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Northwest Fisheries Science Center

National Marine Fisheries Service

2004 Agency Report to the Technical Subcommittee of the Canada-U.S. Groundfish Committee

April 2005

Review of Agency Groundfish Research, Assessments, and Management

A. Agency Overview

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

The Fishery Resource Analysis and Monitoring Division (FRAMD) is the source 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. Members of this program are stationed at both the NWFSC in Seattle and in Newport, Oregon. 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; investigate the design, feasibility, function, and value of marine protected areas; and employ advanced technologies for new assessment.

During 2004, 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 the Center Director, Dr. Usha Varanasi at Usha.Varanasi@noaa.gov, (206) 860-3200.

B. Multispecies Studies

1) Stock Assessment

Stock Assessment Workshops. Two comprehensive workshops were convened during 2004 to enable the delivery of the stock assessments and ensure that the demanding schedule yields the best possible science for groundfish management. The first workshop focused on data sources used in stock assessments, including data typically used as well as data that hold potential to be used in future assessments. The second workshop focused on modeling innovations and needs and included discussions on calculating uncertainty in stock assessments. A third workshop was held in June in Santa Cruz, California to discuss and review recreational fishery datasets and analytical methods used to calculate catch-per-unit-effort (CPUE). Workshop participants included stock assessment authors, members of the Pacific Fishery Management Council's Scientific and Statistical Committee, regional data experts, international stock assessment experts, and the public.

For more information, contact Stacy Miller at Stacey.Miller@noaa.gov, (206) 860-3480.

Bayesian Hierarchical Meta-Analysis of Rockfish Life History Parameters. While nearly 80 species of rockfish in the genus *Sebastes* in the Eastern Pacific Ocean are currently managed under the Pacific Fishery Management Council's Groundfish Management Plan, only a small fraction have been quantitatively assessed for stock status; seven major species are currently depleted including canary (*S. pinniger*), bocaccio (*S. paucispinis*), widow (*S. entomelas*), Pacific ocean perch (*S. alutus*), cowcod (*S. levis*), yelloweye (*S. ruberrimus*) and darkblotched rockfish (*S. crameri*). For the vast majority of rockfish species, determining stock status remains elusive because of limited biological and population dynamics information. Owing to the fact that many

of these species share common life histories, population dynamics and responses to exploitation, we initiated research using meta-analytic approaches for quantitative synthesis of information from both data-poor and data-rich species to explore and elucidate patterns in life history variability. This research will provide the foundation for development of a life history-based assessment model for data-poor species and will contribute additional information for those assessments already conducted.

Thus far our efforts have centered on growth of rockfish. We modeled somatic growth of 46 *Sebastes* species in the Eastern Pacific Ocean using Bayesian hierarchical meta-analysis to estimate parameters, investigate growth variability among species and elucidate meaningful biological covariates. Growth of species in the genus *Sebastes* varied by more than 300% in terms of maximum attainable size (L_∞; 12 cm to 80 cm) and by more than 88% in terms of instantaneous growth rates (K; 0.008 yr^{-1} to 0.08 yr^{-1}). Results from this method also confirm the theoretical, but often untested, view that growth parameters L_∞ and K are negatively correlated among species of fish; Bayesian credibility intervals ranged from –0.2 to –0.7 with the posterior median of –0.4. The Bayesian hierarchical growth model showed less variability in growth parameters and lower correlations among parameters than those from standard techniques used in population ecology. This suggests that the absolute value of the correlation between L_∞ and K may be lower than the general perception in the ecological literature, where values in the range of -0.8 to -0.9 are often [reported | hypothesized]. Size at 50% maturity was correlated positively with asymptotic size and negatively with K. Depth showed little predictive power for any growth parameters.

Future efforts will involve augmenting otolith collections for some of the minor rockfish species based on the sampling platform and procedures already being utilized as part of the FRAMD shelf/slope survey. While otolith collections of these data-limited species is our initial priority, we propose future expansion of sampling to include gonad material for staging maturity at a time when meaningful biological/ecological groups of rockfish have been established. Species and sample requirements for proposed collection of rockfish age-structures are given in the table below; only twelve commonly encountered species (not included in the table) currently have sufficient age and growth samples for this type of analysis.

As the inventory of rockfish otoliths accumulates, additional funding will be sought to support a graduate stipend or other position working closely with the aging lab to validate and establish aging techniques for age determination. Likewise funding will be sought to develop and establish maturity staging techniques when future gonad collections begin. Both aspects of this research will include collaboration with experienced researchers at the SWFSC and AKFC to optimize efficiency in developing methods where species have not been extensively aged in the past.

