Alaska
Fisheries Science
Center

National Marine
Fisheries Service

U.S DEPARTMENT OF COMMERCE

AFSC PROCESSED REPORT 97-03

A Review of Groundfish Research, Assessments, and Management Conducted at the Alaska Fisheries Science Center During 1995.

A Report to the 1996 Annual Meeting of the
Technical Subcommittee, Canada-U.S. Groundfish Committee

March 1997

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NATIONAL MARINE FISHERIES SERVICE
1871
125th ANNIVERSARY
1996

A REVIEW OF GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT CONDUCTED AT THE ALASKA FISHERIES SCIENCE CENTER DURING 1995

A Report from the Alaska Fisheries Science Center,
National Marine Fisheries Service, to the 1996 Annual Meeting
of the Technical Subcommittee, Canada-U.S. Groundfish Committee

Compiled by

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March 1997

Preface

Groundfish research at the Alaska Fisheries Science Center (AFSC) is conducted by the Center's Resource Assessment and Conservation Engineering (RACE) Division, the Resource Ecology and Fisheries Management (REFM) Division, and the Auke Bay Laboratory (ABL). The groundfish research and assessments of these organizations are divided along regional or disciplinary lines into a number of tasks and subtasks. A review of pertinent work by these tasks from 1995 to 1996 is presented below. A list of recent publications and reports produced by RACE, REFM, and ABL scientists are presented in the Appendix.

Resource Assessment and Conservation Engineering (RACE) Division

In 1995 the primary activity of the Resource Assessment and Conservation Engineering (RACE) Division continued to be fishery-independent stock assessments of important groundfish species of the northeast Pacific Ocean and Bering Sea. Major survey emphasis in 1995 was along the continental west coast (California-Oregon-Washington-British Columbia), in keeping with the triennial rotation of comprehensive surveys among three major geographic areas (Bering Sea/Aleutian Islands, Gulf of Alaska, and West Coast). Two bottom trawl surveys were completed off the west coast in addition to the annual Bering Sea crab/groundfish bottom trawl survey.

The Midwater Assessment and Conservation Engineering (MACE) Task conducted four acoustic surveys of pollock abundance in the Gulf of Alaska and Bering Sea in early 1995 and a major survey of the Pacific whiting resource along the West Coast during the summer of 1995. The Conservation Engineering group within MACE has also been refining methods used to stabilize research survey trawls, monitor the fishing configurations of sampling trawls, and explore possible methods of reducing bycatch. Underwater video and scanning sonar are being used to study the behavior of fish encountering trawl gear with the purpose of detecting behavior differences among species and size classes which might be exploited to reduce bycatch.

The Recruitment Processes task conducted three Fisheries-Oceanography Coordinated Investigations (FOCI) cruises in the spring of 1995, investigating the interaction between the environment and the spawning products of Gulf of Alaska and eastern Bering Sea pollock. An additional FOCI study near the Pribilof Islands in late summer 1995 looked at young-of-the-year pollock.

The Fisheries Behavioral Ecology Program at the Hatfield Marine Science Center in Newport, Oregon, continued investigations of post-capture survival of sablefish and walleye pollock in simulated trawl bycatch situations. Studies are aimed at evaluating: 1) the potential for long-term survival following capture; 2) whether fish that survive capture suffer effects that may compromise their ability to feed successfully and avoid predation; 3) whether the capability of surviving and recovering from capture differs with age and species and; 4) how environmental factors interact with the stresses imposed by capture to influence survival and recovery of behavioral mechanisms. The group is also studying early juvenile stages of walleye pollock and their ability to modify their behavior according to environmental conditions they encounter.

Research by the Fisheries Resource Pathobiology Program is aimed at monitoring the distribution and prevalence of diseases affecting the fishery resources of the North Pacific. Pathobiologists in this program have also been collaborating with the Environmental Protection Agency on a broad histopathological study of three Florida shrimp species that could potentially identify a useful bioindicator of pollution.

For more information on overall RACE Division programs, contact Division Director Dr. Gary Stauffer (206)526-4170.

Resource Ecology and Fisheries Management (REFM) Division

The research and activities of the Resource Ecology and Fisheries Management Division (REFM) are designed to respond to the needs of the National Marine Fisheries Service regarding the conservation and management of fishery resources within the U.S. 200-mile Exclusive Economic Zone (EEZ) of the northeast Pacific Ocean and Bering Sea. Specifically, REFM's activities are organized under the following tasks: the Observer Program, Age and Growth Studies, Socioeconomic Assessments, and Marine Assessment and Resource Ecology. Scientists at the AFSC provide stock assessments for groundfish in three management regions (Bering Sea/Aleutian Islands, Gulf of Alaska, and Washington-Oregon-California), conduct research to improve the precision of these assessments, and provide management support through membership in regional groundfish management teams.

For more information on overall REFM Division programs, contact Division Director Dr. Richard Marasco (206)526-4172.

Auke Bay Laboratory (ABL)

The Auke Bay Laboratory (ABL), located near Juneau, Alaska, is a major division of the AFSC. ABL's Groundfish Task (part of the laboratory's Marine Fisheries Assessment Program) is primarily involved with the research and assessment of sablefish and rockfish stocks in the Gulf of Alaska. Presently, the groundfish task is staffed by 10 permanent biologists.

During the 1995-96 field research season, the Groundfish Task conducted the annual NMFS sablefish longline survey in the Gulf of Alaska. Other field studies by ABL in 1995-96 included: 1) rockfish maturity and genetic sampling; 2) an experiment to determine small-scale distribution of Pacific ocean perch aggregations; and 3) continued juvenile sablefish studies, notably a pilot study that used a small-mesh gillnet for surveying young-of-the-year fish.

Ongoing analytic activities involved management of ABL's sablefish tag database and preparation of three annual status of stocks documents for Gulf of Alaska groundfish: sablefish, slope rockfish, and pelagic shelf rockfish. An age-structured model analysis was also used to estimate catchability of sablefish in the longline survey and to determine alternative estimates of sablefish biomass.

For more information on overall ABL programs, contact Laboratory Director Dr. Michael Dahlberg (907) 789-6001.

Multispecies Studies (Research)

1995 RACE Bering Sea Crab/Groundfish Bottom Trawl Survey

The 1995 eastern Bering Sea crab-groundfish bottom trawl survey was conducted from 1 June to 2 August, continuing the annual series of eastern Bering Sea resource assessment surveys which began in 1971. The primary purpose of the survey was to assess the abundance, distribution, and biological condition of the major demersal fish and crab resources on the eastern Bering Sea shelf. Further research conducted during the standard survey included: collection of stomachs from various groundfish for use in trophic interaction studies; additional sampling in areas of high king crab and Tanner crab abundance to reduce variability of population estimates; sampling to monitor the distribution and prevalence of Bitter Crab Syndrome in the snow and Tanner crab populations; retrieval and redeployment of bottom temperature sensors in Bristol Bay which record seawater temperatures for a 12-month period; and an evaluation of potential bias in subsampling methods for large bottom trawl catches.

The survey encompassed an area approximately 465,000 km^2, which included continental shelf waters from inner Bristol Bay west to the 200 m depth contour and from the Alaska Peninsula north to St. Matthew Island. The survey was conducted aboard two chartered fishing vessels. A total of 394 bottom trawls were completed during the survey using the standard AFSC 83-112 eastern bottom trawl. These included 379 successfully completed trawls and 11 unsuccessful hauls at scheduled sampling sites, and 4 opportunistic hauls to collect additional information on king and Tanner crab. Seawater temperature profiles and tow bottom depths were collected at most sampling sites using micro-bathythermographs (MBT) attached to the headrope of the net.

Estimates from the survey indicated a moderate reduction in biomass compared to 1994 for almost all the flatfish species and Pacific cod. There was a slight increase in the estimate for walleye pollock; however, this was for the demersal component of the population only since there was no hydroacoustic survey during 1995.

For more information, contact Gary Walters (206) 526-4143.

1995 RACE West Coast Surveys

The year 1995 was a "triennial year" for focusing research survey efforts in the West Coast region off Washington, Oregon, California, and British Columbia. As such, two bottom trawl surveys and one echo integration/midwater trawl survey were conducted in this area by the AFSC. The seventh in a series of coastwide triennial groundfish surveys was conducted during June through September to monitor the distribution and abundance of groundfish resources of the continental shelf between depths of 55 and 500 m. In October and November, a bottom trawl survey of the continental slope waters (183-1,280 m) off southern Oregon and northern California repeated investigations done in 1990 of the deeper groundfish resources off the Pacific coast.

1995 RACE West Coast Triennial Bottom Trawl Survey

The West Coast Groundfish Subtask continued its series of triennial bottom trawl surveys of the groundfish resources off California, Oregon, Washington, and British Columbia during the summer of 1995. The survey began 8 June near Pt. Conception, California, and concluded on 6 September off Nootka Sound, British Columbia. Two chartered vessels successfully completed trawl hauls at 524 of the scheduled 610 stations between the depths of 55 and 500 m.

The West Coast triennial survey series dates back to 1977. In the earlier surveys (1977-1986), the survey design emphasized estimating rockfish abundance for resource management. Experience from those surveys showed that area-swept trawl surveys did not provide sufficiently precise rockfish abundance estimates due to patchy distribution of rockfish. The survey design was altered in 1989 to emphasize multispecies objectives and to improve the precision of Pacific whiting and sablefish biomass estimates. The 1992 survey replicated the 1989 survey design.

The 1995 trawl survey extended the depth range of past triennial surveys; previous surveys covered depths from 55-366 m while the 1995 survey covered depths from 55-500 m. Four strata of high station density used in 1989 and 1992 were downgraded to the background station density because we found that the small precision improvements in sablefish abundance estimates realized by the higher station density did not justify the time spent sampling the extra stations. By reallocating the high-density stations to the deep stratum, we attempted to more comprehensively cover the habitat of slope rockfish species (except thornyheads). The new stations in the deep strata were located in a manner consistent with the survey design of the shallower strata. Shallower than 366 m, the survey replicated stations fished during the 1989 and 1992 triennial surveys.

For more information, contact Mark Wilkins (206) 526-4104.

1995 RACE West Coast Continental Slope Bottom Trawl Survey

In October-November 1995, we resumed the annual series of upper continental slope (100-700 fm) bottom trawl surveys of groundfish resources that was begun in 1988. The survey period in 1994 was used to conduct research on the survey trawl efficiency and video sled comparisons of fish density. In 1995, we surveyed the Eureka International North Pacific Fisheries Commission (INPFC) area (40°30' to 43°00' N lat) aboard the NOAA ship Miller Freeman. Data derived from annual slope surveys are used by fishery managers to assess stock conditions and establish annual harvest guidelines for sablefish, Dover sole, and two species of thornyhead rockfish. It presently takes 4-5 years to complete a trawl survey of the entire U.S. West Coast because of the length of the coastline, the time necessary to collect trawl samples from deep water, and the availability of only 1 month of vessel time for the survey each year. Slope groundfish resources in the Eureka INPFC area were last surveyed in 1990.

