent of the multibeam imagery collected in 1998 (OSU Masters Thesis completed by Curt E. Whitmire, and manuscript being developed). The next step is to extrapolate fish densities observed via submersibles to the larger geographic extent of these new habitat predictions.

These analyses are in preparation for a series of presentations to be given at conferences in 2004:

"Using Remote Sensing, In situ Observations, and Geographic Information Systems to Map Benthic Habitats at Heceta Bank, Oregon." Curt E. Whitmire, Robert Embley, W. Waldo Wakefield, Susan Merle, Brian Tissot, and Noelani Puniwai

"Fish habitat studies at Heceta Bank on the Oregon outer continental shelf." Julia E.R. Clemons, W. Waldo Wakefield, Robert W. Embley, Brian N. Tissot, Mary M. Yoklavich, Ted D. Hart, Susan G. Merle, Curt E. Whitmire, and William H. Barss

Some of the goals of the Heceta Bank Project and related projects, currently under development or funded, are:
1) Design of better stock assessment surveys;
2) Development of a more quantitative approach to mapping essential fish habitat for the U.S. EEZ;
3) Improvement in West Coast rockfish assessments; and
4) Incorporation of baseline data from this and related projects into the process of identifying habitat areas of particular concern and siting marine protected areas/reserves.

For more information, contact Waldo Wakefield at (541) 867-0542, Waldo.Wakefield @noaa.gov, or Julia Clemons at (541) 867-0539, Julia.Clemons@noaa.gov.

9) Habitat Requirements of Pacific Coast Groundfish Species - Update

The 1996 Sustainable Fisheries Act significantly amended the Magnuson-Stevens Act by requiring the Fishery Management Councils and the Secretary of Commerce, through the National Marine Fisheries Service (NMFS), to include provisions in fisheries management plans that describe, identify, conserve, and enhance essential fish habitat (EFH). In 1998 the NMFS recommended to the Pacific Fishery Management Council (PFMC) that the Pacific Coast Groundfish Management Plan be amended to include a limited number of composite EFHs for all Pacific Coast groundfish species and attach an appendix document to the amendment that describes the life histories and EFH designations for each of the 82 individual species included in the Fishery Management Plan (FMP). This publication, titled "Essential Fish Habitat West Coast Groundfish Appendix" was prepared by Casillas et al. (1998).

The EFH regulations also indicate that the Councils and NMFS should periodically review and revise the EFH components of FMPs at least once every 5 years. Such review should include information regarding the description and identification of EFH, threats to EFH from fishing and non-fishing activities, and measures that could be taken to minimize those threats. In 2003 habitat requirements of the 82 groundfish species on the West Coast as previously described by Casillas et al. (1998) were updated. This most recent update of the "Appendix" was performed by conducting literature searches, and resulted in the identification of additional habitat associations for various life history stages of 70 of the species.

For more information, contact Bruce McCain at (541) 867-0523, Bruce.McCain@noaa.gov.

10) Samples and Data from Spiny Dogfish to Aid Stock Assessment and Demographic Analysis

The most recently published study of spiny dogfish (Squalus acanthias) from the West Coast of the U.S. is from 1954. Since then, Canadian scientists have validated an ageing method using second dorsal spines, but it has primarily been applied to dogfish in British Columbia. In order to understand the population dynamics and stock structure of spiny dogfish in U.S. waters and their links to the B.C. population (as well as those farther afield), age distributions, length and maturity at age data, and genetic information will be crucial. This species covers a remarkable range of habitat from Mexico to Alaska and nothing is known about genetic or demographic variation over this range.

In 2002, spines were collected from the NWFSC slope survey, but samples from the full range of depths will be necessary to have a complete and unbiased study of this species which has in previous surveys been more abundant in shallower waters on the shelf. At least three graduate students, Ian Taylor (stock assessment), Cindy Tribuzio (reproduction & development), and Nicole Vega (genetic & demographic variation) would benefit greatly from the data that would be result from this project.

For further information, contact Ian Taylor at (206) 221-6776, itaylor@u.washington.edu.

11) Science for Ecosystem-based Management Initiative

Current projects:

1. Using Leslie matrices to identify essential fish habitat. NMFS is required by statute to identify and protect habitat areas of particular concern (HAPCs)—subsets of EFH that are especially ecologically important, sensitive to human-induced environmental degradation, stressed by development activities, and/or rare. We seek to develop of methodology that could be used nation-wide to designate and delineate HAPC.