As available growth information for data-poor rockfish increases, these data will be pooled with our already extensive data base for the more common rockfish. The pooled data will be analyzed using Bayesian hierarchical meta-analysis to model the life history processes, their variability, and to explore biological and environmental covariates among a coherent set of species within this single genus. More detailed analysis and modeling can be done using incremental otolith

analysis to elucidate coherent correlations among groups of species and environmental covariates. Overall, we seek a unified quantitative approach which integrates all relevant life history parameters and ecological relationships to better understand the response of *Sebastes* species assemblages to exploitation. This research fosters preparation for an inevitable increase in the number of rockfish stock assessments likely to be performed in the future.

For more information, contact Tom Helser at Thomas.Helser@noaa.gov, (206) 860-3481 or Ian Stewart at Ian.Stewart@noaa.gov, (206) 860-3456.

C. By Species, by Agency

1) Shelf Rockfish

West Coast

a) Research

Mathematical Modeling and 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. 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. 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. In 2004, we developed a mathematical model to describe the increase in radiocarbon in otolith cores and in coral and are currently developing a statistical method to rigorously compare reference radiocarbon data sets to each other and to compare test data sets to reference data sets. This work, in preliminary form, was presented in July 2004 at the Third International Otolith Conference in Townsville, Australia.

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. This work was presented in July 2004 at the Third International Otolith Conference in Townsville, Australia. A manuscript describing this work is currently in press in The Canadian Journal of Fisheries and Aquatic Sciences.

We have also applied this method to darkblotched rockfish and will be using the methodology

under development for final analysis of the data. Two different annulus count ageing methodologies are compared for darkblotched rockfish. Preliminary Pacific Ocean Perch otoliths were selected and cored and we are currently awaiting lab results.

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

A Model-based Approach for Developing Biomass Indices from Multi-vessel Surveys. Recent efforts have focused on developing biomass indices for slope species caught in the NMFS continental slope surveys. The primary objectives are to: (1) determine a post-stratification frame based on biological for each species or species groups and, (2) apply a model-based approach to estimate biomass and variances for inclusion in Stock Synthesis. Thus far we have analyzed 11 slope species using a generalized linear mixed model analysis. Specifically, we employ a generalized linear mixed model (GLMM) that treats year and spatial cell as fixed effects while treating vessel as a random effect is used to examine fishing power among chartered industry-based vessels and a research trawler, the *FRV Miller Freeman*, for bottom trawl surveys on the upper continental slope of U.S. West coast. A Bernoulli distribution is used to model the probability of a non-zero haul and the gamma, log-normal or inverse Gaussian error distribution was used to model the non-zero catch rates, depending on the specific species. The use of vessel as a random effect allows the data for the various vessels to be combined and a single continuous time-series of biomass indices to be developed, for some species in which vessel effect was nominal. Generally, the GLMMs fit the data reasonably well for all 11 species. As such treating vessel as a random effect is a reasonable approach to developing abundance indices.

For more information, contact Tom Helser at Thomas.Helser@noaa.gov, (206) 860-3481.

2) Sablefish

West Coast

a) Research

Plans are being made to convene the Third International Sablefish Symposium. Dr. Michael Schirripa organized a meeting during the 2004 Western Groundfish Conference to determine interest level and to formulate a participant list. To start the meeting, Dr. Schirripa read the Original Task Statement, from the Technical Subcommittee of the Groundfish Committee directing him and Dr. Rick Stanley to provide terms of reference and oversight in the development of a sablefish-working group. The working group should consider survey methods, feasibility of survey calibration, tagging programs, ageing techniques, and the exchange of other data when drafting terms of reference for the sablefish workshop.

Dr. Schirripa then provided a brief statement on the background of sablefish symposia held in 1983 and 1993 that brought together scientists and managers to share information, data, and discuss future needs. The Proceedings of the International Sablefish Symposium, March 29-31,

1983, held at the University of Alaska with symposium coordinator Brenda R. Melteff, was published as Alaska Sea Grant Report 83-8. Mark E. Wilkins and Mark W. Saunders edited the Biology and management of sablefish, *Anoplopoma fimbria*, papers from the International Symposium on the Biology and Management of Sablefish, held in Seattle, Washington, 13-15 April 1993. It was published as NOAA Technical Report NMFS 130, June 1997 (275 pgs.).

Dr. Schirripa then read the current meeting objectives, passed around a sign-up sheet for participants to provide name and address. He then asked participants to introduce themselves and provide a brief background statement of their interest in sablefish. Following the round of introductions, Michael opened the floor for discussion that centered on the need for and format of a Sablefish Symposium to be held in the near future.