During the past 2 years the fishing industry and an independent review panel of fishery scientists criticized the slope survey gear performance and the resulting survey data. In 1995, we implemented changes to the trawl gear and trawling methodology based on the results of RACE studies conducted in 1994 to improve gear performance. Gear and trawling changes included the

use of a 4-point door bridle to improve door stability, shortened drop chains connecting the ground gear to the footrope to allow less escapement along the footrope, and an increased target towing speed from 2.0 knots to 2.3 knots to improve net stability. We also added instrumentation to the trawl to improve our ability to monitor gear performance. Besides the regular SCANMAR equipment for measuring net dimensions and the bottom depth data logger, we also attached a bottom contact sensor to the footrope, a tilt sensor on the trawl doors, and a new Wesmar net sonar system to the headrope. The Wesmar sonar provides a real-time image of the mouth of the trawl while it is fishing on bottom. It provided us with a better understanding of the trawl's dynamics when adjustments were made in speed and wire length. We also took video footage of the new 4-point trawl door configuration and the ground gear while they were fishing on the bottom. A fisherman representing the Oregon fishing industry participated for 3 days during the second leg of this year's cruise and was able to observe and critique the modifications to the sampling gear while the survey was in progress.

Analyses of the 1995 survey data have shown that the modified configuration of the trawl is more stable while fishing, maintaining a more constant net width and height. Large quantities of mud in the catches also occurred much less often. Samples collected with the modified trawl reflected catch rates similar to those seen with the unmodified gear in the same area in 1990. Our results indicate that, although the trawl was unstable while fishing during past surveys, this problem may not have significantly affected catch rates.

For more information, contact Bob Lauth (206) 526-4121.

REFM Age and Growth Task

The Age and Growth Task of the REFM Division serves as the Alaska Fisheries Science Center's ageing unit for groundfish species. The task consists of a biometrician, age validation researcher, data manager/technician, and eight age readers. Ages are usually determined from otoliths, but scales and/or finrays are sometimes used.

Data provided by the task are used in stock assessment work, which contributes to the estimation of the allowable catch of many commercially important groundfish species. These species include walleye pollock, Pacific whiting, Pacific cod, sablefish, Pacific ocean perch, northern and dusky rockfishes, Atka mackerel, yellowfin sole, rock sole, rex sole, and other miscellaneous sole and rockfish species.

The radiometric lab of the Ageing Unit is currently focusing on the ageing of several rockfish species: Pacific ocean perch, shortspine thornyheads, shortraker, rougheye, northern, and dusky rockfish. Recently published work[1] indicate that radiometric ageing is best accomplished using otolith cores (centers) rather than whole otoliths.

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[1]KIMURA, D. K., and C. R. KASTELLE. 1995. Perspectives on the relationship between otolith growth and the conversion of isotope activity ratios to fish ages. Can. J. Fish. Aquat. Sci. 52: 2296-2303.

A study is currently underway with the National Marine Mammal Laboratory to apply radiometric ageing techniques to gray whales and other baleen whales. We have found that obtaining the necessary ear bones (i.e., whale bullae) is itself a major difficulty. Also, the possible reconstruction of the whale bone as it ages may invalidate the radiometric ageing method.

Delsa Anderl has completed work with Dr. Akira Nishimura of Japan's National Research Institute of Far Seas Fisheries, and Sandra Lowe on the first year growth in the otoliths of Atka mackerel. Anderl is also continuing working with Jon Heifetz on a study based on known age sablefish.

For more information, contact Dr. Daniel Kimura (206) 526-4200.

REFM Trophic Interactions Program

The Trophic Interactions Program continued regular collection of food habits information on key fish predators in the North Pacific. Program personnel and fishery observers collected about 12,279 fish stomachs from the Bering Sea, 1,409 from the Gulf of Alaska/Aleutian Islands, and over 2,500 from the West Coast region. Bering Sea species sampled were walleye pollock, Pacific cod, yellowfin sole, Alaska plaice, rock sole, flathead sole, skates, arrowtooth flounder, Greenland turbot, and Pacific halibut. Gulf of Alaska/Aleutian Island species sampled included walleye pollock, arrowtooth flounder, and Pacific cod. Pacific whiting stomachs were collected from the West Coast region. Shipboard scans of fish stomach contents were performed on 116 fish (primarily walleye pollock) in the eastern Bering Sea and 76 fish (sablefish and thornyheads) in the West Coast region. Laboratory analysis of stomach contents by regions totaled 10,300 and 2,198 stomachs for the Bering Sea and Gulf of Alaska/Aleutian Islands regions, respectively.

A report on ecosystem implications of the current groundfish fishery bycatch, utilization, and discard practices was completed. Results highlighted the magnitude of offal (processed fish waste) relative to fishery discards. It appears that about 59% of the total (retained+discarded) catch weight of groundfish fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska becomes offal and is returned to the sea. Discards, however, constituted only about 15% of the total catch weight of groundfish fisheries. Groundfish inhabiting these regions are documented consumers of offal. It is estimated that groundfish in the eastern Bering Sea may consume over 160,000 t (metric tons) of offal during the May - September feeding period each year. Population trends of offal consumers, including birds, were examined and did not appear to show increases related to increased availability of offal. The combined amount of offal and discards in the eastern Bering Sea is only about 1% of the estimate of unused detritus already going to the bottom, implying these amounts are negligible when energy flow of the whole system is considered.

A comparative approach to learning about groundfish food webs was undertaken by the group. Groundfish food webs of the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands regions were constructed and various aspects were compared, particularly with respect to the role of pollock in each. Walleye pollock was the central groundfish species in the Bering Sea web. It was not only the most abundant species, but it was also the most important prey for many piscivorous groundfish species. Pollock shared its central role in the other two regions with arrowtooth flounder in the Gulf of Alaska and with Atka mackerel in the Aleutian Islands region.

The key feature of all three groundfish food webs was that the most abundant groundfish species in the pelagic realm was one that relied heavily on euphausiids and copepods for prey and thus had a lower trophic level than other abundant groundfish species. The average trophic level of walleye pollock was lower in the Bering Sea than in the Gulf of Alaska and Aleutian Islands regions. Similarly, groundfish that relied heavily on pollock for prey had lower trophic levels in the Bering Sea. It's possible that the shorter food chain length leading to pollock in the eastern Bering Sea relative to the Gulf of Alaska and Aleutian Islands areas leads to higher stability (shorter return to equilibrium) in the eastern Bering Sea.

Work is continuing on parameterizing a multispecies virtual population analysis model and a static energy balance model (ECOPATH) for two time periods in the eastern Bering Sea.

For more information, contact Pat Livingston (206)526-4242.

Multispecies Studies (Stock Assessment)

REFM Marine Assessment and Resource Ecology Task

The Marine Assessment and Resource Ecology Task (MARE) is responsible for providing groundfish stock assessments and management advice for the North Pacific Fishery Management Council (NPFMC) and the Pacific Fishery Management Council (PFMC). In addition, Task members conduct research to improve the precision of these assessments and provide technical support for the evaluation of potential impacts of proposed fishery management measures.

During the past year, stock assessment documents were prepared by the REFM MARE task for the Gulf of Alaska and Bering Sea/Aleutian Islands plan development teams of the NPFMC and for the groundfish management team of the PFMC.

Assessment scientists provided analytic assistance on many current fisheries management issues. These included: 1) identification and prioritization of research activities that may lead to improved groundfish stock assessments; 2) modeling of groundfish stock structure; 3) contributed to a comprehensive report on bycatch, utilization and discards; 4) provided analytical advice to the NPFMC to establish an overfishing definition; and 5) made presentations to the National Research Council (NRC) for the national review of stock assessment methods.

Research activities spanned a broad range of topics. Field studies initiated by staff members included the continuing development of a demersal rockfish trawl for improved stock assessment and maturation studies for Atka mackerel. Significant research contributions on bycatch analysis, food web analysis, methods for quantifying uncertainty in stock assessments and Pacific whiting migration were presented at various symposia. In addition, staff members participated on nationwide NMFS committees for overfishing definitions, risk assessment in stock assessment analyses, and NRC review of stock assessment methodology. Staff members also served on national and international steering committees of Global Ocean Ecosystem Dynamics (GLOBEC) and the North Pacific Marine Science Organization (PICES).

For more information, contact Dr. Vidar Wespestad (206) 526-4249 or Dr. Anne Hollowed (206) 526-4223.

Multispecies Studies (Management)

Observer Program - REFM

The Fisheries Observer Program is responsible for placement of observers on vessels fishing for groundfish species in the U.S. Exclusive Economic Zone (EEZ) of the northeastern Pacific Ocean and Bering Sea. Observers collect data which provide the basis for in-season management of the groundfish fisheries by NMFS, provide a means for evaluating and developing management strategies by regional management councils and NMFS and are used in the stock assessment process. Observers play important roles in providing information that is critical to the welfare of the U.S. fishing industry.

During 1995, no foreign vessels were allowed to catch or process fish in the U.S. EEZ along the West Coast and Alaska. All of the allotted groundfish were given to U.S. vessels and processing plants, both for catching and processing. The Observer Program trained and deployed 550 observers to vessels fishing off Alaska, and 17 observers to vessels fishing off the Washington-Oregon-California coast. The Program was responsible for defining the sampling duties and data collection methods used by observers, training of the observers prior to deployment, debriefing of observers upon their return, and editing and managing the resulting data. The catch data were provided to the Alaska and Northwest Regional Offices to assist in management decisions regarding the catches of groundfish and prohibited species. These data were also used in the implementation of the Vessel Incentive Program in Alaska, where vessels were prohibited from exceeding certain prohibited species catch rates. Valuable data were also collected regarding the operations of the groundfish fishery.

For more information, contact Dr. William Karp (206) 526-4194.

