Alaska
Fisheries Science
Center

National Marine
Fisheries Service

U.S DEPARTMENT OF COMMERCE

AFSC PROCESSED REPORT 99-03

A Review of Groundfish Research, Assessments, and Management Conducted at the Alaska Fisheries Science Center During 1998

A Report from the Alaska Fisheries Science Center,
National Marine Fisheries Service, to the 1999 Annual Meeting
of the Technical Subcommittee, Canada-U.S. Groundfish Committee

August 1999

ERRATA NOTICE

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Compiled by

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Preface

Essentially all groundfish research at the Alaska Fisheries Science Center (AFSC) is conducted within the Resource Assessment and Conservation Engineering (RACE) Division, the Resource Ecology and Fisheries Management (REFM) Division, and the Auke Bay Laboratory (ABL). The RACE and REFM Divisions are divided along regional or disciplinary lines into a number of tasks and subtasks. A review of pertinent work by these tasks during 1998 is presented herein. A list of recent publications and reports produced by RACE, REFM, and ABL scientists are presented as Appendix I. Staff lists or organization charts of groundfish personnel in these three units are included as Appendices II, III, and IV.

Resource Assessment and Conservation Engineering (RACE) Division

In 1998 the primary activity of the RACE Division continued to be fishery-independent stock assessments of important groundfish species of the northeast Pacific Ocean and Bering Sea. The Division's major emphasis in 1998 was in the Aleutian Islands and Eastern Bering Sea regions, in keeping with the triennial rotation of comprehensive surveys among three major geographic areas. The focus will be in the Gulf of Alaska region in 1999. Two major bottom trawl surveys of groundfish resources were conducted in 1998 by RACE researchers in the Bering Sea and along the West Coast. The Midwater Assessment and Conservation Engineering (MACE) Program conducted comprehensive acoustic/trawl surveys of pollock abundance in the eastern Bering Sea in early March 1998 and in the Gulf of Alaska in late March 1998. They also conducted an acoustic/trawl survey of Pacific whiting off the West Coast and British Columbia in July and August 1998. The Conservation Engineering group has been refining methods used to monitor the fishing configurations of sampling trawls and explore possible methods of reducing bycatch. Underwater video systems mounted on sampling trawls are being used to study the behavior of fish encountering the gear and inside trawls to investigate behavior differences among species and size classes. The Recruitment Processes task conducted several Fisheries-Oceanography Coordinated Investigations (FOCI) cruises during the spring and summer of 1998, investigating the interaction between the environment and the spawning products of Gulf of Alaska and eastern Bering Sea pollock.

The RACE Division lost an invaluable staff member when Dr. Jim Traynor, manager of the Midwater Assessment and Conservation Engineering Program, died last May while at a meeting in Russia. The following personnel have joined the RACE Division over the past year: Debbie Nebenzahl (Groundfish - Bering Sea Team); Lyle Britt, Nate Raring, and Paul von Szalay (Groundfish - Gulf of Alaska/Aleutian Islands Team); Bob Clark and Bill Patton (Midwater Assessment); Rachael Cartwright (Recruitment Processes); and Lisa Appesland (Pathobiology).

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 Observer Program and the following programs: Age and Growth Studies, Socioeconomic Assessments, Resource Ecology and Ecosystem Modeling, and Status of Stocks and Multispecies Assessment. Scientists at the Alaska Fisheries Science Center (AFSC) assist in preparation of stock assessment documents for groundfish in the 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 in Juneau, Alaska, is a division of the NMFS Alaska Fisheries Science Center (AFSC). ABL's Groundfish Assessment Program is primarily involved with research and assessment of sablefish and rockfish in Alaska, and more recently, with the study of fishing effects on the benthic habitat. Presently, the groundfish task is staffed by 12 permanent biologists. One personnel change in 1998 was the hiring of Phil Rigby as the new manager of the ABL's Groundfish Program. Phil formerly worked for the headquarters office of the Alaska Department of Fish and Game (ADF&G) in Juneau.

In 1998 field research, ABL's Groundfish Program, in cooperation with the AFSC's RACE Division, conducted the annual NMFS sablefish longline survey in Alaska. Other field work by ABL included 1) an experimental rockfish trawl survey that investigated a new survey methodology, adaptive sampling; 2) a manned submersible study that compared the seafloor habitat in trawled and untrawled areas; 3) continued juvenile sablefish studies; 4) an ongoing study to identify rockfish larvae to species; 5) a sablefish longline hook cluster experiment; 6) tagging adult sablefish with electronic archival tags; and 7) a habitat study of rockfish in nearshore areas of southeastern Alaska.

Ongoing analytic activities involved management of ABL's sablefish tag database and preparation of three annual status of stocks documents for Alaska groundfish: sablefish, slope rockfish, and pelagic shelf rockfish. Other studies included an analysis of the present survey design for Pacific ocean perch in the Gulf of Alaska, in combination with a distributional study of this species, and a geographic analysis of past commercial bottom trawl activity in the Gulf of Alaska and Aleutian Islands.

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

Multispecies Studies (Research)

1998 RACE Bering Sea Crab/Groundfish Bottom Trawl Survey

The annual crab-groundfish demersal trawl survey of the eastern Bering Sea shelf was conducted from 9 June- 29 July 1998. A total of 375 stations were sampled covering over 500,000 km^2 from inner Bristol Bay to the shelf edge and from Unimak Pass to lat. 62° N near St. Matthew Island. The chartered vessels F/V *Aldebaran* and F/V *Arcturus* were used for the survey for the sixth consecutive year. Preliminary biomass estimates for major species indicated most groundfish species had declined in abundance since 1997, but estimates for the two years were within overlapping confidence intervals.

During 1995 the Bering Sea group made a significant effort to investigate the possibility of shifting from 30 minute tows to 15 minute tows. That work was primarily on groundfish. During 1998 a major effort (94 tow pairs) was made to investigate the effect of such reduced tow durations on crab species. Much of the effort was made during the survey and additional work was performed after survey completion. Results of this experiment are presently being analyzed.

Additional work was also performed to continue our examination of escapement under the footrope of the 83-112 trawl. This work also had a primary focus on invertebrates. Analysis also continues on this experiment.

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

1998 RACE West Coast Triennial Bottom Trawl Survey of Groundfish Resources

RACE Division groundfish scientists completed the eighth in a series of triennial comprehensive bottom trawl surveys of West Coast continental shelf groundfish resources. The survey was conducted aboard the chartered commercial trawlers *Vesteraalen* and *Dominator* from 1 June through 9 August 1998. The vessels worked northward from Pt. Conception, California, to central Vancouver Island, British Columbia, Canada (lat. 34°30'-49°30' N), sampling preselected stations at depths between 55 and 500 m. The triennial groundfish surveys have been conducted by RACE since 1977 and are designed to describe and monitor the distribution, abundance, and population biology parameters of a variety of groundfish stocks off the U.S. Pacific West Coast and a small portion of the southern Canadian coast.

Successful trawl hauls were achieved at 528 of the 536 stations sampled in 1998. Fifty-nine stations were abandoned due to untrawlable bottom and we were unable to sample 13 stations on the northernmost two tracklines due to lack of time. Surface-to-bottom temperature profiles were collected with trawl-mounted data loggers at 507 stations.

Pacific hake (also known as Pacific whiting) was the dominant component of the catch in all International North Pacific Fisheries Commission (INPFC) areas except the Conception INPFC area. Shortbelly rockfish was predominant in that area. Other dominant catch components were splitnose rockfish, Dover sole and chilipepper in the Conception and Monterey INPFC areas; sablefish, Dover sole, and rex sole in the Eureka and Columbia INPFC areas; and spiny dogfish, yellowtail rockfish, arrowtooth flounder , and sablefish in the Vancouver INPFC area. The following table compares biomass estimates (in metric tons (t)) from results of the latest two West Coast triennial surveys for selected groundfish stocks in the entire survey area:

Species	1995 Biomass (t)	1998 Biomass (t)	Percent change
Pacific hake	583,257	497,009	↓ 14.8%
Sablefish	30,327	43,429	↑ 43.2%
Lingcod	6,152	7,181	↑ 16.7%
Dover sole	40,428	49,493	↑ 22.4%
Rex sole	22,664	31,118	↑ 37.3%
Pacific sanddab	49,522	31,665	↓ 36.1%
Spiny dogfish	30,274	74,689	↑ 146.7%
Canary rockfish	3,393	3,342	↓ 1.5%
Yellowtail rockfish	4,036	41,837	↑ 936.6%
Bocaccio	670	439	↓ 34.5%
Chilipepper	13,530	17,149	↑ 26.7%
Pacific ocean perch	6,812	11,527	↑ 69.2%

Survey results are summarized and furnished to teams of researchers developing stock assessments for many West Coast groundfish. Results of the 1998 survey are currently being used to help assess stocks of Pacific hake, lingcod, petrale sole, bocaccio, cowcod, and canary rockfish.

We also dedicated a portion of the survey time to trawl gear research to better understand the catching dynamics of our sampling trawl. During the third leg of the cruise, we conducted a 7-day trawl efficiency study examining escapement of fish under the footrope of the trawl. This study utilized two methods to quantify escapement: direct observations from underwater video cameras attached to the trawl and an auxiliary net mounted behind the footrope of the survey trawl to retain escaping fish. Researchers will compare the results of these two methods and evaluate whether artificial illumination required for the cameras affected the escapement estimates.

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

RACE Participation in 1998 ADF&G Gulf of Alaska Seasonality Study

During 1998, groundfish assessment staff have been participating in an ongoing ADF&G seasonal bottom trawl study of Marmot Bay off Kodiak and Afognak Islands in the Gulf of Alaska (GOA). The first phase of the study was from 16 to 25 June, followed by additional sampling periods in August and October.

The primary purpose of the study, which includes additional sampling periods scheduled for January, March, and June of 1999, is to document seasonal trends in depth and inshore/offshore distribution of crab and groundfish resources including Tanner crab, Pacific cod, walleye pollock, arrowtooth flounder, flathead sole, rock sole, yellowfin sole and skates. Additionally, the seasonal nature of the sampling design will provide quantitative measures of changes in co-occurrence of the demersal groundfish and crab complex, document the changes in distribution of Pacific cod relative to Federal and State waters, and document intra-annual changes in the distribution of Tanner crab associated with maturation.

Along with these objectives, the ADF&G invited AFSC scientists to conduct ancillary studies including specimen collections, food habit studies, research in seasonal gonad development, and size-at-maturity for selected species. The RACE Division Groundfish Program also recognized the unique opportunity the seasonality study provided to introduce ADF&G to standard RACE Division sampling protocol which, if implemented, would provide data sets from the ADF&G annual crab/groundfish survey of the western GOA similar to those obtained by the AFSC GOA bottom trawl surveys. The ADF&G R/V *Resolution* was subsequently equipped with RACE Division sampling gear including sorting and weighing tables, electronic length-frequency units, bottom contact sensors, micro-bathythermographs, and computers and software for length-frequency, catch entry, and other data collections.

Thirty-one bottom trawl samples were completed during each sampling period with the ADF&G standard 400-mesh Eastern survey trawl at depths ranging from 35 to 250 m. All catches were sampled and processed to obtain species composition by weight for all components of the catch. Length frequencies were obtained electronically for all commercial groundfish species. Additionally, during 1998 over 1,600 stomachs, 1,100 otoliths, and 1,000 ovaries were collected from major species occurring in the study area including Pacific cod, walleye pollock, and flathead sole.

For further information, contact Eric Brown, (206) 526-4157.

REFM Age and Growth Program

The Age and Growth Program of the REFM Division serves as the Alaska Fisheries Science Center's ageing unit for groundfish species. The program 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 program 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 misc. sole and rockfish species.

Craig Kastelle recently completed a radiometric study on the ageing of several rockfish species: Pacific ocean perch, shortspine thornyheads, shortrakers, rougheye, and northern. The results generally confirm the strategy of using broken and burnt otoliths for ageing these species. The manuscript will be published in the proceedings (by the journal Fisheries Research summer/fall 1999) of the 'Fish Otolith Research and Application' symposium that was held in Bergen, Norway, in June, 1998. Still continuing is a study with the Center's National Marine Mammal Laboratory to apply radiometric ageing to gray and bowhead whales. Results from these studies have some puzzling aspects and are continuing to be evaluated.

Delsa Anderl co-authored a paper on a study of age determination based on known age sablefish (Heifetz et al. 1999) . Further studies of age 0-2 year old sablefish otoliths are planned which include measurements of marginal growth increments.

Nancy Roberson is continuing work on research to help unravel the long-term problems we have had with the ageing of Pacific cod. She will concentrate on developing preparations which show otolith growth patterns well, and then focus on ageing strong year classes, trying to infer from this the problems with current ageing criteria. A few otoliths from tagged Pacific cod are also available for analysis.

The Ageing Program has recently hired three new age readers: Christopher M. Gburski (University of Washington), Peter G. Risse (Evergreen State University), and Jonathan A. Short (Oregon State University).

For further information contact Dr. Daniel K. Kimura (206) 526-4200.

REFM Resource Ecology and Ecosystem Modeling Program

Our main opportunity for collection of groundfish stomach samples is through the echo-integration-trawl surveys and bottom trawl surveys of the RACE Division. In 1998, the Resource Ecology and Ecosystem Modeling Program participated in the RACE Division bottom trawl surveys of the Washington-Oregon-California shelf and the eastern Bering Sea to collect samples from dominant groundfish species in those areas. In addition, we participated in the ADF&G seasonal bottom trawl survey of the Kodiak shelf region to collect samples.

Program personnel, fishery observers, and others collected fish stomachs for our group. About 7,445 stomachs were collected from the Bering Sea, 1,360 from the Gulf of Alaska/Aleutian Islands and 4,948 from the West Coast region. Species sampled in the Bering Sea were walleye pollock, Pacific cod, yellowfin sole, Alaska plaice, rock sole, flathead sole, skates, arrowtooth flounder, Greenland turbot, Pacific halibut, and sculpins. Species sampled in the Gulf of Alaska/Aleutian Islands were walleye pollock, Pacific cod, rock sole, flathead sole, arrowtooth flounder, and Pacific halibut. Shipboard scans of the stomach contents of 372 fish were conducted in the Bering Sea. Laboratory analysis was conducted on 8,035 fish stomachs from the Bering Sea, 2,177 from the Gulf of Alaska/Aleutian Islands and 197 from West Coast regions.