The degree to which fish successfully complete their lives is determined by the rates that

individuals move through their life cycle. By creating a matrix of estimates of birth, growth, maturation, fertility and mortality rates for each life history stage it is possible to translate events happening to individuals to the dynamics of the population. Using elasticity analysis one can then estimate which life stages contribute most to the growth rate of the population, and thus determine which life history stages should be the focus of conservation. Once critical life stages are identified, the next task is to determine what habitats are important to those life stages. In particular, we need to know how changes (i.e. degradation or restoration) in habitat affect vital rates. Using these estimates of habitat effects on vital rates, one can model how different management actions that target specific habitats will affect populations. Thus, this set of models will ask the question, how much habitat (of different types) does one need to have in order to meet a management goal?

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

2. Risk Analysis of West Coast Groundfishes. Many populations of marine fish have declined steeply over the last several decades. On the other hand, many populations have increased or remained stable. By applying the methodology of SEMI team member, Eli Holmes, we will conduct a standardized assessment of risks faced by groundfish on the continental shelf of the US Pacific coast. Using the same techniques of population viability analysis that have been used on Pacific salmon (as well as numerous other at-risk terrestrial and marine species), we will estimate population growth rates and the probability of reaching various conservation or management benchmarks (e.g. probability of 90% decline in 100 years, probability of rebuilding in 100 years, etc.). Additional analyses will illuminate what life history attributes are associated with high risk species. Our hope is that this work will serve as a "partial" assessment for a number of currently unassessed species.

For more information, contact Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Kevin Piner at (858)546-5613, Kevin.Piner@noaa.gov, or Elizabeth Holmes at (206) 860-3369, Eli.Holmes@noaa.gov.

3. Impacts 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 versus managing for the health of coast ecosystems—2 of the missions of the NMFS. 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, contact Chris Harvey at (206) 860-3228, Chris.Harvey@noaa.gov, or Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Rich Zabel at (206) 860-3290 x166, Rich.Zabel@noaa.gov.

4. Role of *Spartina alterniflora* in estuarine food webs. We are studying the importance of *Spartina alterniflora*-derived organic matter in the food web of Willapa Bay on the coast of Washington. *S. alterniflora*, an exotic cordgrass native to eastern North America, has taken over

substantial areas of Willapa Bay that were formerly mudflats or eelgrass beds. It dies back each fall, producing large amounts of detritus that may be an important component of the diets of filter feeders and scavengers. We are using stable isotope analysis to trace flows from various primary producers to oysters in both bays, in order to determine the importance of *S. alterniflora* in oyster diets and its affects on oyster growth. We will expand our analysis to other key consumers, such as juvenile groundfish and salmon

For more information, contact Chris Harvey at (206) 860-3228, Chris.Harvey@noaa.gov or Blake Feist at (206)860-3408, Blake.Feist@noaa.gov.

5. Spatial and temporal scale effects of climate variability on groundfish assemblages. Groundfish species on the West Coast experience different temperatures, upwelling patterns, and other climate-related variables on many spatial and temporal scales. Variability of these factors is driven by forces such as north-south gradients, large- and small-scale currents, large-scale climate events (e.g., El Niño, Pacific Decadal Oscillation), and interactions between these forces. We will examine time series of climate patterns over a 25-year period and West Coast shelf trawl survey data over the same time series to determine if there are ecologically meaningful associations between climate patterns and abundances of particular species or species assemblages of groundfish. Such information will provide some idea of how climate has contributed to population trends of many groundfish species, particularly the sharp decline in many species of *Sebastes*.

For more information, contact Nick Tolimieri at (206) 302-2444, Nick.Tolimieri@noaa.gov, or Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Teresa Turk at (301)713-2328 x164, Teresa.Turk@noaa.gov.

6. Community composition of coastal shelf rockfish communities. In conjunction with the previous agenda item, we will use data from the West Coast shelf trawl surveys to identify rockfish that are most likely to coexist in predictable community assemblages in different regions. We will use statistical methods such as principal components analysis or its non-parametric analogs to determine which species tend to coexist, and under what conditions those groups are likely to be found. We can further determine if those assemblages constitute guilds, based on ecological information derived from the literature, and examine how small-scale guild population dynamics behave. For example, rather than using traditional single species stock-recruit relationships, we can see if the stock size of a guild of species influences the recruitment of that guild, or of individual species within the guild. Such information would greatly benefit managers who are interested in multi-species or community-level fisheries management plans, as opposed to single-species plans.