Socioeconomic Assessment Task - REFM

During 1995, the Socioeconomic Assessment Task was actively involved in providing economic information used in the evaluation of management measures being considered by the Pacific and North Pacific Fishery Management Councils. Task members served on the BSAI, GOA, and West Coast groundfish plan teams and on both NPFMC and PFMC technical work groups and contributed significantly to, and in several cases had the lead for, the analyses and review of the following fishery management actions: 1) NPFMC license limitation program for the groundfish and crab fisheries off Alaska, 2) North Pacific Fisheries Research Plan (i.e., the Observer Program and user fees to support it), 3) NPFMC amendments to control bycatch in the GOA and BSAI groundfish fisheries, 4) NPFMC increased retention and utilization of groundfish catch, 5) NPFMC harvest priority in the groundfish fishery (i.e., reserve part of a Total Allowable Catch (TAC) or season for vessels that meet specific bycatch and discard standards), 6) NPFMC total weight measurement (i.e., the use of scales or marked bins to provide better estimates of total catch for at-sea and on-shore processing), 7) NPFMC vessel bycatch account (VBA) program (individual bycatch quotas), 8) moratorium for the BSAI and GOA groundfish fisheries and the BSAI crab fisheries, 9) the continuation of the NPFMC allocation of BSAI pollock GOA

pollock and Pacific cod between on-shore and at-sea processors, 10) the expansion of the community development quota (CDQ) program in the BSAI groundfish and crab fisheries, and 11) PFMC sablefish management (stackable licenses and trip limits). Also in support of the PFMC, a Task member assisted in improving both the historical groundfish catch data and access to the data.

Task members prepared publications on the following topics: 1) the economics of bycatch; 2) the management of high seas fisheries; 3) the economic status of the Alaska groundfish fisheries; 4) the exports of edible fishery products from the Pacific Northwest and Alaska; 5) the CDQ and open access BSAI pollock fisheries; 6) the use of marketable permits for pollution; and 7) catch, bycatch, utilization, and discards in the Alaska groundfish fisheries.

Task members provided economic advice and technical review and support for: 1) Saltonstall-Kennedy, Sea Grant, and Alaska Science and Technology Foundation research proposals; 2) the redefined PacFIN system; 3) the evaluation of the Alaska halibut and sablefish IFQ program; 4) university research proposals; 5) the economic counterpart to "Our Living Oceans"; 6) a preliminary assessment of the effects of the PFMC limited entry program; 7) U.S. Forest Service and NMFS workshops on ecological and economic valuation assessment techniques for resource management; 8) NMFS limited entry workshops; 9) NMFS fishing cost data workshops; 10) NMFS efforts to improve their data collection and catch estimation programs; 11) NMFS efforts to determine the feasibility of monitoring catch and bycatch of individual fishing vessels in support of future Community Development Quota (CDQ), Individual Transferrable Quota (ITQ), and Vessel Bycatch Account (VBA) programs; 12) the Organization for Economic Co-operation and Development (OECD) study of the economic aspects of the management of living marine resources; and 13) the annual cooperative NMFS and Alaska Department of Fish & Game (ADF&G) survey of Alaska groundfish processors.

For more information, contact Dr. Joe Terry (206) 526-4253.

Pacific Cod Stock Assessment

Bering Sea/Aleutian Islands

The length-based Synthesis model used in the previous two stock assessments was retuned for the present assessment, incorporating additional length frequency information, revised catch estimates, and the 1995 trawl survey estimate of stock size. The 1995 trawl survey biomass estimate of 1.00 million t was down about 27% from the 1994 survey estimate. However, the 1994 survey estimate was nearly double the 1993 level and was most likely an overestimate. The new biomass and catch projections from the model are very much in line with last year's projections, with projected biomass increasing by only 1% and projected catch (under an $F_{35\%}$ harvest strategy) increasing by 9%. The 1992 year class continues to look very strong in the 1995 trawl survey size composition, and the 1989-1991 year classes continue to appear at least average in size.

Using an $F_{35\%}$ (=0.36) harvest strategy, the assessment model projects a 1996 allowable biological catch (ABC) of 313,000 t for the EBS portion of the stock and 357,000 t for the EBS

and Aleutians combined. Reliable estimates of F_{MSY} and B_{MSY} (the levels of fishing mortality (F) and biomass (B) at which Maximum Sustainable Yield (MSY) is achieved) are not available for this stock. The assessment model projects a 1996 overfishing level (OFL) (under an $F_{30\%}$=0.43 harvest strategy) of 368,000 t for the EBS portion of the stock, or 420,000 t for the EBS and Aleutians combined. Pacific cod in the EBS and Aleutian Islands is managed as a unit, although nearly all of the assessment research focuses on the EBS portion of the stock.

Gulf of Alaska

The latest assessment features some major improvements to the model which included separating the catch and size composition data into different fishery categories (e.g., trawl, longline, and pot gear), the use of mean size-at-age data within the model, and investigations on sensitivity to different natural mortality rates, trawl survey selectivities, and survey catchability coefficients.

The projected biomass (ages 3 and above) for 1996 is 557,000 t, representing a 3% decrease from the 1995 biomass projected in last year's assessment. For calculation of ABC, an $F_{40\%}$ strategy is used resulting in a 1996 ABC projection of 110,000 t which is about 50% of the value expected under average conditions with no fishing. However, fishery managers believe that a lower harvest level would be prudent because of a continuing decline in stock abundance below any level previously estimated and because recent recruitment levels appear to be below average.

At the September meeting, the Team selected a range of ABC values corresponding to the maximum likelihood estimate and the lower 95% confidence bound. The lower 95% confidence bound was estimated by assuming that the log-likelihood values are true likelihoods and applying the principle that the log-likelihood values are distributed as chi-squared. This resulted in a range of ABC values between 65,000-110,000 t (4,000 t of which the author anticipates as bycatch in the halibut fishery).

The assessment also included an additional analysis on alternative survey catchability values. Preliminary results suggest a poor ability to estimate catchability when several key parameters are estimated simultaneously. The likelihood was flat over a range of catchability coefficient values suggesting a greater degree of uncertainty in current stock size than previously estimated. Given this uncertainty, there exists less confidence that an ABC value of 110,000 t (which is about 50% higher than any annual harvests recorded in the Gulf) would be risk-averse.

Consequently, an ABC value of 65,000 t was used for 1996 corresponding to the lower 95% confidence bound. The reasons for selecting this value are as follows:

- this harvest level is similar to historical values both prior to and after the peak abundance levels of the mid-1980s;
- stock abundance is declining below any level previously estimated and recent recruitment levels appear to be below normal;
- based on a model the NPFMC's Plan Team considered reasonable, this harvest level represents a conservative interpretation of statistical confidence bounds; and

- preliminary analyses on the survey catchability coefficient suggest that the absolute abundance *may* be significantly lower than previously assumed—a plausible alternative model configuration provided an ABC value of about 65,000 t.

For more information, contact Dr. Grant Thompson (206) 526-4232.

Shelf Rockfish Stock Assessment

Gulf of Alaska

Pelagic Shelf Rockfish

The pelagic shelf rockfish assemblage is comprised of five species that inhabit waters of the continental shelf of the Gulf of Alaska and that are thought to exhibit midwater schooling behavior. At certain times, however, some of these fish are caught in bottom trawls. Dusky rockfish appears to be the most abundant species in the group and has been the target of a bottom trawl fishery in recent years. A jig fishery for black rockfish has also developed in the central Gulf of Alaska since 1991. Current exploitable biomass for the pelagic shelf assemblage is based on the average of the biomass estimates from the 1987, 1990, and 1993 triennial trawl surveys: 57,644 t. Results of these surveys, however, are highly uncertain for rockfish, especially when applied to species that may be somewhat pelagic in distribution. Pelagic shelf rockfish are presently managed using an $F=M$ strategy in which the annual exploitation rate is set equal to the estimated rate of natural mortality for dusky rockfish (0.09). Applying this exploitation rate to the current exploitable biomass yields a Gulfwide ABC of 5,190 t for 1996.

In past years, the Gulf of Alaska Groundfish Plan Team recommended that black rockfish in the central Gulf be separated from the pelagic shelf group and assigned a separate ABC. These proposals stemmed from a concern that under the present management regime, black rockfish may be selectively overharvested in localized areas; also, most black rockfish reside in nearshore waters that are not sampled in the present trawl surveys. The recommendations, however, have never been enacted at the Council level. As an alternative solution to the problem of black rockfish management, the Plan Team in 1995 drafted a proposed management plan amendment. If adopted, this amendment would separate dusky rockfish from the pelagic shelf assemblage, and transfer management authority for the other species in the group to the ADF&G, in both state and Federal waters.

For more information, contact David Clausen (907) 789-6049 or Jon Heifetz (907) 789-6054.

Slope Rockfish Research

Gulf of Alaska

Maturity Studies

Slope rockfish maturity studies were initiated by ABL in 1995 to determine new estimates of the size and age of maturity for female Pacific ocean perch and other species in the Gulf of Alaska. This project was a cooperative study with the University of Alaska Fairbanks, Juneau Center, School of Fisheries and Ocean Sciences. The two most recent studies of Pacific ocean perch maturity in the Gulf of Alaska were conducted over 20 years ago and showed conflicting results as to the size of maturity for females. This, together with the current need for valid maturity information in population dynamics models, provided the rationale for the study. Maturity samples were collected off southeastern Alaska in May and July 1995 during two cruises of the NOAA RV John N. Cobb, and off Kodiak in March-April 1996 during a cruise of the NOAA RV Miller Freeman. The sampling focused on female Pacific ocean perch, but also included female sharpchin, black, northern, and dusky rockfish. Ovaries were visually examined and assigned maturity codes, and otoliths and histology samples were also taken for laboratory analysis. A preliminary analysis of the data for female Pacific ocean perch off southeastern Alaska indicates size of 50% maturity was around 35-36 cm fork length.

For more information, contact Jon Heifetz (907) 789-6054 or Dave Clausen (907) 789-6047.

Genetic Studies

The ABL's Genetics Task completed an initial analysis of shortraker and rougheye rockfish from the eastern Gulf of Alaska and Aleutian Islands regions. Approximately 30 enzymes were screened electrophoretically from 400 adults of each species. Several loci showed fixed differences for the common allele mobility between species, providing a useful tool for species identification. In addition, it appears there are some geographically based allelic frequency differences between the eastern Gulf of Alaska and Aleutian regions.

In cooperation with Dr. Anthony Gharrett and Andy Gray at the University of Alaska, a study on the use of polymerase chain reaction amplification of mitochondrial DNA to study rockfish genetics is nearing completion. Results will be used to examine phylogenetic relationships among rockfish species, determine if separate genetic stocks exist for various species of slope rockfish, and verify species identification of larval and post-larval rockfish. As part of this study, rougheye rockfish samples were compared between the eastern Gulf of Alaska and Aleutian Islands regions. The results confirm observations from the electrophoretic studies that there are genetically based stock differences between rougheye rockfish from the eastern Gulf of Alaska and Aleutian Islands regions.