Bering Sea ecosystem research communication and coordination is ongoing. The second interagency Bering Sea workshop held in June 1998 in Anchorage provided new research perspectives from a broader scientific and constituent audience. The comments and perspectives presented have been summarized in a workshop proceedings and a revised Bering Sea ecosystem research plan. Both documents are now available on the World Wide Web and can be viewed from the Alaska Fisheries Science Center web site at: *http://www.refm.noaa.gov/reem/*
or from NOAA's Bering Sea Theme Page: *http://www.pmel.noaa.gov/bering/pages/inter-agency/*

Cooperative work on predator-prey interactions with the US Fish and Wildlife Service, Alaska Maritime Wildlife Refuge (USFWS/AMWR) has recently begun. Investigators from the USFWS/SMWR have a program for obtaining stomach samples of groundfish predators in important bird foraging areas in the Gulf of Alaska and eastern Bering Sea using longlines or landed commercial or charter boat catches, including some of the sites that are part of the Seabird, Marine Mammal, Oceanography Coordinated Investigations (SMMOCI). Investigators hope to learn more about food webs and forage fish abundance and utilization in bird foraging areas. Task personnel are now receiving these groundfish stomach samples and performing lab and data analysis on them. These samples should enhance the existing groundfish food habits data base maintained by our task by providing more information about inshore food webs.

Russian Hydrographic (1950-1997) and Trawl (1952-1977) Data

There is now an AFSC Oracle database that contains hydrographic data collected during Russian research surveys of the eastern Bering Sea, Aleutian Islands, Gulf of Alaska and Washington-Oregon-California regions from 1950-1997. There are a total of 8,468 stations with 4,293 stations in the eastern Bering Sea, 257 for the Aleutian Islands, 2,652 for the Gulf of Alaska, and 1,266 for the Washington-Oregon-California area. The data collected at the hydrographic stations includes temperature, salinity, oxygen, alkalinity, phosphates, total phosphorus, and silicates at various water column depths. Some of these stations coincide in space and time with Russian research trawl survey information described below.

There is also an AFSC Oracle database that contains trawl data collected during Russian research surveys of the eastern Bering Sea shelf in the years 1952 and 1957-1977. Over 14,000 hauls were conducted from Norton Sound south to the Alaskan peninsula. Haul, catch, and length information were collected for more than 150 species. Presently, data on the following 12 species were loaded into Oracle tables: Pacific cod, walleye pollock, arrowtooth flounder, flathead sole, Pacific halibut, rock sole, yellowfin sole, longhead dab, starry flounder, Alaska plaice, Greenland turbot, and 26 species of Cottidae grouped under the general category of sculpins. Plans for the database include adding data from the remaining species and adding further data acquired from the Russians in their surveys of the Gulf of Alaska and Washington-Oregon-California coast regions. For assistance using these data, contact Pat Livingston (email: Pat.Livingston@noaa.gov phone: (206)526-4242).

Food Habits of Pacific Hake off Northern California and Southern Oregon

Because of its large biomass, Pacific hake is an important predator in the California Current ecosystem, and its impact on other commercially valuable species has been the object of several studies. During the 1995 Slope Survey the stomach contents of 377 Pacific hake were collected from waters over the outer continental shelf and upper continental slope in the Eureka INPFC area (approx. Cape Mendocino, California to Cape Blanco, Oregon). By weight, the stomach contents consisted mostly of euphausiids (31%), flatfishes (25%), sergestid shrimp (13%), lanternfishes (13%), cannibalized Pacific hake (8%) and pink shrimp (3%). Similar to other studies, the importance of euphausiids in the diet decreased with increasing size of Pacific hake. The diet composition of Pacific hake examined in this study contained more lanternfish and sergestid shrimp and less pink shrimp than other studies conducted in the Eureka INPFC area. Differences between the results of this study and other studies conducted in the same area were attributed mainly to the water depths where the samples were collected (Table 1).

Table 1. - Summary of studies on feeding habits of Pacific hake in the Eureka INPFC area.

Study	Season	Size(cm)	# w/ food	Depth(m)	Diet: weight (W) or volume (V)
Gotshall 1969	All	10-81	449	109-185	(V) 44% pink shrimp, 29% fish, 18% euphausiids
Livingston 1983	Autumn	10-20	40	130-160	(W) 98% euphausiids
Buckley & Livingston 1997	Summer	40-50	23	55-182	(W) 60% euphausiids, 35% pink shrimp
This study	Autumn	12-55	224	227-1206	(W) 46% fish, 31% euphausiids, 13% sergestid shrimp

ECOPATH/ECOSIM Models of the Eastern Bering Sea

Mass-balance models and simulations of the eastern Bering Sea ecosystem in the 1950s and 1980s have been developed in collaboration with researchers at the University of British Columbia. Some initial results of these models were recently presented at the 1998 Lowell Wakefield Symposium on Ecosystem Considerations in Fisheries Managment, held in Anchorage, Alaska. Over the past 10 years there has been increasing criticism of management decisions that are based on single-species approaches and a call for the implementation of ecosystem approaches. The major criticism of single-species models is that they cannot predict changes in community structure. Unfortunately, our experience in modeling the Bering Sea shows that this same criticism can also be leveled against ecosystem models.

We employed trophic mass-balance models (Ecopath and Ecosim) to examine some possible explanations for the changes that have occurred in the Bering Sea between the 1950s and 1980s. We removed fish and mammals from the modeled system and tracked how other components of the ecosystem responded. Our mass-balance models indicate that neither whaling nor commercial fisheries were sufficient to explain the possibility of a 400% increase in pollock biomass and other changes that may have occurred between the two time periods. The simulations further suggest that environmental factors, affecting recruitment or primary production, may be more important in determining the dynamics of the Bering Sea ecosystem than predator-prey interactions alone. These findings illustrate that mass balance models that do not account for the impact of climate variability on year-class strength cannot provide reliable estimates of trends in marine fish production. The findings also highlight our lack of knowledge of the state of the eastern Bering Sea during the 1950s period. We will be doing further work on these models to improve the parameters and processes modeled. These improvements, with a more rigorous validation of model results, will provide more credibility to the model results and move it into a position where it might be used to provide ecosystem management advice.

PICES GLOBEC Climate Change and Carrying Capacity (CCCC) Program

The CCCC program of the North Pacific Marine Science Organization (PICES) was co-chaired by AFSC scientist, Pat Livingston in 1998. This was an active year for the program, which saw the formation of a new task team, continued activities of existing task teams, and advances in communicating our work not just within PICES but to the international scientific community as a whole. As part of our efforts to better communicate our activities, we have organized and added more information about the CCCC program on the PICES web site. For 1999, we anticipate more advances, particularly beginning activities to aid research coordination in regions such as the subarctic North Pacific and the Japan/East Sea that are being studied by many different research programs of several nations but which do not yet have funding for a coordinated GLOBEC program of research. We will also have new co-chairs for the CCCC program and many of the task teams. Their new ideas and perspectives will ensure that we move forward with renewed energy to continue with our goal of integrating and stimulating national activities on the effects of climate variations on the marine ecosystems of the subarctic N. Pacific. Below is a summary of our activities for 1998 and plans for 1999. Visit the PICES web site regularly to get more details on CCCC program activities, past, present, and future!

The **BASS (BAS**in **S**tudies) Task Team, which coordinates biological and physical studies in the central subarctic Pacific, is completing the review process for the papers from their 1998 BASS Symposium. These papers will be published in an upcoming volume of Progress in Oceanography. This volume will provide an excellent summary of what is known about the eastern and western subarctic North Pacific gyres at all ecosystem levels and provide some initial guidance on research gaps. BASS would like to build on this work by holding a workshop on the development of a conceptual model of the subarctic North Pacific gyres. They hope to use the information brought together in the BASS symposium volume to identify research questions and opportunities, particularly with respect to : physical structure of the gyres in relation to climate change; long-term changes in plankton abundance and species composition; and trophic relationships of fish, birds, and mammals.

BASS is also planning to annually compile a list of cruises in the subarctic North Pacific through contacts in each member country and through other organizations such as North Pacific Anadromous Fish Commission (NPAFC). These cruises and names of contact persons will be listed on the PICES web site to aid researchers interested in developing collaborative research efforts in this region.

MODEL Task Team has continued with their primary role of facilitating communication among modeling studies and with field programs. They have built on their web directory of existing circulation models to include biological models. They plan to include a nutrient database directory on the web this year.

A small workshop was held just prior to PICES VII in Fairbanks to deal with lower trophic level model comparison issues and to gather information for nutrient data bases. A proceedings of the workshop will be published later this year in a volume of the PICES Scientific Report series. Based on the discussions at this workshop, the task team recommended that a prototype lower trophic level model with 12 compartments that would be executable on the web be made available in 1999. Plans are developing to hold a workshop in the year 2000, to apply the model to two sites (Station P and Sanriku area), compare it with an existing Bering Sea model, and plan for its application to higher trophic level models, regional circulation models, and JGOFS models.

The newly formed MONITOR Task Team held a workshop just prior to PICES VII in Fairbanks to review existing activities of PICES member nations and to identify monitoring needs and intercalibration experiments that might need to be conducted. The workshop was highly successful with 15 papers presented. A workshop report will be prepared and published in 1999 in the PICES Scientific Report series.

Based on the discussions at the workshop, the task team will be working on several projects in the coming year. One project is to construct a table of present shipboard monitoring in the subarctic North Pacific by time and space to more clearly identify monitoring gaps and assist in the design of an improved monitoring system. They will also be preparing a summary of the zooplankton sampling gear used in many of the long time series of zooplankton observations in the North Pacific shelf and basin ecosystems and identifying the most important intercalibration experiments that need to be carried out in the near future. Another key project will be to develop a white paper on the use of continuous plankton recorder (CPR) observations in the North Pacific. The task team will also be developing recommendations about biophysical moorings and zooplankton production.

The **REX** (**RE**gional **EX**periments) Task Team, which identifies and carries out cooperative research experiments among the PICES regions, made significant progress this year. They published the report of last year's developmental workshop in PICES Scientific Report No. 9, which forms the basis for their long-term work plan. A highly successful topic session was held jointly with the PICES Fisheries Science Committee during PICES VII, highlighting the research findings of GLOBEC and GLOBEC-like programs. This topic session will be continued in future years to ensure a place for GLOBEC researchers to present their findings at PICES scientific meetings. This is an important aspect of scientific networking that provides rapid transfer of information to the GLOBEC research community.

The task team held an interesting and successful workshop on climate effects on small pelagic species just prior to PICES VII in Fairbanks. Nine scientific papers were presented and reviews of existing research programs on small pelagics in each of the PICES nations were provided. Key questions and hypotheses relating to small pelagic species were discussed and several research recommendations for the future were made. A full workshop report will be published in 1999 in the PICES Scientific Report series. The task team plans to hold a workshop in 1999 just prior to PICES VIII in Vladivostok, Russia on the comparative dynamics of herring and euphausiids. They also plan to compile a summary of the sampling strategies and methods used to assess the stocks of small pelagic species.

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

Multispecies Studies (Stock Assessment)

REFM Status of Stocks and Multispecies Assessment Program

The Status of Stocks and Multispecies Assessment Program is responsible for providing stock assessments and management advice for groundfish in the North Pacific Ocean and the Bering Sea. In addition, program 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 program for the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Plan teams of the North Pacific Fishery Management Council and for the groundfish management team of the Pacific Fishery Management Council.

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) contribution to a comprehensive report on bycatch, utilization and discards; 4) helping to develop overfishing definitions for the NPFMC, 5) providing analysis of environmental impacts of the pollock and Atka mackerel fisheries on Steller sea lions, and 6) working with the NMFS Alaska Region to provide a supplemental environmental impact statement for the setting of TACs.

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 hydroacoustic approaches for rockfish habitat determination. Significant research contributions on: 1) the examination of climatic effects on the recruitment of North Pacific groundfish species, 2) relationship of Bering Sea oceanography to pollock recruitment, 3) modeling the Pacific whiting fishery behavior, 4) analysis of the geographic and genetic variation in Atka mackerel in the Aleutian Islands, and 5) incorporation of predation in the Gulf of Alaska pollock assessment were presented at various symposia. In addition, staff members participated on nationwide NMFS committees for specifying a precautionary approach to fisheries management; used a Leslie depletion model to analyze Atka mackerel fishery CPUE data; investigated restratifying fisheries data along biological lines as opposed to traditional INPFC areas; worked with other fishery labs in developing and implementing a new stock assessment model, and continued the international cooperative analysis of Bering Sea pollock stocks with

Russian scientists. Staff members also served on national and international steering committees of GLOBEC and PICES.

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

Multispecies Studies (Management)

REFM North Pacific Groundfish Observer Program

The North Pacific Groundfish Observer Program is responsible for placement of observers on vessels fishing for groundfish species in the U.S. 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 continuation of the US fishing industry.

During 1998, no foreign vessels were allowed to catch or process fish in the U.S. EEZ along the west coast and Alaska. The Observer Program trained and deployed 614 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. Data were also collected regarding the operations of the groundfish fishery.

The Observer Program has developed a computer software application (ATLAS) which allows groundfish observers to enter and send data directly from their vessels and plants to the NMFS office in Seattle. The implementation of this data-reporting system benefits NMFS and the fishing industry in numerous ways. It reduces the data processing time considerably, and the error-checking functions of the software provide all users with higher quality data.

Using this application also benefits observers. It has markedly reduced debriefing time and the time required to complete paperwork at sea. The reduction in paperwork allows observers to focus more of their time and energy on collecting data. Electronic reporting of observer sampling data from sea using ATLAS is now occurring on about 76 at-sea processing vessels, 11 shoreside plants and 7 shoreside delivery vessels.

Further expansion of the Multi-Species Community Development Quota (MSCDQ) program occurred in 1998. This quota system was developed for the purpose of allocating fishery resources to eligible Western Alaska communities to provide the means for starting or supporting commercial fishery activities that would result in ongoing, regionally based, commercial fishery or related businesses. CDQ was initiated in 1992 with pollock and expanded to include fixed gear halibut and sablefish in 1995, and in 1998 it was further expanded to include other groundfish and crab. In 1999 the NMFS will be responsible for monitoring the groundfish (including pollock and sablefish) and halibut CDQs and the State of Alaska will be responsible for monitoring the crab CDQs.

MSCDQ catch accounting for catcher/processor vessels is based entirely on data collected by observers and, unlike the open access fisheries where observer data is used to manage a fleet wide quota, industry participants in the MSCDQ fisheries require individual accounting of fish harvested in each haul or set. This change in expectations placed on observers, their data, and the Observer Program in general, has required increased Observer Program staff effort in the development of special selection criteria and training requirements for MSCDQ observers, development of new sampling strategies and regulations to enhance the observer's working environment, and changes to the data collection and data management software systems.