The idea of a symposium and attaching it to the next Groundfish Conference (GFC) was suggested to be too compact a schedule. The possible attaching of just a symposium, a workshop or presented papers together with a series of sablefish workshops makes attaching to the next GFC quite difficult to schedule. Assuming that 25 papers might be presented, it would be difficult for the symposium attendees to keep alert and focused after a week at the GFC. Reversing the order would make GFC attendance difficult. There was definite interest in both presented papers and workshops that would allow sablefish researchers and managers to communicate. Workshops will permit more discussion and collaborative interactions. Papers will provide the mechanisms for efficient communication of recent results. The format of presented papers was discussed and it was suggested that there should be more time for presentations and discussion of presented material in full detail. Structure of the Symposium and workshops were discussed briefly. It was suggested that invited papers could be used to present the range and structure of sessions and, in so doing, provide natural leads into workshops. A suggestion was made that workshop attendance be mandatory but there was concern raised that this might not be effective. It was suggested that workshops should be summarized and leaders should be provided with time at the end of the Symposium to present an overview of the discussions and results of workshops to the full audience of attendees. Such structure would assist in the display of the current knowledge, state of the art and construction of framework for future collaborations. Finally, the idea of publishing the proceedings was widely supported. While another Sea Grant Program or NOAA Technical publication was discussed, the attendees appear to favor a blind peer-reviewed journal process. While the blind peer-review process is quite difficult to manage, several attendees argued that it would be great if it could be done. The "Alaska Fishery Research Bulletin" journal is one possible outlet. Other journal publishers should be contacted to explore possible alternative outlets.

A steering committee was developed that will be made up of the following: Michael Schirripa (NWFSC), Dave Carlile (ADFG), Tom Hurst (AFAC), Rob Kronlund (DFO), Dave Clausen (AFSC), and Chris Lunsford (AFSC).

It was agreed that the steering committee would first review and then send the results of this meeting (minutes and an initial symposium/workshop program structure outline) to all interested parties for input. This document will provide information on possible cities, locations, and venues for holding the meeting. It was recognized that to make the meeting most useful and

successful requires early advertisement so that folks are able to get support for attendance and keep their calendars open. A timeline for meeting planning and implementation will be developed.

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

3) Pacific Hake

West Coast

a) Research

US-Canada Hake/Whiting. A joint US-Canadian Pacific hake research cruise was conducted aboard the CCGS W.E. RICKER from September 14-20, 2004. The area of operation was the Barkley Sound, and La Perouse and Swiftsure banks off southern Vancouver Island, British Columbia. Lead scientists were Ken Cooke, DFO, Pacific Biological Station, Nanaimo and Guy Fleischer, NMFS, NWFSC, Seattle. Additional scientists in attendance were Robert Kieser (DFO), Greg Workman (DFO), Patrick Ressler (NOAA), Steve de Blois (NOAA), Ken Foote (WHOI), and Mark Henderson (UW).

The goals of this cruise were primarily two-fold. The first was to calibrate the W.E. RICKER EK500 and NMFS EK60 38kHz acoustic systems prior to conducting additional survey operations. System performance measurements included on-axis target strength and integration measures of a standard calibration sphere at approximately 30m range for each acoustic system, recording of internal performance values for the EK60 system, LOBE beam pattern measurements for each acoustic system, on-axis target strength measures at 5, 10, 20, and 30m ranges with the EK60 system, and on-axis target strength measures at small (~3cm) incremental ranges over a fixed distance (~30cm) at ranges of 5, 10, 20, and 30m to evaluate sampling rate of the EK60 system. The second goal was to collect Pacific hake target strength (TS) measures by exploration of selected study site to locate daytime aggregations of hake and other species, daytime trawl sampling to identify species composition of aggregations and of single target layers, continuous acoustic observation over a 12-18h period of selected targets to monitor diel distribution patterns and to record changes in behavior, night time trawl sampling to identify species composition of single target layers, night time surface trawling to collect fresh Pacific hake samples for observation of intake swim bladder structure and preservation of samples for modeling, biosampling of trawl catches to provide meristics on selected targets, and profiling temperature and salinity at selected sites to calculate speed of sound in water.

All aspects of the program were completed on schedule and were highly successful. Mayne Bay is a suitable calibration site that provides adequate ranges for target suspension, good shelter and excellent holding ground. Our three TS study sites were selected based on daytime exploratory surveys and discussions with members of the commercial hake fleet working in the area. Continuous acoustic observations maintained over 12-18h periods in each of the study sites provided excellent records of species distribution patterns and diel changes in behavior. We

were able to monitor hake aggregations and maintain target detections throughout the sampling period.

Trawl operations were particularly successful and provided excellent quantity and quality samples for meristic measurements of Pacific hake and other species. The two surface tows conducted were uniquely successful in capturing near-surface hake samples usable for assessment of swim bladder structure and measurement for use in acoustic backscatter models.

