Section 5

Alaska Sablefish Assessment for 2001

by

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Executive Summary

Summary of major changes

Relative to last year's assessment, we made the following substantive changes in the current assessment.

Input data: Relative abundance and length data from the 2000 longline survey, relative abundance and length data from the 1999 longline fishery, length data from the 1999 trawl fishery, and age data from the 1999 longline survey were added to the assessment model. Age data from the 1999 longline fishery also were added to the assessment model; this is the first time that age data from the fishery has been added to the assessment model. This age data and improved length sampling from the trawl fishery are due to much-appreciated additional sampling by the Observer Program. Ages from the 1981 longline survey recently were read and were added to the assessment model.

Assessment results: Sablefish abundance increased during the mid-1960's due to strong year classes from the late 1950's and 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 56,988 mt in 1972. The population recovered due to exceptional year classes from the late 1970's; spawning abundance peaked again in 1987. The population then decreased because these exceptional year classes are dying off.

The survey abundance index decreased 10% in numbers and 8% in weight from 1999 to 2000. These decreases follow increases from 1998 to 1999 in the survey abundance index of 10% in numbers and 5% in weight and in the fishery abundance index of 7% in weight, so that relative abundance in 2000 is similar to 1998. Fishery abundance data for 2000 were not analyzed because the fishery remains open. Exploitable and spawning biomass are projected to increase 3 and 4%, respectively, from 2000 to 2001. **Alaska sablefish abundance now appears low and stable.** This confirms the conclusion from last year's assessment that the abundance trend has changed from low and slowly decreasing to low and stable. Abundance is projected to continue to increase slowly; the size of the increase depends on the actual strength of the above-average 1997 and 1998 year classes.

ABC recommendation and decision analysis: A simple Bayesian analysis was completed by examining the effect of uncertainty in natural mortality and survey catchability on parameter estimation. A decision analysis was completed using the posterior probability from the Bayesian analysis to determine what catch levels likely will decrease abundance. The decision analysis indicates that a yield of 16,800 mt will maintain spawning biomass. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is 16,900 mt. Based on these results, **we recommend a 2001 ABC of 16,900 mt for the combined stock**, similar to the 2000 ABC of 17,300 mt (2% decrease).

Regional ABC recommendation:

Last year, the Council approved an allocation of the 2000 ABC based on survey and fishery data. We used the same algorithm to allocate the 2001 ABC. A 5-year exponential weighting of the survey and fishery abundance indices in weight (relative population weight or RPW) by region and was used to apportion the combined ABC to regions, resulting in the following apportionments: Bering Sea 1,560 mt, Aleutian Islands

2,500 mt and Gulf of Alaska 12,840 mt, which is further apportioned Western 2,010 mt, Central 5,410 mt, West Yakutat 1,880 mt, and East Yakutat / Southeast 3,540 mt.

Response to Council, SSC, and Plan Team comments

At their fall 1999 meetings, the Plan Teams and SSC cautioned against the use of fishery catch rates in the assessment because fishery catch rates may be biased due to changing fishery catchability and non-random distribution of fishing effort. We examined the fishery catch rate data for biases; see appendix C. We examined the effect of excluding fishery catch rates in the assessment model.

Sablefish longline survey - fishery interactions, 1995-2000

Sablefish longline survey - fishery interactions for 1995-2000 are described in appendix D.

Introduction

Distribution: Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea (Wolotira et al 1993). Adult sablefish occur along the continental slope, shelf gulleys, and in deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Kreiger 1997).

Stock structure and management units: Sablefish appear to form two populations, a northern or Alaska population and a southern or west coast population, based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). The Alaska population inhabits Alaska and northern British Columbia waters and the southern population inhabits southern British Columbia and Washington, Oregon and California waters, with mixing of the two populations occurring off southwest Vancouver Island and northwest Washington.

Alaska sablefish are highly migratory for at least part of their life and substantial movement between the Bering Sea-Aleutian Islands and the Gulf of Alaska has been documented (Heifitz and Fujioka, 1991; Maloney and Heifitz, 1997; Kimura et al. 1998). Thus sablefish in Alaska waters are assessed as a single population. However, sablefish are managed by discrete regions to distribute exploitation throughout their wide geographical range. There are four management areas in the Gulf of Alaska: Western, Central, West Yakutat, and East Yakutat/Southeast Outside (SEO) and two management areas in the Bering Sea/Aleutian Islands (BSAI): the eastern Bering Sea (EBS) and the Aleutian Islands region.

Early life history: Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 180 miles (Wing 1997). Near the end of the first summer, pelagic juveniles less than 20 cm drift inshore and spend the winter and following summer in inshore waters, reaching 30-40 cm by the end of their second summer (Rutecki and Varosi 1997). After their second summer, they begin moving offshore, typically reaching their adult habitat, the upper continental slope at 4 to 5 years.

Age and Size of Recruitment: Juvenile sablefish rear in nearshore and continental shelf waters, moving to the upper continental slope as adults. Fish first appear on the upper continental slope, where the longline survey and longline fishery primarily occur, at age 2 and length about 50-53 cm fork length, although only 10% are estimated to reach the slope at that young age. Fish are susceptible to trawl gear at an earlier age than to longline gear, probably because trawl fisheries more often occur on the continental shelf and shelf break inhabited by younger fish.

Growth and maturity: Sablefish grow rapidly in early life, reaching average maximum lengths and weights of 69 cm and 3.4 kg for males and 82 cm and 6.1 kg for females. Fifty percent of females mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.5 years for females and about 5 years for males (Table 1).