The Observer Program added eight new employees to its ranks in 1998 and opened a new field office in Anchorage. The new staff will aid in the accomplishment of MSCDQ-related duties and implementation of the ATLAS communications system. Two staff have been assigned full-time to the Anchorage office, and staff based in Seattle will be rotating to Dutch Harbor and Kodiak on a regular basis, thus expanding the Observer Program presence in the Alaska field offices. In addition, staff in the Anchorage Observer Program office will provide liaison between the Observer Program and the University of Alaska Anchorage Observer Training Center.

For further information or if you have questions about the North Pacific Groundfish Observer Program, contact Dr. William Karp (206)526-4194.

REFM Socioeconomic Assessment Program

From May 1998 through April 1999, the Socioeconomic Assessments Program 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. Center economists served on the 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 bycatch reduction programs for the BSAI and GOA groundfish fisheries, (2) allocation of the BSAI pollock quota among factory trawlers, motherships and on-shore processors, (3) cost recovery program for the Alaska IFQ and CDQ programs, (4) sea lion protection in the BSAI pollock and Atka mackerel fisheries and the GOA pollock fishery, (5) economic and social data collection for the BSAI and GOA groundfish fisheries, (6) American Fisheries Act, (7) industry-funded buyback for PFMC groundfish fisheries, (8) PFMC groundfish allocation by gear type within the commercial fishery and between commercial and recreational fisheries, (9) stacking of PFMC groundfish permits and reduced fishing opportunities, (10) PFMC groundfish trip limits, (11) the factory trawler cooperative in the Pacific whiting fishery, and (12) management options for the 3-tiered PFMC groundfish fishery. Two other activities in support of the NPFMC were: 1) the preparation of a draft supplemental environmental impact statement for the BSAI and GOA groundfish fisheries and 2) the implementation of a program to collect cost, earnings and employment data and develop models to use that data to measure the economic performance of the Alaska groundfish and halibut fisheries. Center economists have participated in a similar program for the PFMC fisheries.

Center economists prepared publications on the following topics: (1) bycatch management, (2) the economic status of the Alaska groundfish fisheries, (3) extended jurisdiction and foreign direct investment, and (4) the effectiveness of vessel buyback programs.

Center economists provided economic advice, technical review and support for: (1) Saltonstall-Kennedy and Sea Grant research proposals, (2) the development of the AKFIN system, (3) the NMFS excess fishing capacity work group, (4) the development of a NMFS bycatch plan, (5) the development of guidelines for Regulatory Flexibility Act analysis, (6) the fishing vessel registration and fisheries information systems, (7) a budget initiative to improve substantially the social science capabilities of NMFS, (8) proposals to amend the MSFCMA, and (9) the Western Regional Seafood Markets and Fisheries Management working group, sponsored by USDA and the Region's Land Grant University Experiment Stations.

Drs. Dan Holland and Todd Lee began working at the Center in July and September, respectively. Their principal responsibilities will be to improve the economic data and models that are available to measure the economic performance in the Alaska groundfish fisheries. Dr. Holland completed his graduate studies at the University of Rhode Island in June. Dr. Lee spent the last two years on the faculty of the University of Alaska, Fairbanks. He completed his graduate studies at the University of Washington in 1996.

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

Pacific Cod Stock Assessment

Bering Sea/Aleutian Islands

The present assessment is a straightforward update of last year's assessment, incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in a biomass estimate of 534,000 t, a 12% decrease relative to last year's estimate. This decline is roughly consistent with the downward trend projected in last year's assessment. Last year, the North Pacific Fishery Management Council's Scientific and Statistical Committee (SSC) determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock, and that Pacific cod therefore qualified for management under tier 3 of Amendment 44. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ from the present assessment are 343,000 t, 0.29, and 0.41, respectively. Fishing at the $F_{40\%}$ rate (0.29) is projected to result in a 1999 spawning biomass of 328,000 t, thereby placing Pacific cod in sub-tier "b" of tier 3. Fishing at the slightly lower rate of 0.28 is projected to result in a 1999 spawning biomass of 329,000 t, which solves the equation for the maximum permissible value of F_{ABC} shown below:

$$F_{ABC} \leq F_{40\%} \times (B_{99}/B_{40\%} - 0.05)/(1-0.05) = 0.29 \times (329{,}000/343{,}000 - 0.05)/0.95 = 0.28$$

Fishing at an instantaneous rate of 0.28 is projected to result in a 1999 catch of 196,000 t, which is the maximum permissible acceptable biological catch (ABC) under Amendment 44. However, the Plan Team concurred with the assessment authors' recommendation to set 1999 ABC at 177,000 t, about 9% below the maximum permissible level. This recommendation is based on a risk-averse optimization procedure which considers uncertainty in the estimates of the survey catchability coefficient and the natural mortality rate in the computation of an $F_{40\%}$ harvest level. The Plan Team felt that a 9% reduction from the maximum permissible ABC is justified not only on the basis of these decision-theoretic concerns, but also because the estimated biomass from the trawl survey has decreased for four years in a row to a point only slightly higher than the all-time low and because the last three year classes (assessed at age 3) have all been well below average. A 1999 catch of 177,000 t corresponds to a fishing mortality rate of 0.25, below the value of 0.28 which constitutes the upper limit on F_{ABC} under tier 3b. The Overfishing Level (OFL) was determined from the tier 3b formula, where fishing at the slightly lower rate of 0.28 is projected to result in a 1999 spawning biomass of 324,000 t, which solves the equation for F_{OFL} shown below:

$$F_{OFL} = F_{30\%}\times(B_{99}/B_{40\%}\text{-}0.05)/(1\text{-}0.05) = 0.41\times(324{,}000/343{,}000\text{-}0.05)/0.95 = 0.39$$

Fishing at an instantaneous rate of 0.39 gives a 1999 catch of 264,000 t, which is the recommended OFL.

Gulf of Alaska

As with the past two Pacific cod assessments, the authors incorporated a risk-averse analysis of alternative values for natural mortality and survey catchability. The ABC recommendation based on $F_{41.4\%}$ =0.18 (risk-averse Bayesian meta-analysis results) gives a 1999 ABC of 90,900 t. Their is concern that the 1995 year class was only observed by the 1996 trawl survey and the subsequent 1997 fisheries, and the above-average estimate for this year-class has a high degree of associated uncertainty in the assessment. Given concerns of increasing the ABC amid projections of spawning stock declines, the recommended 1999 ABC remained fixed at the 1998 ABC of 77,900 t. The 1999 OFL ($F_{30\%}$=0.52) is 134,000 t based on Tier 3a from the current analysis.

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

Shelf Rockfish Stock Research

Gulf of Alaska

Habitat and Assemblages of Rockfish Observed with an ROV in Nearshore Waters of Southeastern Alaska

Scientists in the ABL Habitat Program determined the feasibility of using a remotely operated vehicle (ROV) to examine habitat and assemblages of Pacific rockfish in nearshore waters of southeastern Alaska. An ROV was used to survey 10 sites along a gradient from inside waters near Juneau to outside waters near Sitka in August 1998. At each site we sampled up to four habitat types: <7 m deep eelgrass meadows; <20 m deep, rocky-bottom areas with kelp; steep, bedrock wall faces 20-70 m deep; and flat, soft-bottom basins 25-70 m deep. In eelgrass, the only rockfish observed were adult copper rockfish and unidentified juvenile rockfish. In rocky-bottom areas with kelp, rockfish included adult black or dusky, copper, and yellowtail rockfish and unidentified juvenile rockfish. In bedrock wall areas with high-relief, rockfish included adult black or dusky, copper, quillback, yellowtail, and juvenile yelloweye rockfish. Rockfish were absent in flat, soft-bottom basins with no vegetation and little cover. The ROV worked best with epibenthic fish, on hard substrates, and did not appear to disturb or attract fish. Studies in 1999 will focus on quantifying fish abundance and habitat of juvenile rockfish in a variety of nearshore habitat types.

For more information, contact Scott Johnson at (907) 789-6063 or Mike Murphy at (907) 789-6036.

Shelf Rockfish Stock Assessment

Gulf of Alaska

Pelagic Shelf Rockfish

The pelagic shelf rockfish assemblage is comprised of three 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 is by far the most abundant species in the group, and has been the target of a bottom trawl fishery since the late 1980s. Two varieties of dusky rockfish are seen: an inshore, dark-colored form, and a light-colored variety found offshore. The trawl fishery takes the light variety. Taxonomic work is in progress to determine if these two forms are separate species, which they appear to be.

Similar to previous years, ABC for the assemblage in 1999 is calculated using a biomass-based approach based on trawl survey data. Gulfwide exploitable biomass is based on the average of the biomass estimates from results of the 1990, 1993, and 1996 triennial trawl surveys: 54,220

t. Almost all this biomass comes from dusky rockfish. Applying an F=M strategy to this biomass, in which the annual exploitation rate is set equal to the estimated rate of natural mortality for dusky rockfish (0.09), yields a Gulfwide ABC of 4,880 t for 1999.

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

Slope Rockfish Research

Gulf of Alaska

Adaptive Sampling of Slope Rockfish

In August 1998, ABL scientists used the chartered factory trawler *Unimak Enterprise* for 17 days northeast of Kodiak Island to conduct an experimental survey of three slope rockfish species: Pacific ocean perch, shortraker rockfish, and rougheye rockfish. This study was in cooperation with the University of Alaska Fairbanks, Juneau Center, School of Fisheries and Ocean Sciences, and partial funding was provided by the Sea Grant - NOAA Partnership Program. Scientists from the AFSC RACE and REFM Divisions also participated in the cruise. During the charter, the vessel completed 190 trawl hauls and caught over 370 t of rockfish. The vessel was allowed to retain and sell the catch, which enabled the charter to be at no-cost to the government.

The study's objective was to determine if a new survey methodology, adaptive sampling, would provide improved estimates of abundance for slope rockfish when compared with simple random sampling, which has been the standard design for all previous trawl surveys of rockfish in this region. Adaptive sampling is a technique not yet widely used in fisheries, but previous research has indicated that for clustered populations, such as those observed for many rockfish species, it may have benefits over simple random sampling. The experiment focused on two study areas which were divided into strata, and each stratum was initially sampled by conducting bottom tows at random locations. This was followed by an adaptive phase, in which a systematic pattern of closely spaced tows was made around the random tows in each stratum that showed high catches of rockfish. Estimates of rockfish abundance were computed for each stratum based on just the random tows, and also on two adaptive estimators that incorporated data from both the random and the adaptive tows. Contrary to initial expectations, preliminary adaptive sampling results for Pacific ocean perch showed only modest gains in the precision of abundance estimates when compared with random sampling. These results, however, appeared to be highly dependent on the stratification pattern that was used. For shortraker and rougheye rockfish, adaptive sampling found a substantially larger abundance in one stratum than did random sampling, whereas in the other stratum, the two methods showed almost identical results. Further studies on the efficacy of adaptive sampling for surveying rockfish abundance will be conducted in 1999 using a chartered trawler off Yakutat, Alaska.

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

Survey Design Considerations and Distribution Patterns of Pacific Ocean Perch in the Gulf of Alaska

In the Gulf of Alaska, a stratified-random trawl survey is conducted triennially to obtain abundance estimates for major groundfish species. There is considerable uncertainty in the survey biomass estimates for Pacific ocean perch (POP). Using Geographic Information Systems (GIS) and log-linear analyses, survey and commercial fishery data were analyzed to determine Pacific ocean perch distribution patterns in the Gulf of Alaska. Survey and fishery data appear to encounter Pacific ocean perch in the same areas of the Gulf of Alaska, but distribution patterns differ among the three management areas of this region. Analysis of CPUE data indicates Pacific ocean perch exhibit a tightly aggregated distribution pattern which is related to habitat type. The efficiency of the survey design is low in comparison to two alternative designs based on more generalized stratification schemes. The current survey is a multispecies survey designed to provide accurate biomass estimates of all major groundfish species, one of which is Pacific ocean perch. For this species, the stratification scheme is over-stratified and too much effort is allocated to areas of low Pacific ocean perch abundance and low variability. Altering the allocation and stratification of the current design could improve the precision of Pacific ocean perch biomass estimates but may be limited by the clustered distribution of these fish in the Gulf of Alaska and the need to assess other species.

For more information, contact Chris Lunsford at (907) 789-6008.

Species Identification of Rockfish Larvae

In late spring and early summer, rockfish larvae, *Sebastes* spp., are among the most abundant fish larvae in the eastern Gulf of Alaska. Also, they are the most difficult to identify to species level. ABL scientists, in cooperation with Dr. Anthony Gharrett and Andrew Gray of the University of Alaska Fairbanks, continue working on identification of preflexion rockfish larvae using digital camera records of pigment patterns and mitochondrial DNA (mtDNA) techniques to confirm species identifications. Experiments in May 1996 showed that single preflexion larvae could be identified using mtDNA at smaller sizes than possible with allozyme techniques. In 1997 and 1998, 115 preflexion larvae were subjected to mtDNA analyzes. Nine species of rockfish associated with specific pigment patterns have been identified, *Sebastes babcocki, S. borealis, S. brevispinus, S. ciliatus*, S. *maliger, S. proriger, S. ruberrimus, S. variegatus*, and *S. zacentrus*. As the database grows, plans are to describe the variability of larval pigment patterns within a species and how pigment patterns change with growth. In 1999, the study will be expanded to include postflexion larvae and additional species.

For more information, contact Dr. Bruce Wing (907)789-6043.

Slope Rockfish Stock Assessment

Bering Sea

The POP complex consists of true POP (*Sebastes alutus*) and four other red rockfish species (northern rockfish, rougheye rockfish, sharpchin rockfish, and shortraker rockfish). 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 Aleutian Islands. This was done to avoid excessive catches of the less abundant members of the complex, particularly shortraker and rougheye. Beginning in 1996, the ABC and TAC for true POP have been subdivided within the AI area, based on an average of the biomass estimates from the two most recent trawl surveys: Eastern subarea (541) 25%, Central subarea (542) 25%, and Western subarea (543) 50%.

True POP, Eastern Bering Sea:

The present assessment is a straightforward update of last year's assessment, incorporating new catch information (results from recent EBS shelf trawl surveys are not used in this assessment). Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock and that true POP in the EBS therefore qualified for management under tier 3 of Amendment 44. The updated estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ from the present assessment are 34,400 t, 0.057, and 0.082, respectively. Projected spawning biomass for 1999 is 24,800 t, placing true POP in the EBS in sub-tier "b" of tier 3. The maximum F_{ABC} value allowed under tier 3b is computed as follows:

$$F_{ABC} \leq F_{40\%} \times (B_{99}/B_{40\%}\text{-}0.05)/(1\text{-}0.05) = 0.057\times(24{,}800/34{,}400\text{-}0.05)/0.95 = 0.040$$

Projected harvesting at a fishing mortality rate of 0.040 gives a 1999 catch of 1,900 t, which is the recommended ABC (last year's ABC was set using a lower fishing mortality rate, specifically the $F_{44\%}$ level). The OFL fishing mortality rate is computed under tier 3b as follows:

$$F_{OFL} = F_{30\%}\times(B_{99}/B_{40\%}\text{-}0.05)/(1\text{-}0.05)= 0.082\times(24{,}800/34{,}400\text{-}0.05)/0.95 = 0.066$$

Projected harvesting at a fishing mortality rate of 0.066 gives a 1999 catch of 3,600 t, which is the recommended OFL.