For more information, contact Chris Harvey at (206) 860-3228, Chris.Harvey@noaa.gov, or Nick Tolimieri at (206) 302-2444, Nick.Tolimieri@noaa.gov, or Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Kevin Piner at (858)546-5613, Kevin.Piner@noaa.gov.

7. Groundfish bioenergetics. Bioenergetics models have proven an excellent tool in estimating the energetic demands of fishes, and thereby better understanding 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 plan to develop bioenergetics models for *Sebastes* species, and use these models 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 (that is, 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, contact Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Chris Harvey at (206) 860-3228, Chris.Harvey@noaa.gov.

Projects in the planning stage:

1. 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. In part, this is due to 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 Phil Levin at (206) 860-3473, Phil.Levin@noaa.gov, or Steve Katz at (206)860-3396, Steve.Katz@noaa.gov, or Guy Fleischer at (206) 860-3289, Guy.Fleischer@noaa.gov.

2. Influence of fisheries on coastal food web structure. Restricting or closing fisheries in MPAs has been shown to change the abundances of many species, including both target and non-target organisms. The goal of MPA establishment is often to increase one or more ecologically desirable variables, such as total system biodiversity or standing stock biomass of one or more imperiled species. Less attention has been paid to how community or food web structure is affected by fisheries closures. This is a research topic that deserves more focus, especially given recent studies that cite massive, non-linear changes in communities that have been overfished, and the likely difficulty in reversing those changes. We plan to use stable isotope analysis to examine food web structure within and outside of regions with fisheries restrictions to determine if there are differences in basic food web parameters (e.g., food chain length, indexes of omnivory, importance of benthic vs. planktonic primary production). Scales of interest will be spatial (i.e., sites within MPAs vs. sites on a distance gradient away from the MPA, taking

circulation patterns into account) and temporal (i.e., sites that recently were closed to fishing vs. sites that have been closed to fishing for longer periods of time).

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

Future collaborative projects we are developing:

1. Marine mammals. Dr. Alejandro Acevedo (Western Washington University), a marine mammal ecologist, has expressed interest in working with us. Possible projects would include how pinnipeds affect marine communities. This effort would be based on both empirical study and modeling efforts, including seal bioenergetics modeling and models of density-dependent predation on fish and other prey.

2. Groundfish otolith stable isotopes and microchemistry. Dr. Bill Peterson (University of Saskatoon) has expressed interest in working with us on analyzing the stable isotopes of annual growth rings in groundfish otoliths. The oxygen isotopic signatures in an annual ring should provide information about the temperature experienced by the fish, and the carbon signatures should provide information about the fish's diet. By examining these signatures, estimating growth based on the widths of the otolith annuli, and correlating these values with long-term oceanographic data, we may be able to determine how different groundfish species responded behaviorally, energetically, and ecologically to changes in climate. That is, the isotopes and growth patterns should reveal if different species moved to maintain preferred temperatures, if their growth patterns changed, and if their diet changed during times of climate anomalies.

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

12) Sea-truthing Modern Geophysical and Historic Geologic Data, Working Towards Establishing a Natural Disturbance Mosaic on the Pacific Northwest Margin

A damped gravity corer and seafloor imaging system has been developed as part of a cooperative research project between Oregon State University oceanographers (Rob Wheatcroft, Clare Reimers and Tony D'Andrea) and a NWFSC FRAM Division scientist (Waldo Wakefield). This coring device has been designed to be deployed from commercial fishing vessels as part of a collaborative research program. OSUSSS is a new system that combines a hydraulically damped gravity corer and a video/digital still camera system. The corer collects high quality (i.e., sediment and pore-water intact) cores in coarse sand to mud, thereby permitting quantitative enumeration of benthic macroinvertebrates and high-resolution sediment properties, whereas the digital still camera yields data on epibenthic megafauna and seafloor structure (e.g., ripples, mounds, etc.). The OSUSSS will be used in projects to groundtruth the evolving database and GIS for Oregon and Washington habitats. It will also be used in new projects to examine the environmental effects of fishing. Following is a summary of accomplishments in 2003.