For more information, contact Jon Heifetz (907) 789-6054.

Spatial Distribution of Pacific Ocean Perch Aggregations

The ABL used the NOAA ship Miller Freeman in April 1996 to conduct an experiment on the distribution of Pacific ocean perch in an area called the "Snakehead", (56°06' N, 153°30' W) south of Kodiak Island under the auspices of the AFSC's Rockfish Working Group. For the experiment, 34 trawl hauls were made in the Snakehead area around one large aggregation of Pacific ocean perch and around lesser concentrations of these fish. These data, along with previous ABL data from intensive sampling of Pacific ocean perch in the eastern Gulf of Alaska, will be used to evaluate alternative sampling strategies for estimating abundance of this species.

For more information, contact Jon Heifetz (907) 789-6054 or Dave Clausen (907) 789-6049.

Slope Rockfish Stock Assessment

Bering Sea Pacific Ocean Perch

The POP complex consists of true Pacific ocean perch (*Sebastes alutus*) and four other red rockfish (OR Rock.) species (northern rockfish [NO], rougheye rockfish [RE], sharpchin rockfish [SC], and shortraker rockfish [SR]). Prior to 1991, the complex was managed as a unit in each of the two management areas. Since 1991, however, the Council has managed *S. alutus* separately from the other species in both areas, and has also split out rougheye and shortraker in the Aleutians. This was done to avoid excessive catches of the less abundant members of the complex, particularly shortraker and rougheye. As a change from 1995, the ABC and TAC are subdivided for true POP within the Aleutian Islands (AI) area. Because of the concern about the possibility of localized depletion and because there is an indication, based on length frequency data, that the fishery may be exploiting different components of the Aleutian Islands stock, the ABC and TAC are also subdivided in the Aleutian region. Specifically, the ABC and TAC are allocated in the following proportions, based on an average of the biomass estimates from the two most recent trawl surveys: Eastern subarea (541 t) 25%; Central subarea (542 t) 25%; and Western subarea (543 t) 50%.

The stock assessment for this complex is based mainly on *S. alutus*, which has the most data and is the most abundant species in the complex. An age-based Synthesis model has been used as the primary analytic tool for the last three assessments. Synthesis results indicate that the *S. alutus* stocks in both areas underwent declines in abundance during the 1960s and early 1970s, and remained low in abundance through the early 1980s. For several years, the Council set the TAC well below (normally at 50% of) the ABC to promote rebuilding of the stocks. Through a combination of these management actions and improved recruitment, the stocks have been recovering slowly, although the most recent survey from the EBS slope region indicated some downturn in that portion of the stock.

Reliable estimates of F_{MSY} and B_{MSY} for *S. alutus* are not available. Therefore, the recommended 1996 ABC is based on a harvest strategy that reduces the equilibrium level of spawning biomass per recruit to 44% of the pristine level ($F_{44\%}$). The $F_{44\%}$ (=0.058) level was chosen over an $F_{35\%}$ (=0.077) level because an analysis of *S. alutus* in the Gulf of Alaska showed

that the $F_{44\%}$ level produces the best harvest policy given uncertainty in the stock-recruitment relationship and the life history characteristics of this species. When applied to the projected 1996 age 9+ biomass levels of 44,100 t in the EBS, the resulting 1996 ABC for *S. alutus* is 1,800 t. The 1996 OFL for *S. alutus* is based on $F_{30\%}$ (=0.093), resulting in a catch of 2,860 t.

As in the eastern Bering Sea ABC calculation, results from the 1994 survey were included in the estimation of exploitable biomass for 1996 in the Aleutian Islands. The 1991 survey biomass in the Aleutian Islands was much higher than that predicted by the model, and the 1994 survey estimates were high as well. The additional high survey year increased the model prediction of stock size and, using $F_{44\%}$, resulted in an estimated ABC of nearly 17,000 t--an increase of 70% over 1995. It was felt by the authors that the results from the last two surveys were above the expected long-term mean stock size. In order to address uncertainty in the survey results and to estimate an ABC that would lead to more stable yields, the authors conducted a simulation over 1,000 years of fishing, the average of which gave an ABC of 12,100 t and a female spawning biomass of 133,000 t. Based on the simulated long-term average spawning biomass in the Aleutian Islands at $F_{44\%}$ (=0.063), the resulting 1996 ABC for *S. alutus* is 12,100 t. The 1996 OFL for *S. alutus* based on $F_{30\%}$ (=0.096) under model projections is 25,200 t.

For the other subcomplexes ("others" in the EBS and northern/sharpchin and shortraker/rougheye rockfish in the AI), the 1996 ABC was calculated as the product of the natural mortality rate (0.06 for northern and sharpchin, 0.025 for rougheye, and 0.03 for shortraker) and exploitable biomass. Since estimates of other biological parameters are unavailable, harvesting at the $F=M$ strategy also corresponds to the OFL.

For more information, contact Daniel Ito (206) 526-4231.

Gulf of Alaska Pacific Ocean Perch

Slope rockfish are defined as those species of *Sebastes* that, as adults, inhabit waters of the continental slope, generally in depths greater than 150-200 m. Twenty-one species of rockfish are classified into the slope assemblage, the most abundant of which are Pacific ocean perch, and northern, rougheye, redstripe, sharpchin, shortraker, silvergrey, and harlequin rockfish. The stock abundance of slope rockfish is considered to be depressed compared to its former abundance in the early 1960s. The Stock Synthesis model is applied to Pacific ocean perch. This model incorporates age composition, in addition to using other parameters such as fishery CPUE and estimated biomass from the triennial trawl surveys. Based on this model, our best estimate of exploitable biomass for Pacific ocean perch in the Gulf of Alaska is now 142,470 t. Exploitable biomass for the other species in the assemblage is estimated from the average values in the 1987, 1990 and 1993 trawl surveys and totals 272,470 t.

Pacific ocean perch age samples indicate the presence of a strong 1986 year class, especially in the central and western Gulf of Alaska. This age class was first noted in samples from the 1990 triennial survey and verified in the 1993 survey. Past age samples have also identified a strong 1976 year class.

To prevent possible overexploitation of the more desirable species, the slope rockfish assemblage is divided into four subgroups: Pacific ocean perch, shortraker/rougheye rockfish,

northern rockfish, and other slope rockfish. Separate ABCs are assigned to each subgroup. Pacific ocean perch are presently managed using an adjusted $F_{45\%}$ strategy, where the ABC is adjusted downward in proportion to the ratio of current biomass to a target biomass. Target biomass is set at 150,000 t of female spawning biomass. The other subgroups are managed under an $F=M$ strategy, in which the annual exploitation rate is set equal to the rate of natural mortality. The 1996 ABCs are as follows: Pacific ocean perch, 8,060 t; shortraker/rougheye rockfish, 1,910 t; northern rockfish, 5,270 t, and other slope rockfish, 7,110 t. Recently, a rebuilding plan has been initiated for Pacific ocean perch. Under this plan, an $F_{55\%}$ rate adjusted downward by the ratio of current biomass to target biomass is used to compute a TAC of 6,959 t for Pacific ocean perch.

For more information, contact Jonathan Heifetz (907) 789-6054, James Ianelli (206) 526-6510, or David Clausen (907) 789-6049.

West Coast Pacific Ocean Perch

A rebuilding program was established for Pacific ocean perch in 1981 following depletion of this stock during the 1960s and early 1970s. The updated stock assessment, as in the analysis performed in 1992, indicates that the abundance of Pacific ocean perch has declined dramatically along the West Coast to slightly more than 10% of the estimated levels during the early 1960s. The latest assessment model includes data from NMFS' 1992 triennial survey, as well as recent fishery size composition data. Additionally, size-at-maturity data have been analyzed to revise estimates of the proportion mature. This information was combined with previous estimates of size-specific fecundity to estimate a fecundity-at-age index which is used to monitor reproductive potential of the stock. Previously, mature female spawner biomass was used as a proxy for this measure. The new estimates of proportion mature at age are similar to the schedule used previously; however, adding the fecundity relationship has changed the calculations affecting $F_{35\%}$ and other spawner biomass potential per recruit (SPR) harvest rates. Several sources of information were used which shows some internal inconsistencies. However, the overall conclusion is that the stock is at a low and stable to slightly increasing level. Recommended harvests should remain at minimal levels. Improved information should become available when data from the 1995 summer triennial survey have been analyzed.

For more information, contact Dr. James Ianelli (206) 526-6510.

Thornyheads Stock Assessment

Gulf of Alaska

The current assessment presents a refined analysis of the thornyhead resource in the Gulf of Alaska. The estimate of ABC is slightly lower than that in the 1995 Stock Assessment and Fishery Evaluation report. The decline resulted from a revision in the size at maturity as a more

gradual process and one in which the length at 50% mature is slightly larger. This results in lower estimates of spawner biomass and lower harvest rates. Some restrictions on growth were also eliminated in this year's model which resulted in slightly slower growth than was used previously.

For more information, contact Dr. James Ianelli (206) 526-6510.

Sablefish Research

Gulf of Alaska

Sablefish Longline Survey

The AFSC has conducted an annual longline survey of sablefish and other groundfish in the Gulf of Alaska from 1987 to 1995. The survey is a joint effort involving two divisions of the AFSC: ABL and RACE. It replicates as closely as practical the Gulf of Alaska portion of the Japan-U.S. cooperative longline survey conducted from 1978 to 1994 and also samples gullies not sampled during the cooperative longline survey. Sixteen kilometers of groundline are set each day, containing 7,200 hooks baited with squid. In 1995, 81 stations were sampled from 22 June to 9 September. The survey vessel was the chartered fishing vessel Ocean Prowler. Sablefish relative population weight for the upper continental slope and gullies (combined) decreased 8% from 1994 to 1995.

For more information, contact Michael Sigler (907) 789-6037.

Estimating Survey Catchability with an Age-structured Population Model

Survey catchabilities are unknown for federally managed groundfish fisheries of the northeast Pacific Ocean, and an assumed value is applied. In the primary survey method, trawling, survey catchability in the net path is usually assumed to equal 1.0 (Alverson and Pereyra 1969). Survey catchability and biomass are inversely related. Thus, if survey catchability is assumed known and the value is low, then biomass and consequently allowable biological catch, will be overestimated. Rather than use an assumed value, survey catchability was estimated with an age-structured model for the sablefish fishery in Alaska. Available data included a survey index (the NMFS sablefish longline survey), commercial catches, and survey age and length data. Monte Carlo simulation was used for model validation. The estimates of ending biomass generally were similar to the simulated values, which implies that estimating survey catchability is

reasonable for sablefish in Alaska. These results for sablefish and those for a previous study of widow rockfish[2] imply that survey catchability with an age-structured model is feasible.