True POP, Aleutian Islands:

The present assessment is a straightforward update of last year's assessment, incorporating new catch information (no Aleutian survey was conducted this year). Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock and that true POP in the Aleutians therefore qualified for management under tier 3 of Amendment 44. The updated estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ from the present assessment are 125,000 t, 0.068, and 0.095, respectively. Projected spawning biomass for 1999 is 129,000 t, placing true POP in the Aleutians in sub-tier "a" of tier 3. The maximum permissible value of F_{ABC} under tier 3a is 0.068.

Projected harvesting at a fishing mortality rate of 0.068 gives a 1999 catch of 13,500 t, which is the recommended ABC (last year's ABC was set using a lower fishing mortality rate, specifically the $F_{44\%}$ level). The ABC is apportioned among AI subareas based on survey distribution as follows: Western AI = 6,220 t, Central AI = 3,850 t, and Eastern = 3,430 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value of 0.095 gives a 1999 OFL of 19,100 t.

Other Members of the POP Complex, Eastern Bering Sea:

The present assessment is basically identical to last year's assessment. Traditionally, the biomass estimates from all trawl surveys (both EBS shelf/slope and Aleutian) are averaged over all years to obtain the best estimate of biomass for the species in this subcomplex. Summed over the species in the subcomplex, this procedure produces a biomass estimate of 22,800 t. By species, the biomass estimates are as follows: rougheye rockfish--2,710 t, shortraker rockfish--8,230 t, and northern rockfish--11,900 t. However, last year the Plan Team was alerted to the fact that two exceptionally large tows of northern rockfish from the 1986 Aleutian Islands trawl survey (in the small part of the EBS covered by that survey) were responsible for approximately 94% of the above estimate of northern rockfish biomass. Eliminating the 1986 Aleutian survey's estimate of northern rockfish biomass in the EBS results in a revised average biomass estimate of 693 t. Last year, it was concluded that this revised value represented the best estimate of northern rockfish biomass in the EBS. The SSC also determined that reliable estimates of the natural mortality rate (M) existed for the species in this subcomplex, and that non-*alutus* members of the POP complex in the EBS therefore qualified for management under tier 5 of Amendment 44. The accepted estimates of M for these species in the EBS are as follows: rougheye rockfish--0.025, shortraker rockfish--0.030, and northern rockfish--0.060. It was thus recommended setting F_{ABC} at the maximum value allowable under tier 5, which is 75% of M. On a species-specific basis, this translates into the following F_{ABC} values: rougheye rockfish--0.019, shortraker rockfish--0.023, and northern rockfish--0.045. Multiplying these rates by the best estimates of species-specific biomass and summing across species gives a 1999 ABC of 267 t. The OFL was determined from the tier 5 formula, where setting $F_{OFL}=M$ for each species gives a combined 1999 OFL of 356 t.

Sharpchin and Northern Rockfish, Aleutian Islands:

The present assessment is basically identical to last year's assessment. Because sharpchin rockfish are found only rarely in the Aleutian Islands, northern rockfish are for all practical purposes the only species in this subcomplex. Traditionally, the biomass estimates from all Aleutian bottom trawl surveys are averaged over all years to obtain the best estimate of northern rockfish biomass. This procedure produces a biomass estimate of 94,000 t. Last year, the SSC determined that a reliable estimate of the natural mortality rate (M) existed for this stock, and that northern rockfish in the Aleutians therefore qualified for management under tier 5 of Amendment 44. The accepted estimate of M for northern rockfish in the Aleutians is 0.06. F_{ABC} was set at the maximum value allowable under tier 5, which is 75% of M, or 0.045. Multiplying this rate by the best estimate of biomass gives a 1999 ABC of 4,230 t. The OFL was determined from the tier 5 formula, where setting $F_{OFL}=M$ gives a 1999 OFL of 5,640 t.

Shortraker and Rougheye Rockfish, Aleutian Islands:

The present assessment is basically identical to last year's assessment. Traditionally, the biomass estimates from all Aleutian bottom trawl surveys are averaged over all years to obtain the best estimate of biomass for the species in this subcomplex. Summed over the species in the subcomplex, this procedure produces a biomass estimate of 46,500 t. By species, the biomass estimates are as follows: rougheye rockfish--21,600 t and shortraker rockfish--24,900 t. Last year, the SSC determined that reliable estimates of the natural mortality rate (*M*) existed for the species in this subcomplex, and that shortraker and rougheye rockfish in the Aleutians therefore qualified for management under tier 5 of Amendment 44. The accepted estimates of *M* for these species in the Aleutians are as follows: rougheye rockfish--0.025 and shortraker rockfish--0.030. F_{ABC} was again set at the maximum value allowable under tier 5, which is 75% of *M*. On a species-specific basis, this translates into the following F_{ABC} values: rougheye rockfish--0.019 and shortraker rockfish--0.023. Multiplying these rates by the best estimates of species-specific biomass and summing across species gives a 1999 ABC of 965 t. The OFL was determined from the tier 5 formula, where setting $F_{OFL}=M$ for each species gives a combined 1999 OFL of 1,290 t.

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

Gulf of Alaska

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, silvergray, and harlequin rockfish. Until recently, the stock abundance of slope rockfish, especially Pacific ocean perch, was considered to be quite depressed compared to its former abundance in the early 1960s. The most recent triennial trawl survey of the Gulf of Alaska in 1996 showed a substantial increase in biomass of Pacific ocean perch. This increase followed another large increase in biomass seen in the previous trawl survey in 1993, and suggests that current abundance of Pacific ocean perch is much improved in comparison with its formerly depressed condition. The "stock synthesis" model is applied to Pacific ocean perch. This model incorporates age composition, in addition to using other data such as fishery CPUE and estimated biomass from trawl surveys. Based on the model, our best estimate of exploitable biomass for Pacific ocean perch in the Gulf of Alaska is now 228,190 t, similar to last year's estimate of 243,170 t. Exploitable biomass for the other species in the assemblage is estimated from the average values in the 1990, 1993 and 1996 trawl surveys, and totals 252,460 t. Unlike Pacific ocean perch, survey biomass estimates for the other species have generally not shown large increases in recent years.

Estimated age compositions of Pacific ocean perch indicate the presence of a strong 1986 year class, especially in the central and western Gulf of Alaska. This year class was first noted in samples from the 1990 triennial survey and verified in the 1993 and 1996 surveys. Past age samples have also identified a strong 1976 year class.

To prevent possible over-exploitation 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 $F_{40\%}$ strategy. The other subgroups are managed under an F=M strategy, in which the annual exploitation rate is set equal to or less than the rate of natural mortality. The 1999 ABCs are as follows: Pacific ocean perch, 13,120 t; shortraker/rougheye rockfish, 1,590 t; northern rockfish, 5,000 t, and other slope rockfish, 5,270 t.

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

West Coast

Pacific Ocean Perch

The assessment applies to Pacific ocean perch (*Sebastes alutus*) for the U.S. Vancouver and Columbia INPFC areas combined. Catches were characterized by large removals during the mid-1960s by foreign vessels. The domestic fishery proceeded with subsequent moderate removals of between 1,000-2,000 t per year since 1976. Catches have been further reduced by management measures to about 700 t since 1995.

Previous assessments were done in 1992 and 1995 and involved extensive analyses of diverse data types using an age structured model (the stock synthesis program). The new data presented in the latest assessment include updated catches, a revised length-at-age analysis, and the 1995 NMFS triennial bottom trawl survey estimate of biomass. Also new to the latest assessment is an analysis of the stock-recruitment relationship as an integrated part of the model. This provided estimates of the fishing mortality rate that achieves maximum yield to evaluate compared to the commonly used standard SPR rates (e.g., *F40%*). While analyses on stock-recruitment relationships typically require many assumptions, we feel that the integrated model addresses many of the problems (e.g., errors in the estimate of both stock size and recruitment values).

As with any fish stock assessment, there are a number of sources of uncertainty that complicate the scientific interpretation of the results. The assessment attempted to develop a model that encompasses greater realism in this uncertainty. For example, allowances for uncertainty in natural mortality, total catch (by weight) estimates, and in the survey catchability coefficients. For sensitivity analyses, other plausible alternatives suggest that the overall uncertainty may be greater than that predicted by a single model specification. Nonetheless, it is proposed that the reference case adequately envelopes the range of uncertainty.

The main issues that need addressing include careful consideration of stock-recruitment relationship, particularly as defined by assumptions of what constitutes a "stock". Clearly a significant portion of the reproductive stock lies in Canadian waters yet these fish are not explicitly included in the assessment. This may be important also since we are at the southern extremity of the geographic range of POP. Maturity-at-age data need revising since the assessment shows that assumptions about maturity stage may impact harvest recommendations.

A procedure for estimating F_{msy} and associated yields directly within the larger model was introduced. This was included with the other SPR rates for contrast. Importantly, an evaluation of the ability to estimate F_{msy} and provide associated levels of uncertainty was provided. The value for F_{msy} occurred at slightly higher values than the normal SPR values (e.g., *F35%*). However, the trade-off of lower fishing mortality rates represent only small reductions in overall sustainable yields. Point estimates of female spawning biomass and total age 3+ biomass for 1998 are as follows:

Female spawning biomass = 5,371 t; total age 3+ biomass = 17,629 t.

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

Thornyheads Stock Assessment

Gulf of Alaska

Shortspine thornyheads were assessed using the same model as in the preceding year. The model assumes a prior distribution for trawl survey catchability (q) with a mean value 1.0 for the years when the survey included the deeper waters of the Gulf, and estimates the value for the recent survey years. Rather than fixing natural mortality at some alternative values, the authors assumed a prior distribution for M. Annual fishing mortality rates are an averaged rate over all ages. This contrasts with the "full-selection" values that have become commonly reported in recent years. The assessment also provided the conversion between the "average" $F_{40\%}$ (and $F_{30\%}$) value and the corresponding "full selection" values as:

	Average F	Full-selection F
$F_{40\%}$	0.042	0.080
$F_{30\%}$	0.061	0.112

The ABC recommendation is 1,990 t and the overfishing yield is 2,800 t based on $F_{30\%}$ = 0.112 overfishing level. This ABC recommendation is based on the $F_{40\%}$ (=0.08) harvest rate assuming that approximately 50% of the catch will be taken by trawl gear with the remainder from longline gear. Since this is similar to recent observed catches by gear type, this value seems appropriate.

The ABC is apportioned by areas in proportion to the survey biomass distribution. The assessment authors provided an area apportionment using the three most recent surveys weighted as for slope rockfish species (using ratios of 9:6:4 for survey years 1996, 1993, and 1990, respectively). This gives an area apportionment of:

	Western	Central	Eastern	Total
Wtd. Average	13%	35%	52%	
ABC	260	700	1,030	1,990

For further 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 Alaska from 1987-98. The survey is a joint effort involving two divisions of the AFSC: ABL and RACE. It replicates as closely as practical the Japan-U.S. cooperative longline survey conducted from 1978-94 and also samples gullies not sampled during the cooperative longline survey. The eastern Bering Sea, Aleutian Islands region, and Gulf of Alaska were sampled during the cooperative longline survey, but the AFSC longline survey sampled only the Gulf of Alaska until 1996, when biennial sampling of the Aleutian Islands region and eastern Bering Sea was added. The eastern Aleutian Islands were sampled in 1998. In 1998, 73 stations were sampled in the Gulf of Alaska and 14 stations were sampled in the eastern Aleutian Islands from June 1 to September 5. Sixteen kilometers of groundline were set each day, containing 7,200 hooks baited with squid. The survey vessel was the chartered fishing vessel *Alaskan Leader*. The survey's sablefish abundance index for all regions combined decreased 5.7% in numbers and 5.8% in weight from 1997 to 1998, following decreases of 6.2% in numbers and 12.1% in weight from 1996 to 1997. Approximately 3,299 sablefish, 524 shortspine thornyhead, and 66 Greenland turbot were tagged and released during the survey. An additional 196 sablefish were tagged with archival tags and released (see below). Length-weight data and otoliths were collected from approximately 2,450 sablefish.

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

Sablefish Longline Hook Cluster Experiment

In addition to the sablefish longline survey, a longline hook cluster experiment was also conducted from the chartered fishing vessel *Alaskan Leader* near Yakutat from 21-27 July 1998. The purpose of the experiment was to test an assumption about how to interpret the longline survey results. The survey catch per skate is assumed to be an index of relative abundance; for example, a 10% difference in catch rate reflects a 10% difference in relative abundance. This assumption would be wrong if sablefish have a more difficult time locating bait after several baits are taken; then the relationship between catch rate and relative abundance would be nonlinear and the gear would be said to "saturate". Results from hook-timer experiments show that the probability that a sablefish locates a bait does not change, at least as long as half the baits remain available.

The purpose of the hook-cluster experiment was to test the ability of sablefish to locate baited hooks when there are gaps between clusters of hooks. The gaps are equivalent to line intervals unavailable to capture of fish. Sablefish must locate the clusters of available baits between the gaps. Varying the length of the gaps provides information on the search area of sablefish and their ability to locate available baits. Although the gap varies, the total number of hooks per skate is standardized to eliminate increasing attraction area with more hooks. Gaps from 4 to 42 m were tested. If sablefish catch rate is the same for all gaps, this implies that sablefish are efficient bait predators and that saturation does not occur, at least when baits are spaced less then 42 m apart.

Fifteen sets were completed in the hook-cluster experiment. Each set contained all gap sizes. The sablefish catch rates were similar for all gaps except the widest, which was slightly less, implying that the probability that a sablefish locates a bait does not change until few baits are available. More detailed results will be available in a technical report.

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

Archival Sablefish Tags

During the 1998 sablefish longline survey, about 196 sablefish were surgically implanted with an electronic archival tag. Two fish were tagged and released at each station from the eastern Aleutian Islands throughout the Gulf of Alaska to Dixon Entrance. The archival tag contains a computer chip that records depth and temperature for a period up to 10 years. Data from these tags will provide information about sablefish behavior in the sea as well as the marine environmental conditions they experience. To date, one tag has been recovered from a fish at large for two months that was released and recovered in the eastern Aleutian Islands. A $500 reward per tag is being offered in 1999 to fishermen for the recovery of these tags.