During a 2-week period in August of 2003, researchers from OSU/COAS and NMFS/NWFSC conducted a successful test cruise of the OSU/NOAA corer off central Oregon on board the F/V Watchman. The test cruise demonstrated clearly that: (1) high-quality images and sediment samples could be collected from a range of bottom types on the continental shelf and upper

slope; (2) it is feasible to safely deploy and recover an advanced sampling package off a mid-sized commercial fishing vessel; and (3) collaborations between the fishing community and academic scientists can be quite fruitful.

Cara Fritz, OSU COAS Ph.D. student, working with Rob Wheatcroft and Waldo Wakefield, is working on her dissertation project to develop a natural vs. anthropogenic disturbance mosaic for the Pacific Northwest as part of her effort to provide insight into the impacts of trawling on benthic habitats. She will be presenting this work in a poster at the Western Groundfish Conference in 2004.

For more information, contact Rob Wheatcroft at (541) 737-3891, raw@coas.oregonstate.edu, or Waldo Wakefield at (541) 867-0542, Waldo.Wakefield@noaa.gov.

13) Stable Isotope and Dietary Studies of Demersal Fishes Off of Oregon and Washington

The combination of stable isotope studies with the analysis of feeding habits presents an effective tool for characterizing some of the dynamics of exploited marine ecosystems on both a species and a trophodynamic basis. This area of research began in earnest during the Ocean Exploration cruise to Astoria Canyon in 2001, when tissue samples from several species of rockfish were collected along with a suite of potential prey items to look at tropic relationships in and around the Canyon (Bosley et al. *In press*). This study specifically looked at several commercially-important rockfish species, and the findings indicated a significant amount of direct predation on other rockfish species was occurring. With this information, we expanded the research to include much of Washington and Oregon. During the summer of 2003, NOAA Fisheries conducted a trawl survey of demersal species inhabiting the continental shelf waters along the U.S. west coast. Tissue samples for isotopic analysis, and stomachs for characterizing feeding habits, were collected from several rockfish species to try to assess the degree of competition between species and trophic relationships. With yearly changes in harvest limits, for instance, it is possible that we may be able to track changes in trophodynamics through continued, long-term studies such as these.

The new information from 2003 is currently being analyzed and will be presented in at least one international forum in 2004, the Quantitative Ecosystems Indicators in Fisheries Management meeting in Paris, France.

In addition to scientists from the NWFSC (Bosley, Brodeur and Wakefield), this research has included collaborations with two graduate students, Keri York (Washington State University, Vancouver) and Todd Miller (Oregon State University). For more information, contact Keith Bosley at (541) 867-0506, Keith.Bosley@noaa.gov, or Richard D. Brodeur at Rick.Brodeur@noaa.gov, or Waldo Wakefield at (541) 867-0542, Waldo.Wakefield@noaa.gov.

14) West Coast Essential Fish Habitat: Geologic and Geophysical Bottom Character Database and GIS for U.S. West Coast Groundfish

The database and GIS project for West Coast Essential Fish Habitat is a joint effort between Chris Goldfinger, Chris Romsos, Rondi Robison, Randall Milstein, and Beth Myers from the College of Oceanic and Atmospheric Sciences at Oregon State University, and Waldo Wakefield of the NWFSC FRAM Division.

The goal of this program, begun in 2001, was to create and use a comprehensive, helpful and easily accessible, multi-layered GIS database and associated CD-ROM-based products for groundfish habitat assessment in the Pacific Northwest. The database for Oregon and Washington has been linked to an integrated habitat database for California (Gary Greene at Moss Landing Marine Laboratories and Mary Yoklavich at SWFSC Santa Cruz). For the first time, marine researchers working along the U.S. West Coast have an integrated map of structural habitat for the entire region (San Diego, CA to Cape Flattery, WA). In addition, the combined GIS database for California, Oregon and Washington is being used in the current Essential Fish Habitat Environmental Impact Statement for West Coast groundfish.

Version 1.0 of the maps for Oregon and Washington were completed in 2003. This release is entitled "Active Tectonics and Seafloor Mapping Laboratory Publication 02-01: Interim Seafloor Lithology Maps for Oregon and Washington Version 1.0". The interim habitat maps are now in use at the Northwest Fisheries Science Center. Investigators there are beginning to integrate fisheries data and benthic habitat data to look for associations, and to assess the state of existing benthic habitat data in terms of future needs. One such preliminary analysis will be presented at the Western Groundfish Conference in Victoria, BC in early February 2004:

"Relating high-resolution submersible observational data to regional trawl survey data – a work in progress." Curt E. Whitmire, W. Waldo Wakefield, Richard D. Methot, Brian N. Tissot, Allison Bailey, Levon Yengoyan, Chris Hansen.