All Pacific hake TS data are currently being analyzed and initial results are to be presented at the special symposium entitled "Recent Advances in Hydroacoustic Assessment of Fish Populations in Marine and Riverine Environments" as part of the American Fisheries Society 135th Annual Meeting in Anchorage, Alaska, September 11-15, 2005.

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

b) Stock Assessment

The Pacific hake stock assessment has been developed in the spirit of a treaty signed in November 2003 between the U.S. and Canada for the sharing of this trans-boundary resource. Under this agreement, not yet ratified by Congress, the stock assessment is to be reviewed by a Scientific Review Group (SRG), appointed by both parties. The Review Group meeting was held in Seattle, WA at the Northwest Fisheries Science Center, during Feb 2-4, 2005. While this report forms the basis for scientific advice to managers, final advice on appropriate yield is deferred to Canadian DFO managers by the PSARC Groundfish Sub-committee and the PSARC Steering Committee and to the U.S. Pacific Fisheries Management Council by the Groundfish Management Team.

The coastal population of Pacific hake (*Merluccius productus*, also called Pacific whiting) is distributed off the west coast of North America from 25° N. to 51° N. latitude and was assessed 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 only updated catch at age through 2004 and recruitment indices from the Santa Cruz juvenile survey in 2004. The US/Canadian acoustic survey, which is the primary index of hake abundance, was last conducted in summer of 2003, but another is planned for the summer of 2005. As in last year's assessment, uncertainty in model results 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.

Status of Stock. The hake stock in 2004 was estimated to range from 2.5 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, then declined as these year classes passed through the population and were replaced by more moderate year classes. Stock size stabilized briefly between 1995-1997, but then 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 2004 was estimated to range from 50% to 55% (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

Pacific hake (whiting) catch and stock status table (catches in thousands of metric tons, biomass in millions of metric tons and Age 2 recruits in billions of fish):

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
U.S. landings	253	178	213	233	233	225	208	182	132	144	211
Canadian	106	70	93	92	89	87	22	54	51	62	124
Total	359	248	306	325	321	312	230	236	183	206	335
ABC	325	223	265	290	290	290	290	238	208	235	514
Model (q=1.0)											
Age 3+ stock	2.8	2.2	2.1	2.1	1.8	1.5	1.4	1.3	2.9	2.7	2.5
Female mature	1.5	1.2	1.1	1.0	0.9	0.8	0.7	0.7	1.2	1.3	1.2
Age 2 recruits	0.33	1.71	1.72	0.90	0.85	0.55	0.93	5.34	0.53	0.72	0.34
Total F	0.24	0.22	0.27	0.26	0.30	0.36	0.29	0.34	0.19	0.20	0.32
Depletion level	58%	47%	42%	41%	36%	30%	28%	29%	46%	51%	50%
Exploitation rate	12.6	11.4	14.9	15.4	17.5	20.9	16.8	18.5	6.5%	7.6%	13.2
Model (q=0.6)											
Age 3+ stock	4.2	3.3	3.1	3.1	2.7	2.3	2.2	2.1	4.5	4.3	4.0
Female mature	2.2	1.8	1.6	1.6	1.4	1.2	1.2	1.2	1.9	2.1	2.0
Age 2 recruits	0.39	2.03	2.05	1.13	1.10	0.74	1.37	7.60	0.72	0.89	0.51
Total F	0.18	0.16	0.19	0.19	0.22	0.25	0.18	0.20	0.11	0.11	0.17
Depletion level	60%	50%	44%	43%	38%	33%	32%	34%	52%	57%	55%
Exploitation rate	9.4%	8.2%	10.8	11.2	12.6	14.3	11.0	11.8	4.4%	5.1%	8.7%

The coastwide ABC and OY for 2005 are estimated to be 364,000 mt and 598,000 mt (q=1.0 and q=0.6) based upon a F40% harvest rate and 302,000 mt and 483,300 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 2005 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. Preliminary results from pre-recruit surveys suggest a larger than average 2003 year-class, but this remains unconfirmed until the 2005 acoustic survey. As such, spawning stock biomass is projected to again decline within the precautionary zone (25% - 40% unfished) by 2006-2007.

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

4) Estimates of Pacific Halibut Bycatch and Mortality in IPHC Area 2A in 2003

West Coast

a) Research

The estimate of Pacific halibut bycatch and mortality in the bottom trawl fishery was updated through the calendar year 2003. 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 2003 analysis uses halibut bycatch rates observed from 01 September 2002 thru 31 August 2003 in the West Coast Groundfish Observer Program. These rates are stratified by season, depth, latitude, and level of arrowtooth flounder catch, then multiplied by the amount of trawl effort in each stratum determined from Oregon and Washington trawl logbooks in 2003. Estimated halibut bycatch and mortality in other gear types was not updated for 2003.