For more information, contact Michael Sigler at (907) 789-6037 or Thomas Rutecki at (907) 789-6051.

ABL Sablefish Tag Recovery Program

Processing tag recoveries and administration of the reward program continued during 1998. About 710 tags for 1998 have been received so far, compared to a total of 732 in 1997. As in 1997, about 39% of the fish recovered in 1998 had been at liberty for more than 10 years. The four fish at liberty the longest were all tagged in Chatham Strait, southeastern Alaska, in 1973 and recovered in Chatham Strait in 1998. Tagging continued on the 1998 longline survey, with 3,495 adult sablefish tagged and released (including archival tags).

Otoliths from six known-age sablefish (i.e., fish tagged as juveniles) were recovered during 1998, bringing the total otolith collection of these fish to 87. A manuscript describing the initial findings of this study was accepted for publication by Fishery Bulletin in 1998.

Otoliths from two more oxytetracycline (OTC)-tagged fish were recovered during 1998; in all, otoliths have been collected from 70 of these fish since the tagging was done in 1988. We hope to begin reading these otoliths this year.

Sablefish tags recovered during the 20 years of cooperative and domestic longline surveys are being used to estimate the commercial tag reporting rate. Return rates of research and fishery-caught tags are compared, with the assumption that all research-caught tagged fish are observed (reported). So far it appears that the reporting rate over all areas and years is about 30%.

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

Juvenile Sablefish Studies

Juvenile (age 1+) sablefish studies have been conducted by ABL in Alaska since 1984 and were continued in 1998. Approximately 1,464 juvenile sablefish (age 1+) were tagged and released during a cruise of the NOAA ship *John N. Cobb* at St. John Baptist Bay, Sitka Harbor area, and Silver Bay, near Sitka, in May 1998. During the summer, juvenile sablefish were found in inside waters of southeastern Alaska near Auke Bay for the second consecutive year. 1997 and 1998 were the first years since 1985 that large numbers of juvenile sablefish were found near Auke Bay. A young-of-the-year (YOY) sablefish study, which started in 1995, was conducted again in 1998 using the survey vessel *Alaskan Leader* opportunistically during the sablefish longline survey. A small-mesh surface gillnet was fished at night at offshore locations in the Gulf of Alaska to capture YOY sablefish. Mean lengths of YOY sablefish caught in the gillnets during these surveys have ranged from 10 to 19 cm. A summary report on the 1995-97 YOY surveys was recently published. Both the juvenile tagging and YOY sablefish studies are planned to be continued in 1999.

The NOAA ship *John N. Cobb* was used for 6 days in August 1998 offshore southeastern Alaska to compare the surface gillnets with an alternative sampling gear for YOY sablefish, a surface rope trawl. The rope trawl has been used for several years by scientists in ABL's salmon program to successfully sample juvenile salmon, and catches of YOY sablefish have been taken. The 1998 *Cobb* experiment showed that species composition and numbers of fish differed between the gillnet and rope trawl catches. Overall, rope trawl catches were larger and more diverse than gillnet catches. The results indicated that for a survey dedicated to sampling juvenile sablefish, the rope trawl would probably be the preferred net to use. Fishing a rope trawl, however, is not possible during the sablefish longline survey, so we expect to continue sampling juvenile sablefish with gillnets as an ancillary project in future longline surveys.

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

Sablefish Stock Assessment

Bering Sea, Aleutian Islands, and Gulf of Alaska

Determination of sablefish abundance in Alaska is largely based on results of the annual sablefish longline survey. The population is decreasing from a peak in the mid-1980s. The peak is attributed to strong recruitment in the late 1970s; recruitment has decreased in recent years. If recent recruitment levels continue, the population is projected to continue to decrease until 2000, stabilizing near the historic low. 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 not decreased as much.

Until 1997, yield estimates were 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. For ABCs for 1993 through 1996, 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) was adjusted in proportion to the ratio of current biomass to a target biomass level that is 35% of the unfished level ($B_{35\%}$). For the 1997 and 1998 ABC, new overfishing guidelines adopted by the NPFMC indicated that an adjusted $F_{40\%}$ strategy be considered for sablefish.

In 1997 and 1998, estimates of exploitable biomass and recruitment were determined from an age-structured model, which utilizes longline survey CPUE, survey age and length frequencies, and reported commercial catch in weight. Projected exploitable biomass for 1998 was 208,000 t. This estimate tried to account for possible under-reporting of commercial catches during 1986-90. Yield was 19,000 t using the adjusted $F_{40\%}$ fishing rate. If recent low levels of recruitment continue, these scenarios project that the population will decrease and the adjusted $F_{40\%}$ strategy will result in yields less than 16,000 t in the near future.

The 1998 assessment projected an ABC of about 16,000 t during the next three years, whereas the 1999 assessment projected that ABC will fall to 12,000 t by about 2002. The different projections are not based on real change in population size, but instead some retrospective bias is causing the abundance estimates, and consequently the ABC projections, to change between assessments.

The approach used to recommend the 1997 and 1998 ABC was a linear reduction one third of the way from the current ABC to the respective short-term equilibrium yield. For example, the 1997 combined ABC was 17,200 t, and the short-term equilibrium yield projected in the 1998 assessment was 16,000 t, so the 1998 ABC recommendation was 16,800 t for the combined stock. The rationale for this approach to ABC recommendation was as follows: The yield from an adjusted $F_{40\%}$ strategy in the 1997 and 1998 assessments represented an increase over recent ABCs. Increasing ABC was inconsistent with a declining stock trend and a spawning biomass that was projected to fall near the observed low within a few years. Rather than increasing ABC and then reducing it thereafter toward the predicted short-term equilibrium yield, the 1997 and 1998 assessments recommended an incremental adjustment of ABC toward the short-term equilibrium yield. Furthermore, biomass estimates have changed between assessments and may not result in a rational series of ABCs when an $F_{40\%}$ strategy is applied. Catch and abundance trends are considered to be more reliable measures than biomass estimates, and, in the opinion of the sablefish stock assessment authors, prior ABCs and the abundance trends should be considered when recommending ABC.

The same rationale was used for the 1999 ABC, i.e., an ABC adjustment consistent with the sablefish abundance trend. Survey abundance decreased 5.7% in number and 5.8% in weight from 1997 to 1998, similar to projected decreases for spawning and exploitable biomass of 6.0% and 5.9% from 1998 to 1999. The 1998 combined ABC was 16,800 t. Based on the decreasing abundance trend, a downward adjustment of ABC of 5- 6% to approximately 15,800 - 15,900 t is appropriate. Unlike the last two assessments, the 1999 yield of 15,900 t from an adjusted $F_{40\%}$ strategy is consistent with this rationale. A 1999 ABC of 15,900 t was recommended for the combined stock.

A 5-year exponential weighting of regional relative population weights for sablefish from the longline survey is used to apportion the combined ABC to regions, resulting in the following apportionments: Bering Sea 1,340 t, Aleutian Islands 1,860 t, and Gulf of Alaska 12,700 t, which is further apportioned Western 1,820 t, Central 5,590 t, West Yakutat 1,920 t, and East Yakutat/Southeast 3,370 t.

The high ABCs in the mid- to late 1980s 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 1981, and at present, there is no indication of a comparable strong year class for at least another four years, at 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.

For more information, contact Dr. Michael Sigler (907)789-6037 or Sandra Lowe (206)526-4230.

Flatfish Stock Assessment

Bering Sea

Yellowfin sole

Two abundance estimators (trawl survey 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.

For the most part, the present assessment is a straightforward update of last year's assessment, incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in a biomass estimate of 2,330,000 t, an 8% increase relative to last year's estimate. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock and that yellowfin sole therefore qualified for management under tier 3 of Amendment 44. The estimates of these quantities in the present assessment are 589,000 t, 0.11, and 0.16, respectively. Given that the projected 1999 spawning biomass of 757,000 t exceeds $B_{40\%}$, the ABC and OFL recommendations for 1999 were calculated under sub-tier "a" of tier 3. F_{ABC} is at the $F_{40\%}$ (=0.11) level which is the maximum permissible level under tier 3a. Projected harvesting at the $F_{40\%}$ level gives a 1999 ABC of 212,000 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value of 0.16 gives a 1999 OFL of 308,000 t.

Rock sole

An age-based Synthesis model was used to assess the rock sole stock. The time series of abundances estimated by the model generally parallels that from the trawl survey quite closely apart from the 1994 survey value and the 1997 estimate, which appears to be overestimates. Both the model and the survey indicate a dramatic increase in rock sole abundance throughout the 1980s and early 1990s.

The present assessment is a straightforward update of last year's assessment, incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in a biomass estimate of 2,170,000 t, a 20% decrease relative to last year's estimate. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock and that rock sole therefore qualified for management under tier 3 of Amendment 44. The estimates of these quantities in the present assessment are 275,000 t, 0.16, and 0.23, respectively. Given that the projected 1999 spawning biomass of 663,000 t exceeds $B_{40\%}$, the ABC and OFL recommendations for 1999 were calculated under sub-tier "a" of tier 3. The recommended F_{ABC} is at the $F_{40\%}$ (=0.16) level, which is the maximum permissible level under tier 3a. Projected harvesting at the $F_{40\%}$ level gives a 1999 ABC of 309,000 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value of 0.23 gives a 1999 OFL of 309,000 t.

The model indicates that biomass has remained high and stable during the mid-1990s, with a slight decline for 1999. The 1987 year class was exceptionally strong, and the 1990 year class appears to be above average as well.

Flathead sole

The present assessment includes significant changes from last year's assessment, using a length-structured model as the primary assessment tool for the first time and incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in a biomass estimate of 616,000 t, a 14% decrease relative to last year's estimate (although it should be noted that last year's estimate represented a 31% increase relative to the 1996 estimate). Last year, the SSC determined that reliable estimates of $F_{40\%}$ and $F_{30\%}$ existed for this stock but that a reliable estimate of $B_{40\%}$ did not, and that flathead sole therefore qualified for management under tier 4 of

Amendment 44. The present assessment estimates $B_{40\%}$ at a value of 128,000 t. Anticipating that the SSC will concur, the Plan Team's ABC and OFL recommendations for 1999 were calculated under tier 3. Given that the projected 1999 spawning biomass of 290,000 t exceeds $B_{40\%}$, the ABC and OFL recommendations for 1999 were calculated under sub-tier "a" of tier 3. The recommended harvest level was determined by setting F_{ABC} at the $F_{40\%}$ (=0.25) level, which is the maximum permissible level under tier 3a. Projected harvesting at the $F_{40\%}$ level gives a 1999 ABC of 77,300 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value of 0.39 gives a 1999 OFL of 118,000 t.

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). The present assessment is a straightforward update of last year's assessment, incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in biomass estimates of 453,000 t for Alaska plaice and 73,900 t for the remaining species in the "other flatfish" complex, representing a decrease of 30% and an increase of 5% relative to last year's estimates, respectively. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock complex and that "other flatfish" therefore qualified for management under tier 3 of Amendment 44. The estimate of $B_{40\%}$ (Alaska plaice only) in the present assessment is 109,000 t. Given that the projected 1999 spawning biomass (Alaska plaice only) of 214,000 t exceeds $B_{40\%}$, the ABC and OFL recommendations for 1999 were calculated under sub-tier "a" of tier 3. The recommended harvest level was set F_{ABC} at the $F_{40\%}$ level (=0.29 for Alaska plaice, 0.16 for the remaining members of the complex), which is the maximum allowable under tier 3a. Projected harvesting at the $F_{40\%}$ level gives a 1999 ABC of 154,000 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value (=0.47 for Alaska plaice, 0.23 for the remaining members of the complex) gives a 1999 OFL of 248,000 t.

Greenland turbot

The present assessment is a straightforward update of last year's assessment, incorporating new catch and survey information. This year's EBS bottom trawl survey resulted in a biomass estimate of 28,100 t, a 4% decrease relative to last year's estimate. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock, and that Greenland turbot therefore qualified for management under tier 3 of Amendment 44. The updated estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ from the present assessment are 139,000 t, 0.26, and 0.41, respectively. Projected spawning biomass for 1999 is 110,000 t, placing Greenland turbot in sub-tier "b" of tier 3. The maximum permissible value of F_{ABC} under tier 3b is computed as follows:

$$F_{ABC} \leq F_{40\%} \times (B_{99}/B_{40\%} - 0.05)/(1-0.05) = 0.26 \times (110{,}000/139{,}000 - 0.05)/0.95 = 0.21$$

A fishing mortality rate of 0.21 translates into a 1999 catch of 20,000 t, which would be the maximum permissible ABC under Amendment 44. However, the Plan Team recommended setting 1999 ABC by multiplying the age 1+ biomass projected for 1999 (177,000 t) by the ratio of 1998 ABC (15,000 t) to the current estimate of 1998 age 1+ biomass (188,000 t), giving a value of 14,200 t. A 1999 ABC of 14,200 t would be 29% below the maximum permissible value, a reduction which may be warranted based on the facts that estimated age 1+ biomass has trended downward continually since 1972 and that the three most recent recruitment estimates constitute the three lowest values in the time series. The fishing mortality rate corresponding to a 1999 catch of 14,200 t may be approximated as shown below (where $C_{40\%}$ represents the 1999 catch taken under a fishing mortality rate equal to $F_{40\%}$):

$$F_{ABC} = F_{40\%} \times \text{ABC} / C_{40\%} = 0.26 \times (14{,}200/25{,}300) = 0.15$$

The OFL fishing mortality rate is computed under tier 3b as follows:

$$F_{OFL} = F_{30\%} \times (B_{99}/B_{40\%} - 0.05)/(1-0.05) = 0.41 \times (110{,}000/139{,}000 - 0.05)/0.95 = 0.32$$

A fishing mortality rate of 0.32 translates into a 1999 OFL of 29,700 t.

In addition to the above ABC and OFL recommendations, the Plan Team suggests that it would be prudent to set TAC at a level that would preclude a significant increase in catch (projected to total about 9,000 t for 1998). The rationale is as follows: 1) the ratio of catch to biomass has been well below the ratio of ABC to biomass in recent years, and there does not appear to be a compelling reason to narrow the gap at the present time; 2) if the recommended ABC of 14,200 t was actually caught, this would constitute the highest catch since 1985, even though age 1+ biomass in 1999 is projected to be only half of what it was in 1985; and 3) it is difficult to justify a significant increase in catch from a stock that has declined so consistently for so long.