For more information, contact Michael Sigler (907) 789-6037.

ABL Sablefish Tag Recovery Program

Responsibility for all NMFS and Japanese tags released in Alaska waters during past cooperative longline surveys was transferred from the RACE Division in Seattle to the ABL during 1995. The transfer resulted in a consolidated Alaska sablefish tag database with 283,300 release records and about 18,500 recoveries.

Processing new tags and administration of the reward program continued during 1995, using new programs created by ABL staff. The tag database is now on the AFSC's IT95 UNIX computer, and is accessed using Oracle; tag returns and rewards are processed in a fraction of the time required by the old Burroughs system. Oracle interfaces well with the desktop mapping software package ArcView, which should be of great advantage in the analysis of sablefish movements.

For more information, contact Nancy Maloney (907) 789-6060.

Juvenile Sablefish Studies

Juvenile sablefish tagging studies in southeastern Alaska have been conducted annually by the ABL since 1984. In August and September 1995, about 1,000 juvenile sablefish (age 1+) were tagged and released in St. John Baptist Bay, a small bay 30 km north of Sitka. This is the 11th consecutive year that relatively large numbers of juvenile fish have been found at this locality. A total of 27,542 juvenile sablefish (mostly age 1+) have now been tagged and released in southeastern Alaska, and to date, about 850 of these have been recovered from the commercial fishery.

A pilot study was initiated in 1995 in an attempt to determine the spatial and temporal distribution of young-of-the-year (YOY) sablefish in the Gulf of Alaska. The objective of the study was to determine the feasibility of establishing a YOY sablefish survey that could improve current estimates of sablefish recruitment. A small-mesh surface gillnet was opportunistically fished at a number of stations at offshore locations of the eastern Gulf of Alaska during the 1995 sablefish longline survey using the survey vessel Ocean Prowler. The net was set at about midnight and retrieved at about 0500 hr. It was constructed of monofilament web, measured 300 m long and 3 m deep, and drifted freely with the current. YOY sablefish were caught at all stations where the gillnet was deployed. Individual station catches ranged from 3 to 399 fish, and

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[2]Bence, J. R, A. Gordoa, J. E. Hightower. 1993. Influence of age-selective surveys on the reliability of stock synthesis assessments. Can. J. Fish. Aquat. Sci. 50: 827-840.

lengths ranged 140 to 230 mm. No age 1+ or older sablefish were caught. This study looks quite promising, and plans are to opportunistically deploy the gillnet at stations throughout the Gulf during the 1996 longline survey.

For more information, contact Thomas Rutecki (907) 789-6051.

Sablefish Stock Assessment

Bering Sea, Aleutian Islands, and Gulf of Alaska

The sablefish population in Alaska waters is still at a relatively healthy level, but with no strong recruitment evident in recent years, the population has slowly decreased since the mid-1980s. However, most of the decrease has been concentrated at the outer range of sablefish in the Bering Sea and Aleutian Islands, while abundance in the Gulf of Alaska has been more stable.

Yield estimates are determined from a stock reduction analysis modified to explicitly track estimates of exploitable biomass and provide an estimate of recruitment. The Bering Sea, Aleutian Islands, and Gulf of Alaska regions have been combined and analyzed as one stock since 1989. The recommended yield is then apportioned by management area according to estimates of current biomass using an exponential weighted average of past apportionment estimates. The ABCs for 1990-92 were computed by multiplying the $F_{0.1}$ exploitation rate (0.116) by the estimate of exploitable biomass at the beginning of the fishing year. Beginning in 1993, an adjustable fishing rate strategy was adopted for sablefish, whereby the $F_{35\%}$ fishing rate (that rate which would reduce the spawning biomass per recruit ratio to 35% of the unfished level) is adjusted in proportion to the ratio of current biomass to a target biomass level that is 35% of the unfished level ($B_{35\%}$).

The sablefish assessment uses the cooperative longline survey indices to estimate the abundance trend from 1979 to 1989. Beginning in 1990, and until 1995, an average of the cooperative survey and the domestic survey was used, as it was not clear which survey showed the true abundance trend. The use of this average moderated a substantial decrease in abundance from 1989 to 1990 indicated by the cooperative survey, but not by the domestic survey. Since 1990, the domestic survey indices have been consistently higher than the cooperative survey indices. A study comparing the two surveys used the 1990 to 1995 data to estimate yearly factors to adjust the cooperative survey index to be comparable to the domestic survey. To apply these correction factors to the cooperative survey indices prior to 1990, it is necessary to assume that the survey was conducted consistently throughout the time period. For the 1995 assessment, after the termination of the cooperative survey, it was necessary to use the correction factors to continue the time series. The abundance trend now reflects the more substantial decrease in 1989-90, and therefore indicates a greater relative decrease in biomass since peak abundance in the mid-1980s and decreased estimates of average recruitment. These two results are cause for more conservatism than previously warranted because they indicate that current biomass is closer to the low levels of the late 1970s and early 80s than previously indicated, and the lower recruitment level indicates that sustainable yields are lower. It is noted that the ABCs in recent years were the result of a few large year classes which occurred in the late 70s and early 80s.

The last large year class occurred in 1984 and there is no indication of another strong year class for at least another 4 years, by which time the population could be at historical low levels. The magnitude of the sablefish stock and the appropriate fishing rate largely depends on future recruitment, and little is known about the factors that determine recruitment levels.

Conservatism is added to the assessment method which has been used in the past, by using the average recruitment since the last large year class (1984) recruited, to project biomass to 1996. This recruitment is more conservative than used in previous recommendations. $F_{35\%}$ (=0.125) is also estimated using more exact methods and is lower than the value used previously.

The recommended 1996 ABC for the combined Gulf of Alaska, Bering Sea, and Aleutian Island ABC is 19,550 t. This value, which is down 22% from 1995, is the result of a 10% decrease in the adjusted exploitation rate and a projected 1996 biomass (193,300 t) which is 14% lower than the 1995 projected value (225,000 t). The 1996 biomass projection results from a continued decrease in the longline survey from 1994 to 1995 (8%) and the more conservative predictions of recruitment. ABCs for the Gulf of Alaska, Bering Sea, and Aleutian Islands were 17,100 t, 1,160 t, and 1,310 t, respectively.

The Plan Team discussed $F_{40\%}$ and noted that the current recommended fishing rate of $F_{35\%}$ adjusted (=.112), is still higher than $F_{40\%}$ (=.103), and that sablefish is one of the few stocks where $F(ABC)$ is greater than $F_{40\%}$. An ABC computed using $F_{40\%}$ would be 15,740 t, or if adjusted by the ratio of current biomass to 40% of estimated pristine biomass, 12,410 t. The author also notes that an alternative approach for determining an ABC, based on replacement fishing rates, results in a value of 13,500 t for a Gulf of Alaska ABC. A re-evaluation of appropriate fishing rates for sablefish is planned in time for next year's assessment.

The apportionment of the Gulf of Alaska ABC would be 12.9, 40.4, 17.8, and 28.9% to the Western, Central, West Yakutat, and East Yakutat/Southeast areas respectively. Thus apportionment of the 17,080 t ABC would be 2,200 t to the Western Area, 6,900 t in the Central Area, 3,040 t in the West Yakutat Area, and 4,940 t in the East Yakutat/Southeast Area. An overfishing level obtained by applying an $F_{30\%}$ rate directly, would be 22,800 t.

For more information, contact Sandra Lowe (206) 526-4230 or Jeff Fujioka (907) 789-6026.

Flatfish Research

Bering Sea

A small boat survey was conducted from 18 to 29 May in the Togiak Bay region of inner Bristol Bay. This survey was designed to examine yellowfin sole distribution, maturity, fecundity, and feeding. A 3 m beam trawl was used in shallow waters not normally surveyed. Due to bad weather, only 30 of 80 designated tows were made. Nonetheless, considerable valuable information was acquired. Preliminary results indicate that yellowfin sole are batch spawners in waters of moderate depth and utilize shallow water feeding, such as herring roe, between batches.

For more information, contact Dan Nichol or Terry Sample (206)526-4151.

Additional work was done in 1995 to describe the relationship between flatfish species distributions and diets with bottom sediment types in the eastern Bering Sea.

For more information, contact Dr. Robert McConnaughey (206)526-4150.

Flatfish Stock Assessment

Bering Sea

The abundance of most of the species of flatfish in the eastern Bering Sea have shown substantial increases during the 1980s and are currently at high and stable levels of abundance.

Yellowfin sole

Three abundance estimators (trawl survey, virtual population analysis, and stock synthesis) all indicate that the yellowfin sole resource increased slowly during the 1970s and early 1980s to a peak during the mid-1980s and that the resource has remained abundant and stable since that time. This trend is consistent with the fact that yellowfin sole is a slow-growing species which has been lightly exploited while experiencing average to strong recruitment during the past 15 years. Exceptional recruitment from the 1981 and 1983 year classes has maintained the abundance of yellowfin sole at a high level and additional good recruitment from the 1986-88 year classes should keep the biomass at a high and stable level in the near future.

Projected biomass for 1996 is 2.85 million t. The recommended ABC was calculated according to an $F_{35\%}$ (=0.13) harvest strategy, giving a projected 1996 catch of 278,000 t. The $F_{35\%}$ harvest strategy was considered appropriate given the population's high and stable level of abundance. The 1996 OFL for yellowfin sole is 342,000 t, corresponding to an $F_{30\%}$ (=0.16) harvest strategy. Reliable estimates of F_{MSY} or B_{MSY} are not available for this stock.

Rock sole

An age-based synthesis model was again used to assess the rock sole stock. The time series of abundances estimated by the model parallels that from the trawl survey quite closely apart from the 1994 survey value, which appears to be an overestimate. Both the model and the survey indicate a dramatic increase in rock sole abundance throughout the 1980s and early 1990s. The model indicates that biomass has remained high and stable during the mid-1990s, with a projected 1996 level of 2.36 million t. The 1987 year class continues to appear exceptionally strong, and the 1990 year class appears to be above average as well.

Harvest levels remain well below the ABC level. Harvesting at an $F_{35\%}$ (=0.18) strategy is used to compute ABC for this stock, giving a projected 1996 catch of 361,000 t. The OFL for this stock is defined by the $F_{30\%}$ (=0.22) fishing mortality rate, which corresponds to a 1996 catch of 420,000 t. Reliable estimates of B_{MSY} and F_{MSY} are not available for this stock.