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

5) Flatfish

West Coast

a) Research

Defining Plausible Migration Rates Based on Historical Tagging Data: A Bayesian Mark-recapture Model Applied to English Sole. A generalized Bayesian mark-recapture model was developed to assess movement rates from historical groundfish tagging studies off the west coast of North America. With this approach, substantial parameter uncertainty including tag loss and reporting rates can be integrated out by sampling from the joint posterior distribution for all model parameters. Probabilistic statements can then be made regarding plausible movement rates, conditioned on the hypotheses considered.

This model was applied to English sole (*Parophrys vetulus*), a commercially valuable species with a large amount of historical tagging data not analyzed previously in aggregate. Tag recoveries from coastal waters were modeled by spatial area and movement hypotheses including annual, semi-annual and monthly latitudinal movement were compared using Bayes factors. English sole showed greater movement rates toward the south than toward the north over all hypotheses considered. Although simple hypotheses favored increased movement in the fall, just prior to the spawning season, the best approximating model included small movement rates of 2% per month to the north and 4% per month to the south. Posterior distributions of movement rate parameters are reported for the best models at each level of hypothesis complexity. These parameter distributions and model comparisons can guide managers and stock assessment scientists in selecting the spatial and temporal complexity of future analyses. The Bayesian framework could be easily generalized for application to similar species or more data-rich examples.

For more information, contact Ian Stewart at Ian.Stewart@noaa.gov, (206) 302-2447.

D. Other Related Studies

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

Thesis title: Age, growth and maturity for the longnose skate (*Raja rhina*) along the U.S. West Coast

Finished collection of monthly samples in November 2004. The source of all samples was groundfish trawlers catches landed in Newport. In total, I collected samples for 10 different months of the year, and had a total of 235 monthly samples. The data taken for each sample included: total length, width, weight, sex, maturity status, age structures, and measurements of the reproductive organs. For females: relative width of largest ova, oviducal gland width, uterus width and presence of egg case; for males: clasper length, clasper calcification, seminal vesicle width, and presence of seminal vesicle coiling.

Prepared all vertebral centra for ageing at least once (which required cleaning, mounting, thin sectioning, staining, slide mounting, sanding and polishing). Of all 561 samples collected in total (from the 2003 survey plus the monthly samples), only 10 age structures were missing.

Conducted a double read study with Wade Smith, a Research Associate at the Pacific Shark Research Center at Moss Landing Marine Lab. The initial double read sample (n = 98) was read twice by each of us. This first double read study showed significant bias between the two readers. Results showed a plus bias for me, or possibly a negative bias for Mr. Smith. Due to the large amount of bias in the results, we met to review and compare our ageing techniques a second time (we also did this before the double read study was conducted). We are conducting a second double read study with an entirely new set of samples in order to see if we can reduce this significant difference between readers.

Re-prepared about 100 vertebral centra samples with poor clarity ratings, and estimated age for all 550 samples at least once, though about 200-250 have been aged at least twice if not three times, but these were initial reads, which will not be used in the final analysis.

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

2) At-sea Hake Observer Program

The At-Sea Hake Observer Program continued to deploy observers to collect total catch and species composition data in the at-sea hake fishery on both motherships and catcher-processors. The fishery takes place in waters off the Washington and Oregon coasts. A class of 27 observers was briefed May 5-7. All vessels participating in the 2004 fishery carried two observers each, and fished between May 15th and mid-November. Observers collected species composition samples from 99% of all hauls.

The observer program is run entirely by NWFSC FRAMD staff. However, as all of these vessels also participate in Alaska fisheries, they already have the North Pacific Groundfish Observer Program (NPGOP) observer data transmission system (ATLAS) on board. The data collection protocols followed by the hake observers are similar to those utilized by the North Pacific Groundfish Observer Program. Therefore, because of the assistance provided by the NPGOP,

the collected data is stored in the AFSC's NORPac database and the observers use the same gear 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, and
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 Vanessa.Tuttle@noaa.gov, (206) 860-3479.

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 2004, data collected from the trawl fleet during the second 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 estimate the bycatch mortality associated with management scenarios. Additionally, discard rates for major target species, derived from the observer data, were used to expand model projections of landed catch for those species up to total mortality estimates.