Arrowtooth flounder

The present assessment includes significant changes from last year's assessment, incorporating new catch and survey information as well as a change in the way sex ratios are reflected in the input data. This year's EBS bottom trawl survey resulted in a biomass estimate of 345,000 t, a 28% decrease relative to last year's estimate. Survey data indicate that more than half of each year's sample consists of females (yearly estimates range between 55% and 75%), which is consistent with findings for this species in the Gulf of Alaska. In previous assessments, the sex-specific size composition data from the surveys were weighted so as to imply a 50:50 sex ratio in all years ("balanced" sex ratios). For the present assessment, however, the sex-specific size composition data from each year's survey were weighted to reflect the sex ratio observed in that survey ("observed" sex ratios). Results obtained using the observed sex ratios indicate that males are no more than 40% selected by the survey, even at the length of peak selection. This causes the model's biomass estimates to increase by about 30% relative to last year. Because the effects of using the observed sex ratios are so significant and because the Plan Team did not have the opportunity to review them at its September meeting, the Team was reluctant to go forward with the ABC and OFL values that emerge from using the observed sex ratios. The chapter authors therefore have provided a set of supplemental values and projections (labeled "optional 1998 recommendation" on the first page of the arrowtooth flounder chapter) which result from using balanced sex ratios, as in previous assessments. The Plan Team bases its recommendations for 1999 on these values and projections. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock and that arrowtooth flounder therefore qualified for management under tier 3 of Amendment 44. The estimates of $F_{40\%}$ and $F_{30\%}$ in the present assessment (using balanced sex ratios) are 0.23 and 0.36, respectively. An estimate of $B_{40\%}$ obtained using balanced sex ratios is not given in the chapter, but may be approximated by the product of the $B_{40\%}$ estimate obtained using the observed sex ratios and the ratio of projected 1999 age 1+ biomass obtained using balanced and observed sex ratios, respectively:

$B_{40\%}$ = 228,000 t × 819,000/1,190,000 = 157,000 t.

Likewise, a projected value of spawning biomass for 1999 using balanced sex ratios is not given in the chapter, but may be approximated by the product of the $B_{40\%}$ estimate obtained using the observed sex ratios and the ratio of projected 1999 age 1+ biomasses obtained using balanced and observed sex ratios, respectively:

B_{99} = 743,000 t × 819,000/1,190,000 = 511,000 t.

Even if the above approximations are off by 50% in opposite directions, the projected 1999 spawning biomass would still exceed $B_{40\%}$, meaning that arrowtooth flounder qualify for management under sub-tier "a" of tier 3. The recommended harvest level was determined by setting F_{ABC} at the $F_{40\%}$ (=0.23) level, which is the maximum permissible level under tier 3a. Projected harvesting at the $F_{40\%}$ level gives a 1999 ABC of 140,000 t. The OFL was determined from the tier 3a formula, where an $F_{30\%}$ value of 0.36 gives a 1999 OFL of 219,000 t.

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

Gulf of Alaska

Management of the Gulf of Alaska flatfish resource has been divided into five categories by the North Pacific Fishery Management Council. 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 Pacific ocean perch bycatch in the directed rex sole fishery in 1993. Arrowtooth flounder are now assessed separately.

The 1999 exploitable biomass for each category is based on abundance estimated from the 1996 triennial trawl survey with the exception of Dover sole in the deep water complex. The Dover sole apportionment was based on survey biomass estimates of Dover sole in the 1-500 m depth range due to insufficient information from deep water areas, which were last sampled in 1987. The recommended ABC for each group was apportioned among the regulatory areas in proportion to biomass distributions in the 1996 trawl survey. The harvest was further split among the GOA regulatory subareas. The resulting 1999 ABCs (in metric tons) are:

	WESTERN	CENTRAL	WYAK	EYAK/SEO	TOTAL
Deep water	240	2,740	1,720	1,350	6,050
Rex sole	1,190	5,490	850	1,620	9,150
Shallow water	22,570	19,260	250	1,070	43,150
Flathead sole	8,440	15,630	1,270	770	26,110
TOTAL	32,440	43,120	4,090	4,810	84,460

The overfishing levels for the flatfish groups are determined by the fishing mortality rates determined from the tier structure to the exploitable biomass estimates. Those fishing mortality rates and associated catch levels are:

	F_{ABC}	F_{OFL}	OVERFISHING LEVEL	TIER
Deep water	0.075	0.10	8,070	5,6
Rex sole	0.15	0.20	11,920	5
Shallow water	0.15-0.17	0.2-0.25	59,540	4,5
Flathead sole	0.15	0.20	34,010	5

Arrowtooth flounder

YEAR	ABC	EXPLOITABLE BIOMASS	CATCH
1997	197,840	1,971,170	16,319
1998	208,340	2,062,740	13,063
1999	217,110	2,126,714	

1/ Catch through November 7, 1998.

The 1999 exploitable biomass is based on abundance estimates derived from a length based stock synthesis model. Biomass estimates are estimated to be greater than $B_{40\%}$ and ABC was determined to be 217,110 t based on Tier 3a calculations ($F_{40\%}$ = 0.189). The Team recommended that ABC be apportioned among regulatory areas in proportion to biomass distributions in the 1996 trawl survey. The resulting ABCs are:

	WESTERN	CENTRAL	WYAK	EYAK/SEO	TOTAL
Arrowtooth	34,400	155,930	13,260	13,520	217,110

Using Tier 3a criteria, the overfishing level based on $F_{30\%} = 0.278$ is estimated at 308,875 t.

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

Pacific Whiting Research

Acoustic/Trawl Surveys of US/Canada West Coast Pacific Whiting

Scientists from the MACE program conducted the eighth triennial EIT survey of Pacific whiting off the west coast from Monterey, California, (lat. 36°N) to the Queen Charlotte Islands, Canada, during July 6 to August 27, 1998. The survey was conducted using the NOAA ship *Miller Freeman*. About 3,600 nautical miles of acoustic trackline were covered; transects were spaced 18.5 km apart except in near-shore waters near the U.S./Canada border, where spacing was reduced to 9.3 km to more closely correspond to the survey pattern historically used by Canadian scientists. A total of 108 midwater and bottom trawls were conducted to sample echosign and provide biological data on Pacific whiting. Heaviest Pacific whiting echosign was observed off California near 42°N, off central Oregon from 43 to 44°N, over Juan de Fuca Canyon near Cape Flattery, and off northern Vancouver Island from 50°30'N to the northern boundary of the survey area at 51°28'N. Coastwide estimates of Pacific whiting abundance in the survey area were 2.2 billion fish weighing 905,000 tons. Smaller fish (≤ 40 cm) dominated the population in the Monterey and Eureka INPFC areas. The ratio of smaller to larger fish was nearly equal in the Columbia INPFC area. Adult fish (> 40 cm) were generally more abundant in the northern areas. The size of adult fish tended to increase with latitude. For example, the modal length for adult fish was 41 cm in the Monterey INPFC area, 43 cm in the Eureka and southern Columbia INPFC areas, 44 cm in the northern Columbia and U.S.-Vancouver INPFC areas, and 45 cm in the Canadian Vancouver and Charlotte INPFC areas. A similar latitudinal trend in length was observed for 2-year-old fish. Modal lengths were 29 cm in the Monterey INPFC area, 32 cm in the Eureka INPFC area, and 34 cm in the southern Columbia INPFC area. Two-year-old fish were the dominant age group in the Monterey and Eureka INPFC areas, whereas 3-year-old fish (1995 year class) were dominant in the Columbia INPFC area and 5-year-olds (1993 year class) were dominant in the Vancouver and Charlotte INPFC areas. Overall, 74% of the population was composed of the 1993-96 year classes.

For more information contact Dr. Chris Wilson at (206) 526-6435.

Pacific Whiting Results from West Coast Triennial Bottom Trawl Survey

Results of the 1998 West Coast triennial bottom trawl survey indicated that the abundance of the component of the Pacific whiting stock vulnerable to the trawl survey declined slightly (15% over the entire survey area) since the 1995 survey. The survey estimated 497,000 t of whiting between Point Conception, California, and Nootka Sound, British Columbia. One-year-old whiting were present in the 55-183 m depth stratum throughout the survey area, notably in the Vancouver and Columbia INPFC areas. Age-2 whiting were particularly abundant off northern California and Oregon. These young fish were smaller than in 1995; age-1 fish were approximately 6 cm shorter and age-2 fish approximately 5 cm shorter. This is presumably an effect of the 1997-98 El Niño. Another effect of this event was observed in the weight-length relationship, which decreased from that observed in earlier years.

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

Pacific Whiting Stock Assessment

An assessment of Pacific whiting was carried out by U.S. and Canadian scientists in the winter of 1998-99 through the Pacific hake working group of TSC. In the summer of 1998, a cooperative U.S.-Canada acoustic survey of whiting was conducted by scientists from NMFS and DFO. Because information from this survey was considered essential for evaluating current stock status, the whiting assessment was delayed from the usual assessment cycle so that survey results could be used. To coordinate scientific advice, the 1998-99 assessment was submitted to a joint Canada/U.S. technical review that satisfied the requirements of both the U.S. Pacific Fisheries Management Council (PFMC) and the Canadian Pacific Stock Assessment Review Committee (PSARC). The Review Group meeting was held in White Rock, BC, during 17-18 February 1999.

The assessment indicated that the whiting stock is at moderate abundance. Stock biomass increased to a historical high of 5.7 million t in 1987 due to exceptionally large 1980 and 1984 year classes, then declined as these year classes passed through the population and were replaced by more moderate year classes. Stock size has been stable over the past four years at 1.7-1.8 million t. The mature female biomass in 1998 is estimated to be 37% of an unfished stock. Although 1998 stock size is near a historical low, it is close to average stock size under current harvest policies. The exploitation rate was below 10% prior to 1993, then increased to 17% during 1994-98. Total U.S. and Canadian catches have exceeded the ABC by an average of 12% since 1993 due to disagreement on the allocation between U.S. and Canadian fisheries.

An evaluation of whiting harvest policy led to the recommendation that the 40-10 option, the default harvest policy of the PFMC, be considered for whiting. The 40-10 option results in similar harvest rates as the hybrid F policy used previously for whiting, and may improve economic performance of the fishery by dampening variability in harvests. An appendix to the assessment described a meta-analysis of hake stock-recruit relationships. Results indicated that the genus *Merluccius* may be less resilient to fishing than other gadoids. A Bayesian decision analysis produced estimates of F_{MSY} in the $F_{40\%}$ to $F_{45\%}$ range depending on the degree of risk-aversion.

The 1999-2000 Pacific whiting OY of 290,000 t coastwide (232,000 t for the United States) was adopted by the Pacific Council in March 1999 . The OY was based on 1) an $F_{40\%}$ SPR proxy for FMSY, 2) a 40-10 adjustment because mature female biomass is slightly below 40 percent its unfished level, 3) the average of the OYs for 1999 and 2000, 4) and an 80% U.S. share of the total catch.

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

Walleye Pollock Research

Acoustic/Trawl Surveys of Pollock

Bering Sea

Bottom trawl and echo integration-trawl surveys together provide biomass estimates of demersal and pelagic pollock on the eastern Bering Sea shelf. Bottom trawl surveys are conducted annually and assess pollock from the bottom to 3 m off bottom. Echo integration-trawl surveys have been conducted triennially since 1979 to estimate pollock in midwater. A survey was also conducted in 1996 (outside the triennial series) to address concerns about recruitment.

MACE Program scientists conducted an echo integration-trawl survey of the southeastern Aleutian Basin near Bogoslof Island on 1-10 March 1998. Scientists from Korea and Japan also participated in the survey. The work was conducted aboard the NOAA ship *Miller Freeman.* The target species was walleye pollock. This was the tenth annual survey (no survey in 1990) in a series that began in 1988 with the objective of assessing the population distribution and abundance of spawning pollock in this region. The survey area encompassed a region extending from approximately 166° 00'W long. to 170° 20'W long. and 20-80 nmi offshore. Acoustic data were collected along a trackline consisting of 27 transects spaced at 10 nmi in the region east of 167° 10'W long. and 5 nmi west of that point. Fourteen midwater trawl hauls were made to sample echosign and provide biological data on the spawning pollock. The geographic distribution of pollock was similar to that observed in 1996 and 1997. Approximately 70% of the biomass was located in the off-shelf waters between the Islands of Four Mountains and the west end of Umnak Island. The majority of the fish encountered were in pre-spawning condition. Lengths ranged from 34 to 66 cm with a major mode at 54 cm, and fish less than 48 cm comprised 17% of the population. Preliminary analyses resulted in a biomass estimate of 0.5 million tons.

Gulf of Alaska

An EIT survey to assess the distribution and abundance of spawning walleye pollock within the Shelikof Strait area was conducted between Chirikof Island and Cape Chiniak during 11-25 March 1998. This is the seventeenth annual spawning stock survey of walleye pollock in the Shelikof Strait area since 1980 (no survey in 1982). A total of 1,800 nmi of transect trackline and 31 hauls were completed during the survey. 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 size distributions of pollock from hauls within the strait generally exhibited dominant modes around either 30-39 cm or 50-60 cm fork length (FL). Sixty percent of the females greater than 34 cm FL were either pre-spawning or spawning and only 9% were spent. Pollock from the 1994 year class (ca. 30-39 cm FL mode) formed a strong, well-defined midwater layer (150-200 m depth) which was broadly distributed from about Uyak Bay south to Sitkinak Strait. The areal extent and strength of this layer of 4-year old fish supports earlier EIT survey observations that the 1994 year class is relatively strong.

For more information, contact Neal Williamson (206)526-6417.

Recruitment Processes (FOCI)

Fisheries-Oceanography Coordinated Investigations (FOCI) is a cooperative research program with the Pacific Marine Environmental Laboratory (PMEL), Oceanic and Atmospheric Research (OAR), designed to investigate causes of annual recruitment variations in fish stocks of economic importance in the Gulf of Alaska and Bering Sea ecosystems. The research is directed at understanding the causes of large natural fluctuations of walleye pollock stocks that spawn in Shelikof Strait, Gulf of Alaska, and in the eastern Bering Sea (with support from NOAA's Coastal Ocean Program). This research is based on the paradigm that recruitment of pollock to the mature population is largely set during the egg and larval stages as the result of a host of physical and biological processes determining their survival to the juvenile stage. The objective of this research is to improve the accuracy and extend the time horizon of estimates of recruitment for forecasting future population trends on which to base management decisions on optimal harvest levels.