Flathead sole

Due to a change in the Bering Sea/Aleutian Islands directed fishing standards, the NPFMC directed that flathead sole be separated from the "other flatfish" management category beginning in 1995. Trawl surveys indicate that the biomass of flathead sole has tripled since 1982, remaining high and stable since 1990. Except for a very high value in 1994, the survey biomass estimates have fluctuated between 570,000 t and 620,000 t since 1990. No assessment model has been developed for this stock.

The authors use an $F_{35\%}$ (=0.19) strategy in computing ABC for this stock, giving a projected 1996 catch of 116,000 t for the EBS and Aleutians combined. The OFL for this stock is defined by the $F_{30\%}$ (=0.23) fishing mortality rate, which corresponds to a 1996 catch of 140,000 t for the combined areas. Reliable estimates of B_{MSY} and F_{MSY} are not available for this stock.

Other flatfish

Beginning with the 1995 fishing season, flathead sole were removed from the "other flatfish" complex, leaving Alaska plaice as the dominant member of the complex. The complex has remained at a stable, and presumably high level of abundance throughout the modern history of the EBS survey time series (i.e., since 1982, when the present survey net configuration was adopted). Survey biomass estimates have fluctuated between 550,000 t and 850,000 t during this period, with the 1995 estimate coming in at a value of 590,000 t. No assessment model has been developed for this complex.

The resource has remained lightly exploited and the authors recommend an ABC value based on an $F_{35\%}$ (=0.17 for Alaska plaice) harvest strategy, giving a complex-wide 1996 catch of 102,000 t. Setting OFL at the $F_{30\%}$ (=0.20 for Alaska plaice) level gives a complex-wide 1996 catch of 120,000 t. As with the other flatfish species, reliable estimates of F_{MSY} and B_{MSY} do not exist for this complex.

Greenland turbot

The length-based synthesis model which has been used to assess the Greenland turbot stock for the last 2 years was updated for the present SAFE[3] report. The assessment model estimates that the biomass of Greenland turbot peaked during the early 1970s, followed by a persistent decline to the present level, which is estimated to be about one-half the pristine abundance level. Year classes since the 1980 cohort have consistently been well below the

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[3]Wilderbuer, T. K., and T. M. Sample. 1995. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands regions as projected for 1996. Section 5. North Pacific Fishery Management Council, Anchorage, AK.

average level of the 1968-1979 cohorts, and no upturn in stock biomass is anticipated for the next several years. For these reasons, the a number of conservative features have been built into the stock assessment model, including the omission of the Aleutian component of the stock from abundance indices used as model inputs, the choice of a low emphasis value for the longline survey index (the longline survey tends to indicate an increasing abundance trend since the mid-1980s), and the recommendation of a conservative ($F_{40\%}$=0.24) harvest strategy.

The Plan Team believes that this assessment is suitably conservative and concurs with the projected 1996 biomass estimate of 135,000 t and the suggested 1996 ABC of 17,000 t. However, the available evidence indicates that this stock is not capable of replacing itself under present conditions. Since no threshold level has been determined for this species, a prudent course for management would be to minimize fishery impacts. Therefore, the Plan Team recommends that the TAC be set at a level commensurate with a bycatch-only fishery and that the fishery be managed on that basis. In particular, the Plan Team recommends against allowing a directed fishery if the 1996 TAC is set close to recent TAC levels because of the high potential for the species to reach "prohibited" status under such circumstances.

Under an $F_{30\%}$ (=0.37) harvest strategy, 1996 OFL is projected to be 25,100 t. Reliable estimates of F_{MSY} or B_{MSY} are not available for this stock.

Arrowtooth flounder

A new length-based synthesis model of the arrowtooth flounder stock was introduced in the present SAFE report. Both the model and the annual trawl survey of the EBS shelf indicate that the arrowtooth flounder resource continues to be in excellent condition as a result of minimal exploitation and steady increases in biomass throughout the 1980s. Good recruitment from the 1981, 1984, 1986, and 1987 year classes should maintain the stock at a high and stable level for the near future.

The projected biomass for 1996 is 576,000 t. The recommended ABC for 1996 is 129,000 t, based on an $F_{35\%}$ (=0.27) harvest strategy. The OFL for this stock is defined by the $F_{30\%}$ (=0.34) fishing mortality rate, which corresponds to a 1996 catch of 162,000 t. Reliable estimates of B_{MSY} and F_{MSY} are not available for this stock.

Gulf of Alaska

Management of the Gulf of Alaska flatfish resource has been divided into five categories by the NPFMC. These categories include: shallow water flatfish, deep water flatfish, arrowtooth flounder, flathead sole, and rex sole. This reclassification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow and deep water flatfish species and also because of the dominant biomass of arrowtooth flounder which could cause the other flatfish species to be overfished if it was not separated from the group and managed under a separate TAC. Flathead sole are also managed under a separate TAC because they overlap the distributions of the shallow and deep water categories and rex sole were given a separate TAC because of a problem with POP bycatch in the directed rex sole fishery in 1993.

Due to halibut bycatch in commercial trawl fisheries, the total catch of Gulf of Alaska flatfish species continues to be well below their combined TAC, as in past years. In 1994 the shallow water flatfish, deep water flatfish, flathead sole, rex sole and arrowtooth flounder ABC apportionments were 11%, 31%, 7%, 31% and 10% harvested, respectively. Biomass estimates from the 1993 Gulf of Alaska trawl survey indicate that the total flatfish resource remains stable with no significant changes estimated for any species between survey years. Trawl survey size compositions indicate the continued presence of juvenile fish recruiting to the stock for most species. For 1996, the flatfish species are managed using the $F_{35\%}$ approach, resulting in a combined ABC of 305,000 t and a TAC of 84,140 t.

For more information, contact Thomas Wilderbuer (206) 526-4224.

West Coast

Dover Sole

Size and age composition data from the U.S.-Vancouver INPFC area and the northern part of the Monterey INPFC area were analyzed by the length-based version of stock synthesis, a separable catch-at-age model. For both areas, the model was run at various levels of virgin recruitment to generate a range of fits to slope survey abundance estimates. Runs with the slope survey ratio (Q, which equals the observed survey biomass divided by the population biomass after survey selectivities are applied) between 0.5 and 1.0 were taken as a plausible range of biomass levels. Recruitments were fixed to be constant at the virgin recruitment level for both areas. Fishery selectivities were estimated for different time periods in both areas.

In the U.S.-Vancouver INPFC area, recent landed catches have declined to 1,136 t in 1994. MSY, estimated under an assumed level of density-dependent recruitment is 859 t to 1,015 t for slope survey Qs from 1.0 to 0.5. The 1996 female spawning biomass is estimated to be below the $F_{20\%}$ level for the low biomass scenario and about midway between the $F_{20\%}$ and $F_{35\%}$ levels for the high biomass scenario. The recommended yield for 1996 is calculated by applying $F_{35\%}$ (fishing mortality that reduces female spawning biomass per recruit to 35% of its unfished level) to the exploitable biomass. This results in a yield of 501 t (landed catch 477 t and discards 24 t) to 983 t (landed catch 936 t and discards 47 t) for 1996. The current ABC in the U.S.-Vancouver INPFC area is 2,400 t.

In the northern Monterey INPFC area the 1994 catch was 708 t. MSY, estimated under an assumed level of density-dependent recruitment, is 965 t and 1,316 t for the low and high biomass runs, respectively. The 1996 female spawning biomass is estimated to be above the target level ($F_{35\%}$) for the high biomass scenario and at the $F_{35\%}$ level for the low biomass scenario. The low and high biomass range produce 1996 yields (applying $F_{35\%}$) of 1,326 t (landed catch 1,263 t and discards 63 t) and 2,631 t (landed catch 2,506 t and discards 125 t), respectively. In 1994 the catch was 708 t in the northern Monterey INPFC area and 2,091 t in the Monterey INPFC area. The current quota for the Monterey area is 5,000 t.

For more information, contact Jack Turnock (206) 526-6549.

Pacific Whiting Research

West Coast

Acoustic Surveys
Midwater Assessment and Conservation Engineering (MACE) Task

Scientists from the MACE program conducted the seventh triennial echo integration/midwater trawl survey of Pacific whiting off the West Coast from central California to Dixon Entrance, Alaska, during 1 July to 1 September 1995. Areal coverage for the survey was more extensive compared to earlier surveys due to the increased effort offshore and to the north. Increased survey coverage within Canadian waters resulted from the cooperative efforts with Canadian scientists. Relatively dense Pacific whiting echo sign was observed off California near Point Arena and Cape Mendocino, off central Oregon (43-45° N), over Juan de Fuca Canyon near Cape Flattery, and off northern Vancouver Island. No echo sign was attributed to Pacific whiting north of 51° N or south of about 38° N. Although Pacific whiting were sometimes caught south of 38° N, scattering from other species was so prevalent that it prevented identification of Pacific whiting echo sign from this area. Pacific whiting were observed over bottom depths of 50-1500 m. The size composition of Pacific whiting differed over the survey area. Young-of-the-year fish (2-8 cm fork length) were only captured in the southern California area (34°55'-40°30' N). Fish comprising the 20-30 cm mode (primarily 1-year olds) were also present in the southern California area, strongly represented in the northern California area (40°30'-43°00' N), moderate in Oregon (43°00'-45°46' N), and present in relatively low numbers in the northern areas (i.e., Washington (45°46' N to the U.S./Canada border), south Vancouver INPFC area (the US/Canada border to 49°00' N), and north Vancouver INPFC area (49°00' to 51°03' N)). The distribution of 1-year old fish extended farther to the north than that reported from previous EIT surveys. Fish comprising the 30-40 cm length mode (primarily 2-year olds) were strongly represented in the California areas and nearly absent in the northern areas. Adult fish (>40 cm) were present throughout the survey area, although their contribution was minimal in the southern California area. Preliminary coast wide estimates are 5.84×10^9 fish weighing 2.534×10^6 t.

1995 Triennial Bottom Trawl Survey of West Coast Groundfish Resources

Pacific whiting biomass and population estimates from the 1995 bottom trawl survey were larger than in any of the previous triennial surveys. Estimates in the 55-366 m depth zone, which is comparable to the total survey area in prior surveys, totaled approximately 548,000 t of biomass and 1.25 billion fish. Juvenile whiting made up a large proportion of the population in all areas of the survey. Two-year old whiting were the largest age class off southern and central California, although 1-year olds were also important. Atypically, 1-year old whiting were the predominant age class from northern California to the northern extent of the survey area. For the second consecutive triennial survey, we were able to collect temperature profiles at virtually all

trawl stations and the relationships between the distribution of juvenile whiting and observed temperature anomalies will be studied.

For more information, contact Mark Wilkins (206) 526-4104.