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

4) Cooperative Ageing Unit

The NWFSC continued its collaborative effort with Pacific States Marine Fisheries Commission to maintain the Cooperative Ageing Program (CAP), located at the NWFSC Berry Fisher Building in Newport, Oregon. Much of 2004 was devoted to producing ages in support of seven stock assessments conducted by the NWFSC. These species include Pacific hake, sablefish, Pacific ocean perch, canary rockfish, darkblotched rockfish, and Dover sole. In 2004 the NWFSC trawl survey expanded its otolith sampling to rockfish species that have not yet been assessed, but are part of the Pacific Fisheries Management Council's Fisheries Management Plan. Future work will focus on cross training between readers, expanding the number of species the age examines, as well as investigating thin sectioning as means to reduce variance in age estimates.

In addition to the supplying assessment ages, scientists with the CAP contributed several scientific presentations, either oral or poster. These included:

Age validation of canary rockfish using bomb radiocarbon dating. Jennifer L. Menkel.

Identity crisis(?): determining the level of blackgill rockfish otolith contamination in darkblotched rockfish otolith collections for years 2000, 2001, and 2002. Jennifer L. Menkel.

Difficulty in age determination between Pacific hake (*Merluccius productus*), Pacific ocean perch (*Sebastes alutus*), and sablefish (*Anoplopoma fimbria*). Susan K. Coccetti.

Using marginal increment analysis to validate the periodicity of annulus formation in Dover sole, *Microstomus pacificus*. Lisa M. Lysak

Environmental variations effect on growth in Pacific hake (*Merlussius productus*). Omar Rodriguez.

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

5) Cooperative Resource Surveys

West Coast

a) Slope and Shelf Groundfish Survey

The NWFSC conducted its seventh annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2004 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* and *B.J. Thomas* were contracted to survey the area from Cape Flattery, Washington to the Mexican border in Southern California, beginning in the later part of May and continuing through the third week of October. Each vessel was chartered for eight weeks with the *Ms Julie* surveying the coast during the initial pass from May to July. The *Excalibur* and *B.J. Thomas*, operating in tandem, surveyed the coast during the second pass from mid-August to late October. 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 540 sampling locations, with 200 on the shelf (30-100 fms) and 340 on the slope (100-700 fms). Each of the three vessels occupied a different subset of 180 cell sites.

In 2004, we also continued to utilize the FSCS data collection system with updated software applications, 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 Aimee.Keller@noaa.gov, (206) 860-3460.

West Coast

b) Triennial Survey

In 2004, the NWFSC conducted the 10th in a series of triennial surveys that were previously undertaken by the Alaskan Fisheries Science Center (AFSC). The National Marine Fisheries Service instituted this series in 1977 to supplement commercial data used in assessments of groundfish resources off the U.S. West Coast. The objective of the NWFSC triennial survey was to extend the pre-existing West Coast triennial survey series, historically conducted by the AFSC. The survey covered the area between Point Conception, California and Cape Flattery, Washington between depths of 30 and 275 fm. The 2004 triennial survey provided information on the distribution and relative abundance of demersal species within this region. 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 *Morning Star* and *Vesteraalen* were contracted to survey the area in tandem beginning in the later part of May and continuing through the end of July. The survey followed a combined fixed and random sampling design with over 380 30-minute tows successfully completed. Sampling density was similar throughout three depth strata: 30-100, 101-200, and 201-275 fm. Stations were located randomly along fixed tracklines at the rate of one station per four nmi of linear distance in the shallow stratum and one station every five nmi of linear distance in the two deeper strata. Tracklines were spaced at 10 nmi intervals.

During the triennial survey, we also utilized the FSCS data collection system, wireless networking, and NOAA national bottom trawl protocols throughout the survey. A series of special research projects were undertaken in cooperation with other NOAA groups and various Universities. The data collected provide a measure of the changes in relative abundance, distribution, and condition of groundfish stocks over time, which is of interest to fisheries managers, fishers and concerned citizens.

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

6) Economics Research Program

During 2004, 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 2004, the

NWFSC continued developing plans to collect data that will be used to estimate the economic value of recreational groundfish, salmon, and halibut fishing off Oregon and Washington. Data collection will begin in 2005. Also during 2004, preparations continued for 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 will begin during the summer of 2005. Results 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. Todd Lee at Todd.Lee@noaa.gov, (206) 302-2436.

7) 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 1980s 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 1980s 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 and 2004. 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. Results from this project were presented at the 2004 Western Groundfish Project. An overview of the Heceta Bank Project is now in pressin"Benthic habitats and the effects of fishing" an American Fisheries Society Symposium volume (Wakefield et al. in press).

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 submitted for publication in the soon to be published "GeoHab" volume).

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

8) Fishery-independent Estimates of Density, Size Selectivity and Catch Efficiency of a Survey Bottom Trawl for Thornyheads

Through a collaboration between the NWFSC and AFSC a pair of papers were recently published estimating the size selectivity and catching efficiency of a survey bottom trawl for thornyheads, *Sebastolobus* spp., as well as providing a fishery-independent estimate their density based on direct counts from a towed video camera sled.