In 1998 FOCI conducted 5 cruises in mid- and late spring aboard the NOAA ship *Miller Freeman* and 2 aboard the Oregon State University ship *Wecoma*. A cruise aboard the Hokkaido University research vessel *Oshoro-maru* surveyed the distribution of age-0 walleye pollock in summer in the southeastern Bering Sea. In September FOCI scientists continued process studies initiated in 1994 to study the habitat characteristics of juvenile walleye pollock around the Pribilof Islands during a two-week cruise aboard the *Miller Freeman*. In summer 1998, as in 1997, we observed anomalous atmospheric and oceanographic features over the Bering Sea shelf. The most visible of which was sustained discoloration of shelf waters by a bloom of coccolithophorids (small phytoplankton covered with calcium carbonate plates). The aquamarine colored waters were first noticed at sea in July and persisted through September when they were photographed by NASA's new ocean color satellite (SeaWIFS). The bloom occurred concurrently with massive die-offs of marine birds (short-tailed shearwaters) and an anomalously low return of salmon to Bristol Bay. This prompted FOCI to sponsor a workshop in changing conditions in the Bering Sea (see: Report on the FOCI International Workshop on Recent Conditions in the Bering Sea, S.A. Macklin ed. NOAA ERL Spec. Rep. Jan. 1999).

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

Walleye Pollock Stock Assessment

Bering Sea and Aleutian Islands

This year's pollock assessment features new data from the 1998 fishery and bottom trawl survey. The 1998 bottom trawl survey estimated a biomass of 2,210,000 t, a decrease of 27% relative to the 1997 estimate. Nine alternative models are presented in the chapter, all of which follow the statistical age-structured approach that was used last year to set ABC for 1998. All but three of these nine models estimate 1998 age 3+ biomass to fall between 5,100,000 t and 5,130,000 t (the other three models give values ranging from 4,160,000 t to 4,980,000 t). Of the nine models considered, harvest recommendations for 1999 were based on Model 2, which assumes a Ricker stock-recruitment relationship and uses the average commercial fishery selectivity pattern from the most recent three years to make projections of future catch and stock size. Model 2 estimates a decrease of 3% in age 3+ biomass between 1997 and 1998, followed by a projected increase of 37% between 1998 and 1999. The large projected increase between 1998 and 1999 is fueled by the entry of the 1996 year class into the age 3+ stock, a year class which is currently estimated to be well above average in strength.

Last year, the SSC determined that reliable estimates of B_{MSY} and F_{MSY} exist for this stock, with values of 6,000,000 t and 0.38 respectively, and that EBS pollock therefore qualified for management under tier 2 of Amendment 44. However, the present assessment has made considerable improvement in the estimation of B_{MSY} and F_{MSY}, and it now appears that last year's estimates are no longer the best available. Moreover, the modeling approach described in the present assessment now enables estimation of a full probability density function (pdf) for F_{MSY}. The assessment's senior author believes this pdf to be reliably estimated allowing EBS pollock to qualify for management under tier 1 of Amendment 44. Under Model 2, the projected level of spawning biomass in 1999 (1,630,000 t) is less than the new point estimate of B_{MSY} (1,740,000 t), thereby placing EBS pollock in sub-tier "b" of tier 1. Fishing at a rate of 0.58 is projected to result in a 1999 spawning biomass of 1,630,000 t, which solves the equation for the maximum permissible value of F_{ABC} shown below (μ_H represents the harmonic mean of the pdf for F_{MSY}):

$$F_{ABC} \le \mu_H \times (B_{99}/B_{MSY} - 0.05)/(1-0.05) = 0.62\times(1{,}630{,}000/1{,}740{,}000-0.05)/0.95 = 0.58$$

The 1999 catch corresponding to the above fishing mortality rate is 1,370,000 t. The Plan Team believed that a 1999 ABC of 1,370,000 t was too high, and instead recommended a value of 992,000 t, which would be the maximum permissible value if the stock were managed under tier 3b (i.e., it corresponds to an $F_{40\%}$ harvest strategy adjusted by the ratio of projected spawning biomass to $B_{40\%}$, giving a fishing mortality rate of 0.29). Setting 1999 ABC in this manner would be approximately consistent with the method used to set ABC last year. A 1999 ABC of 992,000 t constitutes a reduction of nearly 27% from the maximum value permissible under Amendment 44, but such a reduction is warranted for the following reasons: 1) the 1998 trawl survey biomass estimate is the lowest since 1980 and the second lowest in the entire time series; 2) future catches and biomass levels will be heavily dependent on the strengths of the 1996 and 1997 year classes, the estimates of which are currently accompanied by high levels of uncertainty; 3) the projected 1999 spawning biomass is only 31% of the estimated pristine level (if no stock-recruitment relationship is assumed); 4) pollock has been the most common item in the diet of Steller sea lions, which are listed as an endangered species; 5) the impacts of Russian harvests of pollock in the western Bering Sea on future recruitment to the eastern Bering Sea stock are currently unknown but potentially significant; 6) the age distribution of the stock is narrower than was the case during the late 1980s and early 1990s, raising possible concern about the short-term spawning capacity of the stock; and 7) the harmonic mean of the pdf for F_{MSY} is much higher than expected, raising possible concern about its use as a target harvest rate.

Fishing at a rate of 0.80 is projected to result in a 1999 spawning biomass of 1,550,000 t, which solves the equation for F_{OFL} shown below (μ_A represents the arithmetic mean of the pdf for F_{MSY}):

$$F_{OFL} = \mu_A \times (B_{99}/B_{MSY} - 0.05)/(1-0.05) = 0.90 \times (1{,}550{,}000/1{,}740{,}000 - 0.05)/0.95 = 0.80$$

Under Model 2, the 1999 catch corresponding to a fishing mortality rate of 0.80 is 1,720,000 t, which is the recommended OFL.

Aleutian Islands:

Last year's bottom trawl survey of the Aleutian Islands region resulted in a biomass estimate of 106,000 t, an increase of 23% relative to the 1994 estimate. Last year's stock assessment concluded that the model which had been used to recommend ABC for 1997 was no longer reliable due to the confounding effect of immigration from other areas, and the SSC determined that Aleutian pollock qualified for management under tier 5. The recommended 1998 ABC was 23,800 t, computed as the product of the 1997 survey biomass estimate and 75% of the natural mortality rate (0.3). The recommended 1998 OFL was 31,700 t, computed as the product of the 1997 survey biomass estimate and the natural mortality rate. Anticipating that the SSC will continue to find that Aleutian pollock qualify for management under tier 5, the Plan Team recommends retaining the 1997 survey biomass estimate as the best available estimate of biomass in 1999 (by assuming that growth and recruitment balance mortality), and keeping 1999 ABC and OFL at their respective 1998 levels.

Bogoslof:

The 1998 hydroacoustic survey of the Bogoslof region resulted in a biomass estimate of 492,000 t for Area 518. Last year, the SSC determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ existed for this stock, with values of 2,000,000 t, 0.27, and 0.37 respectively, and that

Bogoslof pollock therefore qualified for management under tier 3 of Amendment 44. In the present assessment, the chapter authors support continued use of an $F_{40\%}$ value of 0.27. As in previous assessments, the recommended estimate of next year's Bogoslof biomass was calculated by using a natural mortality rate of 0.2 to decay the present year's survey biomass estimate. This procedure produces a projected 1999 biomass of 403,000 t. Given this estimate, the recommended harvest rate is a F_{ABC} value at the maximum level allowed under tier 3b, which is computed as follows:

$$F_{ABC} \leq F_{40\%}\times(B_{99}/B_{40\%}\text{-}0.05)/(1\text{-}0.05) = 0.27\times(403{,}000/2{,}000{,}000\text{-}0.05)/0.95 = 0.043$$

A fishing mortality rate of 0.043 translates into an exploitation rate of 0.038 which, when multiplied by a projected biomass of 403,000 t, gives a 1999 ABC of 15,300 t. This ABC value notwithstanding, the Plan Team recommended that the existing prohibition against directed fishing on this stock be continued for the 1999 season.

The OFL fishing mortality rate is computed under tier 3b as follows:

$$F_{OFL} = F_{30\%}\times(B_{99}/B_{40\%}\text{-}0.05)/(1\text{-}0.05) = 0.37\times(403{,}000/2{,}000{,}000\text{-}0.05)/0.95 = 0.059$$

A fishing mortality rate of 0.059 translates into an exploitation rate of 0.052 which, when multiplied by a projected biomass of 403,000 t, gives a 1999 OFL of 21,000 t.

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

Gulf of Alaska

The projected 1999 exploitable biomass for pollock is 737,670 t which represents age 3+ biomass as estimated from the current stock assessment model. Exploitable biomass for the Eastern area was derived from the relative pollock distribution observed in the 1996 trawl survey.

Relative to the 1998 SAFE, new sources of information include: a) the 1998 Shelikof Strait hydroacoustic biomass estimate; b) length frequency data from the 1998 hydroacoustic survey; and c) age composition and catch data from the 1997 fisheries;

The 1998 Shelikof Strait biomass estimate was 489,900 t (compared to 570,100 t from the 1997 survey). These values were adjusted in the stock assessment to be comparable to estimates from the old hydroacoustic system in order to provide a single time series of a relative abundance index. The model was run using the adjusted values, as well as partitioning the hydroacoustic time series into two unadjusted periods 1981-1991, and 1992-1998. Recent surveys show evidence of a strong 1994 year class. The surveys also show evidence of weak 1995 and 1996 year classes and a moderate 1997 year class.

Port sample length frequency information from the first trimester of the 1998 fisheries showed little evidence of the 1994 year class outside of Shelikof Strait. Some evidence of the 1994 year class was noted in the June port sample length frequency data in Chirikof and Shumagin. Little evidence of the 1994 year class was observed in Kodiak. The 1997 fishery catch-at-age data show the strong 1988 and 1989 year classes. Little evidence of the incoming 1994 year class (age 3) was apparent in the 1997 data.

In addition to a baseline model (A) configured as in the 1997 assessment, the current assessment evaluated four alternative models which explored: B) the influence of partitioning the hydroacoustic survey into two unadjusted time series; C) the impact of increasing the age 2 natural mortality rate to 0.60; D) the impact of different groupings of years for selectivity estimation; and E) an AD Model Builder application. Model (A) was chosen as the analysis to base the 1999 harvest recommendation on. Estimates of various fishing mortality rates based on biological reference points were determined from the stock synthesis model. The estimated $F_{30\%}$, and $F_{40\%}$ full-selection fishing mortality rates were 0.541, and 0.367, respectively. The projected 1999 female spawner biomass of 222,860 t is below the $B_{40\%}$ female spawner biomass estimate of 240,000 t. Average historical recruitment from the 1964-1997 year classes was used to calculate $B_{40\%}$.

Pollock fall under Tier 3b of the ABC/OFL guidelines, thus F_{ABC} cannot exceed the $F_{40\%}$ fishing mortality rate adjusted by the ratio of current spawner biomass to $B_{40\%}$ (0.93). The F_{ABC} ($F_{40\% adjusted}$) fishing mortality rate is 0.34, results in a yield of 94,400 t for the Western/Central Gulf, and is the recommended 1999 Western/Central ABC.

The recommended ABC was apportioned according to the biomass distribution of the exploitable population (>20 cm) in the 1996 bottom trawl survey: 25% in the Shumagin area (23,600 t), 42% in the Chirikof area (39,650 t), and 33% in the Kodiak area (31,150 t).

The overfishing mortality rate (0.502) is $F_{30\%}$ adjusted by the ratio of current spawner biomass to $B_{40\%}$, and corresponds to a harvest of 134,100 t for the Western and Central Gulf of Alaska (W/C). Therefore, pollock are not considered overfished at the ABC level.

No new information was available to set an ABC for the Eastern Gulf. An application of the ratio of 1999 W/C ABC to 1996 W/C survey exploitable biomass to the Eastern Gulf 1996 survey exploitable biomass was used to estimate ABC for the Eastern Gulf. The recommended Eastern Gulf ABC is 8,620 t. Similarly calculated, the overfishing level for the Eastern Gulf is 12,300 t.

The EGOA ABC was further split between the West Yakutat (WYAK) and East Yakutat/Southeast Outside (EYAK/SEO) areas. The rationale for the split is based on: 1) the pollock fishery is a trawl gear fishery; and 2) the distribution of biomass from the 1996 trawl survey shows that only 14% of EGOA pollock biomass is located in the WYAK area, where the greater portion of pollock harvests have occurred in recent years. The point estimate of 14% for WYAK has a CV of 42%. Because of the uncertainty surrounding the distribution of biomass between the WYAK and EYAK/SEO areas, the Plan Team recommended that the split be within a range from 14% (mean value) in WYAK but not to exceed 25%, which is the upper end of the 95% confidence limit. The sum of the split ABCs should not exceed the total recommended EGOA ABC of 8,620 t. This results in the following splits of the EGOA ABC:

WYAK = 1,210 t EYAK/SEO = 7,410 t, but not to exceed
WYAK = 2,160 t EYAK/SEO = 6,460 t

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

Mackerel and Sardine Research

Range Extension in Alaska for Pacific Sardine

During an August 1998 cruise of the NOAA ship *John N. Cobb*, ABL scientists collected eight Pacific sardines from surface rope trawls and gillnets in the Gulf of Alaska between Sitka and Cross Sound. This is a range extension for this species. The only other time Pacific sardines have been captured in Alaska was in 1931, after the strong 1930-31 El Niño event.

For more information, contact Bruce Wing at (907) 789-6043 or Tom Rutecki at (907) 789-6051.

Other Related Studies

Seafloor Habitat Studies

Retrospective Analysis of Commercial Bottom Trawl Activity

The spatial and temporal patterns of bottom trawl effort in the Gulf of Alaska (GOA) and Aleutian Islands (AI) from 1990-1997 were analyzed. Haul data were obtained from the National Marine Fisheries Service (NMFS) domestic observer database (NORPAC) and included gear type, latitude, longitude, and NMFS regulatory and reporting areas. Trawl locations were plotted by management and habitat areas in a geographical information system (ArcView-GIS). Trawl effort was projected as overall bottom trawl activity by year and categorized by NMFS research strata, International North Pacific Fisheries Commission (INPFC) area, and bathymetric range. The total numbers of observed tows for 1990-1997 were 53,833 in the GOA and 32,643 in the AI. If expanded to include unobserved tows, the totals were estimated to be 100,012 in the GOA and 37,036 in the AI. The areas of the highest estimated number of bottom trawls were on the continental shelf at a depth of 1-100 m in the AI and at a depth of 101-200 m in the GOA. Within the GOA, density of bottom trawls was 0.31/km^2 for the entire time series over all depths with the highest density (0.56/km^2) occurring on the continental slope at a depth of 301-500 m. Areas of high bottom trawl density and low bottom trawl density are currently being compared using data from the NMFS triennial research survey. Species composition data from the research trawls will be used to describe attributes of community structure in areas of heavy and low trawl concentrations from similar depths.