The following section describes the basic elements incorporated in the initial version of the habitat maps:

The interim map captures the essential habitat classifications to be found offshore Oregon and Washington, but due to time constraints, lacks ground-truthing, cross checking, and some of the components of rock prediction. Since delivery of the interim maps, work has continued in 2003 on a second iteration of the habitat maps (Version 2) that will include detailed grain size mapping, fully cross-checked and ground-truthed rock prediction mapping, similar cross-checking, ground-truthing of lithologic data to resolve conflicts between datasets, and removal of artifacts. Version 2 will also include additional oil industry core samples from archives of the Minerals Management Service, as well as much more comprehensive interpretation of the sidescan datasets, quantitative classifications of bathymetry data, and will include significant new multibeam/backscatter datasets collected in 2002. In particular, under separate funding, 10 days of high-resolution multibeam mapping aboard the R/V Thomas Thompson was conducted. These data comprise 2 blocks on the Oregon slope, both adjacent to existing high-resolution surveys. These data increase the coverage of the Oregon upper slope between ~200-800 m by ~ 50%. Interpretation of these data will be included in the Version 2 release. Additional multibeam and backscatter data collected by NOAA on the Washington margin will also be

interpreted and incorporated into bathymetry grids, and into the interpreted habitat layers in Version 2. Another significant task underway at present is the use of extensive submersible and ROV video data for ground-truthing the maps. These data are being used to verify and or modify the existing layers, and are particularly useful for calibrating the interpretation of sidescan datasets. Virtually all observational data are co-located with sidescan surveys, which were conducted for use during the dives.

For more information, contact Waldo Wakefield at (541) 867-0542, Waldo.Wakefield@noaa.gov, or Chris Goldfinger at gold@coas.oregonstate.edu.

15) West Coast Groundfish Observer Program

The West Coast Groundfish Observer Program began deploying observers in the summer of 2001. During 2003, the program continued to successfully deploy observers on commercial west coast groundfish vessels. The program is a cooperative agreement between NOAA Fisheries and Pacific States Marine Fisheries Commission (PSMFC). PSFMC has contracted the Seattle-based observer company, Alaskan Observers Inc., to provide qualified, bachelor degreed biologists to be trained as observers. Currently, there are 42 active observers stationed in ports along the coast from San Diego, California to Bellingham, Washington.

The goals of the program continue to be:

1. Estimation of total catch
2. Estimation of total discarded catch
3. Species composition of discarded catch
4. Collection of biological information
5. Provide a timely and efficient system for collection, storage, analysis and communication of collected data.

The program deploys observers on the bottom trawl fleet, the limited entry fixed gear fleet, open access fixed gear fleets that target groundfish, and ancillary fleets such as prawn and shrimp vessels. In addition to collecting the above information, observers also collect fishing effort data including position, depth and gear used. The data is recorded on weatherproof forms and entered into into a NMFS-designed database. The observer is debriefed and the data goes through a number of quality controls before it is released for summarization and analysis.

During 2003, the program summarized and performed final data quality checks to prepare the data collected from the second observation year of the groundfish bottom trawl fleet (Sept 2002-Aug 2003) and three observation years of the sablefish endorsed fixed gear fleet (Aug. 2002-Oct. 2003) for analysis. The results were presented in two reports and made available on-line early this year at: http://www.nwfsc.noaa.gov/research/divisions/fram/Observer/ . The data results were incorporated into a bycatch model for management use presented in the March 2004 Pacific Fishery Management Council meeting (see below).

In addition, the program collected all the at-sea data for the ODF&W-sponsored flatfish trawl EFP. It also aided CDF&G and WDF&W with data collection for the Scottish seine and arrowtooth EFPs, respectively. The program also expanded coverage in the California fixed gear fleets that target groundfish as well as some fleets that take groundfish as bycatch. The program also conducted a Small Boats Workshop in March 2003 to explore the limitations and restrictions of observing small boat fleets.