A video camera sled was used to obtain an independent estimate of the density of *Sebastolobus* spp. (thornyheads) at three different depths (450, 750, and 1150 m) within a given space and time. Camera sled video footage was processed using an oblique grid plane and line transect

methods. Thornyheads were randomly distributed across the seafloor within the sampling area, and variation in the dispersion over increasing spatial scales (10–1280 m) and depths was not significant. Thornyhead density estimates were derived using the program Distance. Densities ranged from 344 to 1005 thornyheads km−2 and CVs from 10 to 18%. Underlying assumptions necessary for obtaining unbiased density estimates using a camera sled and line transect sampling are discussed, including a methodology to account for fish movement in response to the camera sled. (Lauth et al. 2004a).

Data from a video camera sled and research survey trawl were used to estimate size-specific trawl selectivity for *Sebastolobus* spp. Sizes from the camera sled video were extracted using an oblique grid plane and image analysis software. Thornyhead mean densities were 3–5 times higher with the camera sled than the survey trawl. Experimental selectivity patterns failed to conform to traditional parametric selectivity functions so a new non-parametric model was derived. The estimates of catchability for 20–25 cm thornyheads were 0.25–0.75. Catchability estimates for thornyheads larger than 30 cm were much lower (<0.10). A reason for low catchability at larger sizes remains unclear but may be a size-dependent interaction with the trawl, an artifact caused by low sample size of large fish in the study area, an unresolved bias in the video measurement system, or any combination of these factors. (Lauth et al. 2004b)

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov, (541) 867-0542 or Robert Lauth at Bob.Lauth@noaa.gov, (206) 526-4121.

9) Bycatch Reduction: Fish Behavior During Interactions with Bottom Trawls

This project, initiated in 2004 will use conventional underwater video and a state-of-the-art ultrasonic camera (DIDSON or dual frequency identification sonar) to document and categorize fish behavior during the sequence of capture in bottom trawls with an emphasis on a selective flatfish trawl – an experimental net being used in West Coast groundfish fisheries. The selective flatfish trawl has been shown to maintain the catch rate of flatfish while allowing larger and more mobile species (e.g., rockfishes, shortspine thornyhead and hake) to escape by swimming above the headrope. Several Complementary biochemical studies are being conducted to evaluate burst swimming capabilities in selected groundfish species. This work is a collaboratiopm between the NWFSC, Oregon Department of Fish and Wildlife, Alaska Fisheries Science Center and University of South Florida.

For more information, contact Waldo Wakefield at Waldo.Wakefield@noaa.gov, (541) 867-0542 or Bob Hannah at Bob.Hannah@oregonstate.edu, (541) 867-0300.

10) Science for Ecosystem-based Management Initiative

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. 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. We are conducting a standardized assessment of risks faced by groundfish on the continental shelf of the U.S. 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 are estimating 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 goal is to develop this work into a "partial" assessment technique for a number of currently unassessed species.

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

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 Phil Levin at Phil.Levin@noaa.gov, (206) 860-3473.

4. 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 Phil Levin at Phil.Levin@noaa.gov, (206) 860-3473.

5. 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 Phil Levin at Phil.Levin@noaa.gov, (206) 860-3473.

6. 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 developed bioenergetics models for *Sebastes* species, and used 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 Chris Harvey at Chris.Harvey@noaa.gov, (206) 860-3228.

7. 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 Phil.Levin@noaa.gov, (206) 860-3473.

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

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

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

The overarching goal of this project is to develop a model that allows users to examine the effects of large-scale management efforts against a backdrop of environmental variability resulting from climate events, seasonal changes, oceanographic dynamics, food web interactions, and fisheries. To achieve this goal, we are (1) collating data for the processes and functional

groups included in the model; (2) defining the spatial structure of the NCCE; and (3) simulating behavior of the NCCE under alternate fisheries management policies and environmental regimes

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

11) 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 October 2004, researchers from OSU/COAS conducted a successful cruise using the OSUSSS off central Oregon aboard the R/V Wecoma. The cruise was highly successful with the recovery of over 80 gravity cores across a broad depth range from the nearshore to the shelf break.

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. Preliminary findings from this work were presented as a poster at the Western Groundfish Conference in 2004.

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

12) 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. 2004). 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 summers of 2003 and

2004, NOAA Fisheries conducted trawl surveys 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 and 2004 is currently being analyzed and preliminary information was presented in 2004 at 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), as well as scientists from the NEFSC Ecosystems Branch, Sandy Hook, N.J., the SEFSC, Long Beach, Calif., and the United States Coast Guard Academy, Groton, CT (e.g., Witting et al. 2004).