Pacific Whiting Stock Assessment

AFSC scientists conducted an assessment of the coastal Pacific whiting resource in 1995. The assessment reviewed recent developments in the Pacific whiting fishery, tabulated and analyzed the 1994 catch statistics, described a stock synthesis model application using catch and survey data from 1977 to 1994, and presented yield options for 1996-98.

The U.S. and Canadian harvest of Pacific whiting in 1994 was 358,901 metric tons (t). In 1995, the yield will be close to 255,000 t. A geographic version of the stock synthesis model that divided the population into U.S. and Canadian components was used to assess the Pacific whiting population. Population biomass peaked in 1987 and has been declining steadily since that time. The biomass of age 3 and older fish in 1994 was estimated to be 2.269 million t, which is within 5% of the projected 1994 biomass in the 1994 assessment. However, the estimated size of the 1990 year class is 1.803 billion fish, 23% smaller than the 1994 estimate. In addition, the age-2 fish were extremely rare in the 1994 age-composition, indicating a near-complete failure of the 1992 year class. To forecast yields for 1996-98, a stochastic age-structured population model for Pacific whiting was used. Several harvesting strategies were presented: a constant F strategy, a variable F strategy (where fishing mortality for a particular year is proportional to the level of female spawning biomass), and a hybrid strategy that combines features of the other two policies. Three harvest rates were presented for each harvest strategy. These harvest rates were based on the probability that female spawning biomass will fall below a cautionary level of 623,000 t in long-term simulations of the Pacific whiting population. Since there exists considerable uncertainty about the size of the 1994 year class, two sets of projections were made, one set where the 1994 year class was sampled randomly from the 1972-94 recruitment, and an additional set where the recruitment of the 1994 year class was sampled randomly from large year classes (>1.5 billion fish). When a hybrid fishing strategy is applied to the projected numbers at age in 1996, the potential yield for the random 1994 year class scenario is calculated to be 79,000 t at a low harvest rate, 110,000 t at a moderate harvest rate, and 139,000 t at a high harvest rate. For the strong 1994 year class scenario, the projected yield is 87,000 t at a low harvest rate, 123,000 t at a moderate harvest rate, and 153,000 t at a high harvest rate. The immediate future is highly uncertain depending on the size of the 1994 year class. If the 1994 year class is strong, yields should increase in 1997 and 1998. If the 1994 year class is weak, the Pacific whiting population will drop to historically low levels, and coastwide yields will be below 100,000 t.

For more information, contact Martin Dorn (206) 526-6548.

Walleye Pollock Research

Acoustic Surveys - MACE Task

Bering Sea

Bogoslof Island Area (24 February - 9 March, 1995)

An acoustic/trawl survey of spawning walleye pollock was conducted in the southeastern Aleutian Basin near Bogoslof Island from 24 February - 9 March to determine pollock abundance, distribution, and biological composition. Pollock echo sign was observed throughout most of the survey area, with higher concentrations located along the shelf edge between Akutan and Unalaska Islands, over deep water northwest of Bogoslof Island, and along the north side of Umnak Island from 168° W long. to 169°30' W long. The largest pollock aggregations, centered north and west of Umnak Island, were somewhat west of where they had been observed in previous years. Preliminary results indicate a population length composition with peaks at 54, 44, and 48 cm, in order of decreasing importance. Among captured female pollock with lengths greater than 35 cm, 80% were in a pre-spawning (mature) reproductive condition. Only 8% were actively spawning, and 7% were post-spawning (spent).

Eastern Bering Sea Shelf (March 31 - April 14, 1995)

An investigation of spawning walleye pollock on the eastern Bering Sea shelf and slope was conducted from March 31 - April 14 to determine their distribution, biomass, and biological composition. The greatest densities of pollock were observed in Unimak Pass and north of Unimak Island. Most aggregations were within 50 m of bottom. Relatively little echosign was observed west of 167° W. Interestingly, pollock were observed right up to the ice edge along most transects. Male pollock caught in midwater trawl hauls averaged 43.1 cm long; females averaged 46.3 cm. Pollock caught in bottom trawl hauls were larger than those caught in midwater trawl hauls, averaging 46.8 and 53.2 cm for males and females, respectively. Maturity-length compositions for female pollock suggested that the fish near Unimak Pass spawned earlier in the year than those near the Pribilof Islands.

Gulf of Alaska

Shumagin Islands Area (February 14 - 20, 1995)

A comprehensive acoustic/trawl survey of spawning walleye pollock was conducted in the vicinity of the Shumagin Islands. This effort was needed to better describe the spawning biomass of pollock which was first identified in this area during a brief, exploratory acoustic survey during

March, 1994. During the 1995 survey, quantities of mature, pre-spawning pollock were detected throughout the study area, although most fish were concentrated immediately to the northeast of the Islands near Renshaw Point and Stepovak Bay. Significant quantities of mature fish were also detected within the Shumagin Gully. Most pollock echo sign occurred over bottom depths in excess of 100 m. The size distributions of pollock from a total of 14 hauls throughout the area were remarkably similar; mean lengths among hauls ranged between 47-49 cm and distributions were strongly unimodal, except on three occasions where age-1 fish also produced a significant mode. The age-1 fish, which ranged in length between 8-13 cm, were only captured in the Shumagin Gully. About 80% of the fish greater than 33 cm were in a mature stage of gonadal development, and would have been expected to spawn within the next few weeks.

Shelikof Strait Area (March 17 - 27, 1995)

An acoustic/trawl survey of spawning walleye pollock was conducted in the Shelikof Strait area between Chirikof Island and Cape Chiniak. As in previous years, most spawning pollock were distributed along the western side of the Strait with greatest densities near Capes Kekurnoi and Kuliak. Fish were most abundant within 50-150 m of the bottom. The length distributions of pollock from hauls within the Strait generally exhibited dominant modes around either 10-12 cm or 48-50 cm, although weaker modes centered around 23 cm and 36 cm were sometimes present. The mode representing the age 1 fish (10-12 cm), though often numerically dominant, was likely under-represented since the survey was designed primarily to assess the characteristics of the spawning population. Random samples of the females greater than 33 cm suggested that about half were in either a spawning or post-spawning stage of reproductive development. Pollock from the 1994 year class formed a strong, well-defined acoustic layer in midwater (150-175 m depth) which was broadly distributed between Uyak Bay and the southern limits of the surveyed area near Chirikof Island. The areal extent and strength of this layer may be indicative of a relatively strong year-class.

For more information contact Dr. Jimmie Traynor at (206) 526-4163.

Recruitment Processes (FOCI)

Fisheries-Oceanography Coordinated Investigations (FOCI), a NOAA cooperative research program between the Recruitment Processes Task of the RACE Division and the Pacific Marine Environmental Laboratory (PMEL), is designed to investigate the causes of recruitment variations in commercially important fish and shellfish. The program's focus is the well-defined spawning population of walleye pollock in Shelikof Strait, and walleye pollock stock structure and recruitment in the eastern Bering Sea. Bering Sea FOCI is part of the NOAA Coastal Ocean Program. Areas of research include field studies of eggs and larvae in relation to primary and secondary production and the physical environment, biochemical methods for assessing larval starvation and predation and stock structure, and pollock behavior. FOCI conducted three cruises aboard the NOAA ship Miller Freeman during the spring of 1995, one in the Shelikof Strait region

of the Gulf of Alaska, and two in the Eastern Bering Sea to study the effects of the environment on the eggs and larvae of walleye pollock. We also conducted a two-ship study of young-of-the-year juvenile pollock in the Bering Sea near the Pribilof Islands aboard the NOAA ships Miller Freeman and Surveyor in late summer. Laboratory studies on reared pollock larvae were conducted to 1) calibrate biochemical indices; 2) estimate feeding, digestion, and gastric evacuation rates; and 3) calibrate histopathological condition indices. Eggs were spawned from fish trawled in the Shelikof Strait and Bogoslof Island area, maintained in refrigerators aboard ship, and then transported in insulated jugs to the culture center at the AFSC in Seattle and to the M. O. Hatfield Marine Science Center in Newport, Oregon, where behavioral studies were conducted.

For more information, contact Dr. Art Kendall (206) 526-4108.

Walleye Pollock Stock Assessment

Bering Sea and Aleutian Islands

The current assessment includes several separate estimators of pollock abundance, including combined hydroacoustic/bottom trawl surveys, a CAGEAN model, a Synthesis model, and two different versions of the standard cohort analysis. All methods indicate a total biomass (age 3+) in excess of 7 million t for the EBS portion of the stock, at least through 1994 (the year of the last hydroacoustic survey). As in previous years, the assessment uses cohort analysis to compute biomass, ABC, and OFL. The stock assessment presents two different models based on cohort analysis; the version using the least-squares estimation technique is the preferred method since it gave an estimated 1994 biomass almost identical to those estimated by the CAGEAN and Synthesis models (7.09 million t versus 7.16 million t and 7.17 million t, respectively). The cohort analysis model, based on a more subjective estimation technique, in contrast, estimated a 1994 biomass of 8.26 million t. The projected 1996 EBS biomass given by the preferred model is 7.36 million t.

Because the projected 1996 biomass exceeds B_{MSY}, F_{ABC} is capped by the product of ($F_{35\%}/F_{30\%}$) and F_{MSY}, or (0.38/0.46) x 0.38 = 0.31. Harvesting EBS pollock at the $F_{40\%}$ rate gives a 1996 ABC of 1.29 million t, using the preferred model. In addition to providing a buffer between ABC and OFL, exploitation at the $F_{40\%}$ (rather than $F_{35\%}$) rate is warranted on the basis of the stock's strong dependence on the 1989 (and possibly 1992) year class(es). The OFL for EBS pollock is defined by the F_{MSY} harvest strategy, which corresponds to a 1996 catch of 1.59 million t under the preferred model.

For the Aleutian portion of the stock, the projected 1996 biomass estimate is 87,200 t. Applying an $F_{35\%}$ (=0.42) harvest strategy gives a 1996 ABC of 26,200 t. However, the NPFMC believes that the Aleutian pollock fishery should be managed on a bycatch-only basis for the following reasons: 1) the trawl survey time series indicates that the Aleutian pollock biomass has declined sharply and consistently since 1983, and gives no reason to expect an upturn in the foreseeable future; 2) some fish captured in the Aleutian Islands region may be part of the Aleutian Basin stock, a stock on which fishery impacts should be minimized; and 3) pollock has

been shown to be an important prey item for Steller sea lions breeding on rookeries just to the east of the Aleutian Islands management area, rookeries which recently have fared better than those for which the available prey consists largely of Atka mackerel. The 1996 OFL for the Aleutian portion of the stock is 28,800 t, based on an $F_{30\%}$ rate of 0.45. Reliable estimates of F_{MSY} or B_{MSY} do not exist for the Aleutian portion of the pollock stock.