Coverage of the groundfish bottom trawl and fixed gear fleets will continue into 2004. Also, the program expects to expand coverage in the Oregon fleets permitted for nearshore species, rockfish and pink shrimp and continue coverage of similar small boat fleets in California.

For more information, contact Jonathan Cusick at (206) 302-2413, Jonathan.Cusick@noaa.gov.

Appendix 1. Reports and Publications

Able, K.W., Wakefield, W.W., Grassle, J.F., Petrecca, R.F., Vivian, D., Taghon, G., Glenn, S.

2003. Characterization of Substrates/Fish Habitats in the Vicinity of Beach Haven Ridge off Suthern New Jersey. *Inst. of Marine and Coastal Sciences Rutgers Univ. Tech. Report*. 100-19. 30 pp.

Bosley, K.L., D.A. Witting, R.C. Chambers and S.C. Wainright. 2002. Estimating turnover rates of carbon and nitrogen in recently metamorphosed winter flounder, *Pseudopleuronectes americanus*, with stable isotopes. Marine Ecology Progress Series. 236: 233-240.

Bosley, K.L., W. Lavelle, R.D. Brodeur, W.W. Wakefield, R.L. Emmett, E.T. Baker, K.M. Rehmke. *In press.* Feeding relationships among pelagic and benthic communities in relation to the hydrodynamics of Astoria Submarine Canyon, Oregon, USA. Journal of Marine Systems.

McCain, B.B., S.D. Miller, and W.W. Wakefield. 2004. A Pacific Coast Groundfish Habitat Use Relational Database. A CD produced by NOAA Fisheries, Northwest Fisheries Science Center, Seattle, WA, in cooperation with MRAG Americas, Inc., London, UK.

Orensanz, J.M., A.M. Parma, T.A.Turk, and J. Valero. Dynamics, Assessment and Management of Exploited Natural Populations. In: Scallops: Biology, Ecology and Aquaculture. Sandra Shumway, editor. Elsevier, Amsterdam. *In review.*

Rogers, J.B. 2003. Darkblotched rockfish (*Sebastes crameri*) 2003 stock status and rebuilding update. Status of the Pacific Coast Groundfish Fishery through 2003 and Recommended Acceptable Biological Catches for 2004, Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97201

Rogers, Jean Beyer. 2003. Species Allocation of Sebastes and Sebastolobus sp. caught by foreign countries from 1965 through 1976 off Washington, Oregon, and California, USA. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-57, 117 p.

Stout, H.A., R.G. Gustafson, W. H. Lenarz, B.B. McCain, Donald M. VanDoornik, T.L. Builder, and R.D. Methot. Status review of Pacific herring (*Clupea pallasi*) in Puget Sound, Washington. NOAA Tech. Memo. NMFS-NWFSC-45. 175 pp.

Stout, H.A., B.B. McCain, R.D. Vetter, T.L. Builder, W. H. Lenarz, L.L. Johnson, R.D. Methot. Status review of the Copper rockfish (*Sebastes caurinus*), Quillback rockfish (*S. malinger*), and Brown rockfish (*S. auriculatus)* in Puget Sound, Washington. NOAA Tech. Memo. NMFS-NWFSC-46. 158 pp.

Turk, T.A. Spatial Distribution and Selected Habitat Preferences of Weathervane Scallops (*Patinopecten caurinus*) in Alaska. Spatial Processes and Management of Marine Populations. University of Alaska Sea Grant.

Turk, T.A, T. Builder, C.W. West, D.J. Kamikawa, J.R. Wallace, R.D. Methot, A.R. Bailey, K.L Bosley, A. J. Cook, E.L. Fruh, B.H. Horness, K. Piner, H.R. Sanborn and W.W. Wakefield. The 1998 Northwest Fisheries Science Center Pacific West Coast Upper Continental Slope Trawl

Survey of Groundfish Resources. NOAA Technical Memorandum NMFS-NWFSC-50.

Whitmire, C.E. 2003. Using Remote Sensing, In situ Observations, and Geographic Information Systems to Map Benthic Habitats at Heceta Bank, Oregon. M.S. Thesis, Oregon State University, Corvallis, OR, USA, 61pp.

Yoklavich, M.M., C.B. Grimes, and W.W. Wakefield. 2003. Using laser line scan imaging technology to assess deepwater habitats in the Monterey Bay National Marine Sanctuary. Marine Technology Society Journal 37:18-25.