For more information, contact Keith Bosley at Keith.Bosley@noaa.gov, (541) 867-0506 or Richard D. Brodeur at Rick.Brodeur@noaa.gov or Waldo Wakefield at Waldo.Wakefield@noaa.gov, (541) 867-0542.

13) 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.

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 and 2004 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, 2003 and 2004. In particular, under separate funding, 4 days of high-resolution multibeam mapping aboard the R/V Thomas Thompson was conducted off Oregon (collaboration with NOAA's Pacific Marine Environmental Laboratory) and in Southern California with an additional 5 days of mapping in Southern California. Interpretation of these data will be included in the Version 2 release. Additional multibeam and backscatter data collected by NOAA on the Washington margin have also been interpreted and incorporated into bathymetry grids, and into the interpreted habitat layers for 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. Background on the mapping project for surficial geological habitats of the Oregon and Washington continental margin can be found in Romsos (2004).

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

14) 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 43 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, and
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 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 2004, the program summarized and performed final data quality checks to prepare the data collected from the third observation year of the groundfish bottom trawl fleet (September 2003–August 2004), the fourth observation year of the sablefish endorsed fixed gear fleet (April 2004–October 2004) and two observation years of the non-endorsed fixed gear fleet (August 2002–September 2004) for analysis. The results were presented in three reports and made available on-line early this year at: http://www.nwfsc.noaa.gov/research/divisions/fram/Observer/. The results were incorporated into a bycatch model for management use.

In addition, the program aided CDF&G with data collection for the selective flatfish net EFP. The program also expanded coverage in the Oregon nearshore and pink shrimp fleets while maintaining coverage of these fleets in California. Coverage of the groundfish bottom trawl and fixed gear fleets will continue into 2005.

The program also investigated the use of electronic monitoring systems rather than observers to monitor overall catch in the shore-based hake fishery. Program staff worked with a contractor to deploy systems aboard all active hake vessels, collect GPS, winch sensor, hydraulic pressure and video images during fishing and process the images for incidences of non-retention. The use of this technology is promising to monitor discards in this fleet. Further work with this technology on the hake fleet is planned for 2005.

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

Appendix 1. Reports and Publications

Andrews, K. S., T. W. Anderson. 2004. Habitat-dependent recruitment of two temperate reef fishes at multiple spatial scales. Marine Ecology-Progress Series 277:231-244.

Bosley, K. L., W. Lavelle, R. D. Brodeur, W. W. Wakefield, R. L. Emmett, E. T. Baker, K. M. Rehmke. 2004. Feeding relationships among pelagic and benthic communities in relation to the hydrodynamics of Astoria Submarine Canyon, Oregon, USA. Journal of Marine Systems 50:21-37.

Foote, K. J., D. Chu, T. R. Hammar, K. C. Baldwin, L. A. Mayer, L. C. Hufnagle, Jr., J. M. Jech. Protocols for calibrating multibeam sonar. The Journal of the Acoustical Society of America, in press.

Jech, J. M., K. G. Foote, D. Chu, L. C. Hufnagle, Jr. Comparing two 38-kHz scientific echo sounders. ICES Journal of Marine Science, accepted with revisions.

Lauth, R. R., W. W. Wakefield, K. Smith. 2004a. Estimating the density of thornyheads, *Sebastolobus* spp., using a towed video camera sled. Fisheries Research 70:39-48.

Lauth, R. R., J. Ianelli, W. W. Wakefield. 2004b. Estimating the size selectivity and catching efficiency of a survey bottom trawl for thornyheads, *Sebastolobus* spp., using a towed video camera sled. Fisheries Research 70:27-37.

Levin, P., B. E. Kochin. 2004. Publication of marine conservation papers: is conservation biology too dry? Conservation Biology 18:1160-1162.

Romsos, C. G. 2004. Mapping surficial geological habitats of the Oregon continental margin using integrated interpretive and GIS techniques. Master's thesis. Oregon State University, Corvallis.

Tolimieri, N., P. Levin. 2004. Differences in responses of chinook salmon to climate shifts: implications for conservation. Environmental Biology of Fishes 70:155-167.

Wakefield, W. W., C. E. Whitmire, J. E. R. Clemons, B. N. Tissot. In press. Fish habitat studies: combining high-resolution geological and biological data. *In* P. W. Barnes and J. P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.

Witting, D. A., R. C. Chambers, K. L. Bosley, S. C. Wainright. 2005. Experimental evaluation of ontogenetic diet transitions in summer flounder, Paralichthys dentatus, using stable isotopes as diet tracers. Canadian Journal of Fisheries and Aquatic Sciences 61: 2069-2084.