Revised results of the 1995 hydroacoustic survey of the southeastern Aleutian Basin near Bogoslof Island produced a biomass estimate of 1.1 million t. Assuming that growth and recruitment during 1995 will equal mortality, projected 1996 biomass for the Bogoslof area is estimated at 1.10 million t. Applying an $F_{35\%}$ (=0.33) harvest strategy gives a 1996 ABC of 286,000 t. The 1996 OFL for the Bogoslof region is set at 330,000 t, based on an $F_{30\%}$ exploitation rate of 0.30. Reliable estimates of F_{MSY} and B_{MSY} are not available for this portion of the stock.

For more information, contact Dr. Vidar Wespestad (206) 526- 4249.

Gulf of Alaska

The exploitable biomass estimates from 1994 and 1995 are from the stock synthesis (SS) model as determined in those years. The 1996 mid-year biomass is estimated at 574,000 t from the current SS analysis. Comparisons of the 1996 biomass to previous years' levels should be made with biomass levels from the revised hindcast in the current assessment.

Relative to the 1995 SAFE, new sources of information include: a) the 1995 Shelikof Strait hydroacoustic biomass estimate; b) length-frequency data from the 1995 hydroacoustic survey; c) age composition data from the 1994 fisheries; d) revised estimates of biomass and updated age and length frequency data from the 1981-1991 hydroacoustic surveys; e) revised estimates of fishery weight at age; and f) updated estimates of discard and catch for 1994-1995.

The 1995 hydroacoustic survey used the same equipment as in 1994 with improved detectability of pollock in low-density situations and improved measurements from the near-bottom region. The 1995 Shelikof Strait biomass estimate based on the new system is 725,200 t (compared to the estimate of 467,300 t from the 1994 survey). These values were adjusted in the stock assessment to be comparable to estimates from the old system in order to provide a time series of a relative abundance index.

The model has captured the trend in observed Shelikof Strait hydroacoustic biomass estimates from 1988 to 1994. However, from 1994 to 1995 the observed biomass increased in Shelikof Strait while the model showed a decline in predicted biomass and estimated a lower than observed abundance level. A reason for such a discrepancy may be that the stock synthesis model estimates a decreasing selectivity of the hydroacoustic survey for older fish. This is consistent with the behavior of older fish which tend to be closest to the bottom during the spawning period. The hydroacoustic survey cannot discriminate between fish and the bottom in the last half meter above the bottom. In addition, hydroacoustic surveys during the spawning season located large fish outside of Shelikof Strait suggesting that some of the older fish may not have been available for sampling in the Strait. The model would underestimate the hydroacoustic biomass if: a) a larger fraction of the older pollock were off bottom in 1995, or b) the fraction of the older fish

spawning in Shelikof Strait was larger than expected in 1995. However, because the hydroacoustic estimate of the biomass in Shelikof Strait has a variance associated with it, some discrepancy between the assessment model and the survey estimate is expected.

Length frequency data from the 1990 to 1995 hydroacoustic surveys show the progression of the strong 1988 year class through the population. In the 1995 survey, 15% of the biomass was smaller than 17 cm (age 1, 1994 year class). This was the largest number of 1-year olds ever observed in the hydroacoustic surveys. For the years when data were available, the average contribution of age-1 fish has been less than 1%.

The biomass estimate for the Western/Central area from the 1993 bottom trawl survey was 760,800 t, similar to previous survey biomass levels. The age compositions from the 1993 bottom trawl survey revealed strong 1988 and 1989 year classes. The 1989 year class in the Bering Sea has been shown to be strong. The presence of the strong 1989 year class found in the Shumagin, Chirikof, and Kodiak areas suggests that widespread mixing of pollock stocks may occur between the Bering Sea and the Gulf of Alaska. Alternatively, 1989 oceanic conditions may have favored recruitment in the western Gulf of Alaska more than the central portion.

Four stock synthesis models were evaluated that differed as follows: Model A provided a comparison to the 1994 model configuration; Model B estimated the initial age composition of the time series instead of assuming it to be at equilibrium; Model C was similar to Model B but incorporated the revised weight-at-age parameters; and Model D was the same as Model C except that the natural mortality (M) was set equal to 0.4. Model D was included because preliminary runs of the stock synthesis model with predators indicated that M for adult fish may be closer to 0.4 than 0.3. Based on the exploratory runs, Model C was chosen as the most appropriate.

Estimates of various fishing mortality rates based on biological reference points were determined from a dynamic pool model and an age-structured model. The estimated $F_{0.1}$, $F_{30\%}$, $F_{35\%}$, and $F_{40\%}$ full-selection fishing mortality rates were 0.64, 0.50, 0.42, and 0.36, respectively. Additionally, the long-term productive potential of the pollock stock was explored with a stochastic age-structured simulation with different recruitment scenarios. The risk associated with a given fishing strategy was measured by monitoring the frequency that the spawner biomass fell below the threshold level in the simulation. The threshold level was defined as 20% of the unfished spawner biomass level and was estimated at 384,000 t.

In order to estimate a recommended fishing mortality rate, the tradeoffs between increased yield and the risk of falling below the threshold were evaluated. The fishing mortality rate was determined to be 0.3 (full selection value). This fishing mortality rate was associated with a yield of 52,000 t which is the stock assessment authors' recommended ABC for the Western and Central Gulf area.

In 1993 and 1994, the NPFMC's Plan Team requested additional exploitation strategies be explored and recommended an ABC based on the fishing mortality rate that produced a minimal (5%) probability of falling below the threshold spawner biomass level in the long-term (F=0.2). The yield associated with an F of 0.2 is 35,400 t. The Team also requested that alternative short-term strategies be explored to account for current stock conditions. Specifically, the Team requested short-term stock projections out to the year 2000, initialized with the current age composition and then random recruitment selected from the range of values of the 1982-93 year classes. Projections assuming an average, as well as a strong 1994 year, class were requested.

The results of the short-term projections indicated that if the 1994 year class is strong and subsequent year classes are random, there is less than a 0.1% chance that the spawning stock will fall below the threshold by the year 2000 under fishing mortality rates of 0.2, 0.25, and 0.3. If the 1994 year class is average or random, and subsequent year classes are random, there is a greater than 50% chance that the spawning stock will fall below the threshold by 1998 under fishing mortality rates of 0.2, 0.25, and 0.3.

For more information, contact Dr. Anne Hollowed (206) 526-4223.

Other Related Studies

The RACE Division has been active in several studies of the sampling methodology related to bottom trawl surveys, including the effects of herding and escapement on the catch rates observed during surveys, the effect of changing survey trawl haul duration, alternative methods of subsampling large survey catches, and matters related to bycatch. Underwater video and scanning sonar were used to study the behavior of fish encountering trawl gear with the purpose of detecting species and size differences which could be exploited to reduce bycatch. This technology, combined with equipment for measuring trawl operational parameters, was also applied to studies of survey trawl effectiveness.

Trawl Herding and Escapement Experiments

The RACE Groundfish Assessment Task completed two experiments to collect data on the effect of herding by trawl doors and bridles on the magnitude of the catch in research trawl catches. One experiment took place in the Bering Sea during the last 2 weeks of July 1994. The other experiment took place off the coast of Washington during the first 2 weeks of September 1994. Both experiments were conducted by varying the length of the bridles in three increments and recording the numbers and sizes of fish captured using each gear configuration. Analysis of the data indicates that for most flatfish species approximately 25% of the fish between the wingtips and the doors are herded into the path of the trawl. In cases where there is no escapement under the footrope, such herding would lead to a 50% overestimate of density. In addition, experiments were done to estimate the escapement of flatfish under the footrope of the standard RACE Division 83-112 trawl in the Bering Sea during July 1995 using a low-light video camera mounted on the trawl so that it viewed the footrope from directly overhead. The video images were subsequently viewed at the AFSC and flatfish (rock and flathead sole and Alaska plaice) going either above or under the footrope were counted. For flatfish greater than 25 cm, approximately 20% escaped under the footrope. Another experiment was conducted during July, 1996, using a small auxiliary trawl mounted under the main trawl to measure groundfish escapement under the footrope of the standard RACE Division poly-Nor'eastern trawl with a bobbin roller gear footrope. If successful, this experiment will allow estimation of the selectivity curve by species, which is essentially impossible using the video technique.

For more information, contact Dr. David Somerton (206) 526-4116.

Effects of Reducing the Duration of Survey Trawl Hauls

At the end of the AFSC's 1995 annual Eastern Bering Sea bottom trawl survey, an experiment was performed to determine the sampling effects of reducing tow time from 30 minutes to 15 minutes. A low-light camera was also deployed to investigate escapement under the footrope of the standard RACE Division 83-112 trawl. A total of 143 hauls, using the camera on 42 of these, were made. Preliminary results indicate that there is no difference between catch rates for most species. However, some small flatfish, such as yellowfin sole, showed lower catch rates with shorter towing time. Results of the escapement investigation, which showed escapements may possibly be as high as 0.28 for flatfish in the center of the footrope, will be combined with the herding experiments of 1994 to model catchability for the 83-112 trawl.

For more information, contact Pamela Goddard (206) 526-6614.

Escapement of Flatfish Under the Footrope of the Nor'eastern Roller Trawl

Good weather allowed the RACE Groundfish Task to complete the regular survey sampling of the 1995 West Coast triennial bottom trawl survey approximately 20 days ahead of schedule. We used the remaining charter time to look at the interactions between two standard survey trawls and the fish that they encountered. This investigation utilized a video camera mounted in the mouth of the trawl, focused on the footrope bottom contact to view the proportion of fish that escaped capture by passing under the footropes. We looked at the flatfish trawl used in the annual Bering Sea crab/groundfish survey and the high-opening Noreastern roller gear trawl used in the West Coast and Gulf of Alaska triennial surveys.

During the West Coast triennial survey, distribution and abundance information on flatfish is less useful than for other species of groundfish because the footropes of the survey trawls were equipped with roller gear. This makes the trawls less effective at capturing flatfish, but is necessary in order to sample extensive areas with rough bottom substrates. The objective of studying the Noreastern trawl was to examine the extent to which flatfish escape under the footrope of our trawl. Analyses of the data may lead to a way to account for the proportion of flatfish escaping capture during the surveys, improving estimates of their abundance. Video footage was collected from 79 hauls off the coast of Washington in three depths (70, 120, and 165 m) inhabited by different flatfish communities.

For more information, contact Ken Weinberg (206) 526-6109.

APPENDIX

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