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

A Description of Seafloor Habitat in a Trawled Region and a Protected Region of the Central Gulf of Alaska

A study to describe seafloor habitat in a trawled region and a protected region of the Central Gulf of Alaska was initiated by ABL in 1998. A manned submersible was used to observe the seafloor at two areas near Kodiak Island that had been closed to bottom trawling since 1986. These areas were closed by the North Pacific Fishery Management Council to assist in rebuilding severely depressed crab stocks. A bottom-trawl fishery occurs adjacent to the closed areas for walleye pollock, flathead sole, butter sole, arrowtooth flounder, Pacific cod, and several species of rockfish. The purpose of the study was to assess changes to the seafloor caused by chronic, long-term trawling. Study objectives were to compare areas closed to trawling to areas open to trawling to determine if differences exist for infauna composition, fish and invertebrate populations, and substrate characteristics including grain-size composition, biogenic structures, and total organic carbon content.

The two study sites selected were 160 km distant and extensive bottom trawling had occurred at both sites in the last five years. Twenty four transects were completed, and visual counts and observations were made over 72 km of the seafloor. Each transect was 3,000 m long and bisected the boundary between open and protected areas. Three substrate samples were collected with a Shipek bottom sampler along each transect. The seafloor at both sites was a relatively flat and unstructured bottom comprised of mostly fine sand and silt interrupted only by dense beds of several species of sea whips. Evidence of bottom trawling (e.g., trawl door furrows, broken sea whips) were observed at about one-third of the transects. Fish and invertebrates observed from the submersible included adult and juvenile flatfish, weathervane scallops, juvenile Tanner crabs, hermit crabs, sea anemones, sea stars, and sea whips. Video footage is currently being analyzed for counts of fish and invertebrates in the trawled and non-trawled zones. Infauna composition, sediment grain size, and organic carbon content analyses are near completion. Future studies on the effects of trawling are planned at these sites during 1999.

For more information, contact Robert Stone at (907) 789-6031.

Trawling Impact Studies

AFSC scientists conducted some trawl positioning gear trials in Dabob Bay in Hood Canal during May 18-29. The objective of the study was to evaluate three acoustic systems for highly accurate bottom trawl positioning. A total of 35 test tows were made in the U.S. Navy's underwater tracking range near Pulali Point. Actual on-range fishing operations occurred on May 19-20, 22 and 27-28 with manufacturer's representatives of the systems participating in the trials. Each tow with a NMFS-standardized 83-112 Eastern trawl covered approximately 0.5 nmi. The codend of the net was left untied, catches were not processed, and there were no conflicts with the recreational shrimp fishery.

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

Effects of Trawling on Hard Bottom Habitat in the Aleutian Islands

In late spring of 1998 RACE Division scientists constructed a towed underwater camera apparatus based on a design developed by engineers and scientists at the CSIRO Laboratory in Hobart, Tasmania. It uses underwater lighting and a color video camera to record images of the targeted habitat. In towing attitude, distance above bottom is controlled by counterbalancing flotation with the weight of a drag chain. The electronically controlled hydraulic winch uses electrical towing cable, which transmits power and video signals. Live-feed video enables the operator to view the bottom and to control the altitude of the camera body using the remote winch controls.

Sea trials took place during a 5-day period in early August between Akutan and Umnak Islands in the eastern Aleutian region. Initially, efforts were concentrated on learning the capabilities of the camera/winch combination to function over a wide range of bottom habitats and current conditions. Thirteen tows were completed in a variety of habitat types and current conditions, during which 11 hours of digital video recordings were made. Viewed habitats ranged from relatively flat, muddy bottom to high relief rock piles and pinnacles in both low and high current areas. The quality of the video recordings was generally good, although initially an emphasis was placed on not damaging the apparatus. Therefore parts of earlier tows were sometimes too high above the bottom for good resolution of details. With increasing use, we found the apparatus to be quite robust and very maneuverable in all but the most extreme currents. Thus video images improved as operator experience increased. A composite demonstration video has been assembled.

Due to early equipment failure we were not able to reach Seguam Pass to view the target area, but the experience that was gained towing in various other areas was invaluable to define the capabilities of the apparatus.

For more information, contact Harold Zenger at (206) 526-4158.

Seabed Composition as it Relates to Survey Design

The West Coast Groundfish Team of the RACE Division has been conducting a retrospective analysis of our triennial bottom trawl survey series (1977-1998). The project has many interrelated components with the overall objective of improving our understanding of how our survey samples the groundfish populations.

The first component is identifying areas where we have been unable to trawl successfully. This involves plotting locations where our nets were ripped or hung up on bottom and stations which were skipped because the bottom was judged to be too rough. Preliminary results show clustering of bad tows in some areas. For example, approximately 20% of the 55-183 m depth stratum in the Vancouver INPFC area may be untrawlable using the NMFS survey gear. Methods of surveying fish abundance in identified untrawlable areas will need to be developed to comprehensively assess many of the stocks that prefer such habitat.

Information from this project was used in a separate but related NURP-sponsored project with WDFW scientists to explore whether the abundance of some important commercial groundfish species are different in the untrawlable vs. trawlable areas. The study site off the northwest Washington coast contains approximately equal areas of flat, trawlable ground and rough, rocky ground generally not successfully sampled with the survey trawl. This 3 by 16 nmi area is off Cape Flattery, between Juan de Fuca Canyon and Nitinat Canyon, in waters 100-150 m deep. In late spring of 1998 we made a detailed sidescan sonar mosaic and bathymetric map of the study site. In early July 1998 we used the submersible Delta to run transects over eight randomly selected trawlable sampling units and eight randomly selected untrawlable units. More details of this project are available in the Washington Department of Fish and Wildlife agency report.

Another component of this study entails creating a map of surficial sediments covering our West Coast survey area. This is a cooperative project with the Geological Survey of Canada and the U.S. Geological Survey. We have accumulated about 4,000 data points and are constructing a database capable of using different sediment data types. All data will be imported into a GIS so that we can use spatial statistics to interpolate the data and produce maps which can be easily updated.

We also hope to conduct an assemblage analysis on groundfish species, incorporating information on depth, bottom water temperature, and sediment texture to further define these assemblages. Age and length data from our catches, not normally included in assemblage analysis studies, may help us further refine these assemblages. Once completed, we hope to explore the feasibility of using that information to group stations with similar catch compositions and physical features into strata and compare those with the strata we currently use. By minimizing differences in species composition among strata, more accurate estimates of species abundance with lower variance should be possible.

For more information, contact Mark Zimmermann (206)526-4119.

Trawl Survey Methodology

Survey Trawl Catchability Studies

Analysis of net efficiency data has proceeded for the standard NMFS survey trawl used in the eastern Bering Sea. (In hope of achieving a 100% capture rate this net was designed to tend bottom very closely.) Five out of six species (Pacific cod, walleye pollock, Pacific halibut, rock sole, and flathead sole) had a probability of capture near unity across all sizes. Yellowfin sole exhibited length-dependent capture (higher probability with increasing length) with considerably lower capture probability than other species at the same length. These differences suggest that yellowfin sole behave differently in front of the footrope.

Further experiments were done to assess the effect of artificial light on footrope capture processes. Secondary net methods were used to collect the data. The experiment was conducted on the standard net used in NMFS surveys in waters characterized by rough bottom, a polyethylene, high-rise, four-seam trawl with rubber bobbin roller gear. On each tow, two cameras and two lights were attached to the net. On every other tow the lights were turned on, thus illuminating a large portion of the footrope. Lit and unlit tows were done side by side in deep water off the coast of Washington. Data are being analyzed with log odds ratios methods. Initial analyses indicate that escapement increased substantially for those tows with the lights on. The results of this experiment contradict results of a similar study conducted in 1997 in the Bering Sea, which indicated that lights did not alter rates of fish escapement. Possible explanations of the conflicting results include two light sources (as opposed to one), considerably warmer water temperatures, and observation of affects upon two distinct groups of species.

The effect of footrope performance on the efficiency of the net continues to be a concern and experiments are planned to study footrope performance. The first step is to measure the distance between the bottom and the footrope as a function of speed and direction through the water. An experiment is planned for September or October 1999 to collect such data.

A herding experiment was conducted in May 1998 to estimate the herding component of the catch of the polyethylene Noreastern, the standard survey net for the Gulf of Alaska, Aleutian Islands, and the U.S. West Coast. Preliminary analysis indicates that most flatfish species are herded to some degree by this survey trawl. The two primary roundfish caught in the experiment, Pacific cod and walleye pollock, showed little sign of herding, however high variance in the data might mask any herding effects.

For further information, contact Dr. David Somerton, (206) 526-4116, Peter Munro, 526-4292, or Ken Weinberg, 526-6109.

Fish Behavior in Trawls and Bycatch Reduction

Studies on fish behavior in fishing gear and bycatch reduction at the Alaska Fisheries Science Center in 1998 have included:

1. Flexible grates, constructed of fiberglass rods with neoprene spacers, were tested for effective size selection of pollock against similar sized square and diamond mesh panels. The grate performed similarly to the square mesh panel. The selectivity patterns of all three panels, installed as top panels in a four-seam codend with the side panels tapered, indicated that approximately 60% of the pollock did not encounter the panel in a way that would effectively test their ability to escape.

2. A device to sort large halibut from sole catches was tested under commercial fishery conditions, excluding 94% of the halibut while retaining 50 - 80 % of the target species. The design, selected from proposals by sole trawlers, consisted of a circular, rigid grate (15.25 by 15.25 cm square openings) in the intermediate tilted back 28 degrees from vertical with an escape tunnel at the top. A diverter forced fish to encounter the lower half of the grate first. The study was done in cooperation with the Groundfish Forum, an organization of groundfish trawlers.

For further information, contact Dr. Craig Rose, (206) 526-4128.

Sea Lion and Fisheries Interactions

A pilot study on CPUE variability of Atka mackerel and on tagging parameters for Atka mackerel is planned for August 1999. The purpose of the study is to determine the necessary sample size for CPUE as an index of change in Atka mackerel abundance in trawl closure zones around sea lion rookeries. The experiment will take place in Seguam Pass in and around the trawl closure zone. If CPUE data do not provide an efficient means of estimating an index of change, alternate methods might include tagging. Tagging methods will be refined and assessed during the pilot experiment, as well as tag induced mortality.

For further information, contact Peter Munro, 526-4292.

Systematics Studies

Several projects on the systematics of fishes of the North Pacific have been completed or are underway. A taxonomic revision of the rock soles (genus *Lepidopsetta*) has been submitted by J. W. Orr and A. C. Matarase. The revision includes the recognition of a new species and provides a complete description of the adults and early life history of the three species in the genus. Research is also continuing into the systematics of the dusky rockfish complex under the direction of J. W. Orr and in collaboration with J. Blackburn (Alaska Department of Fish and Game) and J. A. Lopez (University of Washington Marine Molecular Biology Laboratory). Other research on the systematics of rockfishes includes the phylogenetics of world Sebastes species with the development of an informational database, directed by A. W. Kendall Jr. in collaboration with J. W. Orr., with the technical assistance of L. Britt. A guide to northeastern Pacific rockfishes was published by J. W. Orr with coauthors M. A. Brown and D. C. Baker of the REFM Observer Program. Distributional notes on several species are being prepared, including the first record of a pelagic basslet (genus Howella) in Alaska (M. A. Busby with J. W. Orr), first records of sculpins (Cottidae) in the Bering Sea (J. W. Orr with G. R. Hoff), and first and unusual records of snailfishes (Cyclopteridae) from the Aleutian Islands (J. W. Orr and M. A. Busby).

For more information, contact Dr. Jay Orr at (206) 526-6318.

Geographic Information Systems (GIS)

Virtually all studies utilizing GIS capabilities at the AFSC are being accomplished using ArcView. Bathymetric and coastline data sets have been developed from "best source" data sets by our resident ArcInfo specialist, Angie Greig of the REFM Division. The GIS file system was overhauled over the past year and reorganized and documented to facilitate use by more staff at the Center. Standardized covers of coastlines, bathymetry, stratum boundaries, and physical features are maintained centrally for the system. Other data sets being used with ArcView (haul locations, sediment classifications, and bottom type data) are project-specific and are maintained by individual users or programs.

For further information, contact Angie Greig (206)526-4236.

APPENDIX I

Recent Publications and Reports Pertaining to Groundfish and Marine Habitats by Authors at the Alaska Fisheries Science Center

BRODEUR, R. D.
1998. Prey selection by age-0 walleye pollock, *Theragra chalcogramma*, in nearshore waters of the Gulf of Alaska. Environ. Biol. Fishes 51: 175-186.

BRODEUR, R. D.
1998. In situ observations of the association between juvenile fishes and scyphomedusae in the Bering Sea. Mar. Ecol. Prog. Ser. 163:11-20.

BRODEUR, R. D., and **M. S. BUSBY**.
1998. Occurrence of an Atlantic salmon *Salmo salar* in the Bering Sea. Alaska Fish. Res. Bull. 5:64-66.

BUSBY, M. S.
1998. Guide to the identification of larval and early juvenile poachers (Scorpaeniformes: Agonidae) from the northeastern Pacific Ocean and Bering Sea. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 137, 88 p.

CARLS, M. G., G. D. MARTY, T. R. MEYERS, R. E. THOMAS, and **S. D. RICE**.
1998. Expression of viral hemorrhagic septicemia virus in prespawning Pacific herring (*Clupea pallasi*) exposed to weathered crude oil. Can. J. Fish. Aquat. Sci. 55:2300-2309.

CIANNELLI, L., **R. D. BRODEUR**, and **T. W. BUCKLEY**.
1998. Development and application of a bioenergetics model for juvenile walleye pollock. J. Fish. Biol. 52:879-898.

CLAUSEN, D. M., D. HANSELMAN, **C. R. LUNSFORD**, T. J. QUINN, and **J. HEIFETZ**.
1999. Rockfish adaptive sampling experiment in the central Gulf of Alaska, 1998: chartered fishing vessel *Unimak Enterprise* cruise 98-01. U.S. Dept. Commer., AFSC Processed Rept. 40 p. (in press).

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1998. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 331-348. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99501.

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FRITZ, L. W., and **R. C. FERRERO**.
1998. Options in Steller sea lion recovery and groundfish fishery management. Biosphere Conservation 1(1):7-19.

FRITZ, L. W., and **S. A. LOWE**.
1998. Seasonal distributions of Atka mackerel (*Pleurogrammus monopterygius*) in commercially-fished areas of the Aleutian Islands and Gulf of Alaska, 29 p. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-92, 29 p.

FRITZ, L. W., **A. GREIG**, and **R. F. REUTER**.
1998. Catch-per-unit-effort, length, and depth distributions of major groundfish and bycatch species in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions based on groundfish fishery observer data. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-88, 179 p.

GODDARD, P. D., and **D. J. RUGH**.
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1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the Gulf of Alaska. Masters thesis. University of Alaska Fairbanks, Juneau AK. 153 p. (in press).

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