Maximum age and natural mortality: Sablefish are long-lived; ages over 40 years are regularly recorded (Kimura et al. 1993). Reported maximum age for Alaska is 94 years (Kimura et al. 1998); the previous reported maximum was 62 (Sigler et al 1997). Canadian researchers report age determinations up to 55 years (McFarlane and Beamish, 1983). A natural mortality rate of M=0.10 has been assumed for previous sablefish assessments, compared to M=0.22 estimated by Low et al (1976) prior to the latest ageing techniques and M=0.112 assumed by Funk and Bracken (1984). Johnson and Quinn (1988) used values of 0.10 and 0.20 in a catch-at-age analysis and found that estimated abundance trends agreed better with survey results when M=0.10 was used. In the current assessment, natural mortality is estimated rather than assumed to equal 0.10 as in assessments before 1999.

Prey and predators: Sablefish are opportunistic feeders. Fish constituted 3/4 of stomach content weight, with the remainder invertebrates, in a diet study of Gulf of Alaska sablefish (Yang 1993). Pollock were the most important fish; eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish also were found. Squid were the most important invertebrate and euphasiids and jellyfish both also were found. Fish made up 76 percent of the diet in feeding studies conducted off Oregon and California (Laidig et al 1997). Euphausiids dominated the diet off the southwest coast of Vancouver Island; herring and other fish were increasingly important with sablefish size (Tanasichuk 1997).

Adult coho and chinook salmon feed on sablefish; they prey on young-of-the-year sablefish, which were the fourth most commonly reported species from the salmon troll logbook program from 1977 to 1984 (Wing 1985). Only one other fish species was reported as preying on juvenile or adult sablefish in a food habit study of fishes of the Gulf of Alaska, Pacific halibut, and sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999).

Fishery

Description of the directed fishery

Early U.S. fishery, 1976 and earlier

Sablefish have been exploited since the end of the 19th century by U.S. and Canadian fishermen. The North American fishery on sablefish developed as a secondary activity of the halibut fishery of the United States and Canada. Initial fishing grounds were off Washington and British Columbia and from there spread to Oregon, California, and Alaska during the 1920's. Since then, and up to 1957, the sablefish fishery was exclusively a U.S. and Canadian fishery, ranging from off northern California northward to Kodiak Island in the Gulf of Alaska; catches were relatively small, averaging 1,666 mt from 1930 to 1957, and generally limited to areas near fishing ports (Low et al 1976).

Foreign fisheries, 1958 to 1987

Japanese longliners began operations in the eastern Bering Sea in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 mt in 1962 (Table 2, Figure 1). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the Aleutian Islands region and the Gulf of Alaska. In the Gulf of Alaska, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 mt overall in 1972. Catches in the Aleutian Islands region have historically remained at low levels with Japan harvesting the largest portion of the sablefish catch. Most sablefish harvests were taken from the eastern Being Sea until 1968, and then from the Gulf of Alaska until 1977. Heavy fishing by foreign vessels during the 1970's led to a substantial population decline and fishery regulations in Alaska which sharply reduced catches. Catch in the late 1970's was restricted to about one-fifth of the peak catch in 1972.

Japanese longliners had a directed fishery for sablefish. Sasaki (1985) described the gear used in the directed Japanese longline fishery. He found only minor differences in the structure of fishing gear and the fishing technique used by Japanese commercial longline vessels. There were small differences in the length of hachis (Japanese term for a longline skate) and in the number of hooks among vessels, but hook spacing remained about 1.6 m. The use of squid as bait by vessels also remained unchanged, except some limited number of vessels used Pacific saury as bait when squid was expensive. The standard number of hachis fished per day was 376 (Sasaki 1978) and the number of hooks per hachi was 43 until 1979, when the number was reduced to 40 (T. Sasaki, Japan Fisheries Agency, 4 January 1999).

Japanese trawlers also caught sablefish through directed effort toward sablefish, but mostly as bycatch in fisheries targeting other species. Sasaki (1973) reported two trawl fisheries catching sablefish in the Bering Sea through 1972, the North Pacific trawl fishery which caught sablefish as bycatch to the directed pollock fishery and the landbased dragnet fishery that sometimes targeted sablefish. The latter fishery mainly targeted rockfishes, Greenland turbot, and Pacific cod, and only a few vessels targeted sablefish (Sasaki 1985). The landbased fishery caught more sablefish, averaging 7,300 mt from 1964 to 1972, compared to the North Pacific trawl fishery, which averaged 4,600 mt. In the Gulf of Alaska, Sasaki (1973) reported that sablefish were caught as bycatch to the directed Pacific Ocean perch fishery until 1972, but some vessels started targeting sablefish in 1972. Most net-caught sablefish were caught by stern trawls, but significant amounts also were caught by side trawls and Danish seines the first few years of the Japanese trawl fishery.

Other foreign nations besides Japan also have caught sablefish. Substantial U.S.S.R. catches were reported from 1967-73 in the Bering Sea (McDevitt 1986). Substantial R.O.K. catches were reported from 1974-1983 scattered through Alaska. Other countries reporting minor sablefish catches were Republic of Poland, Taiwan, Mexico, Bulgaria, Federal Republic of Germany, and Portugal. The U.S.S.R. gear was factory-type stern trawl and the R.O.K. gear was longlines and traps (Low et al 1976).

Recent U.S. fishery, 1977 to present

The U.S. longline fishery began expanding in 1982 in the Gulf of Alaska and in 1988, harvested all sablefish taken in Alaska except minor joint venture catches. Following domestication of the fishery, the previously year-round season in the Gulf of Alaska began to shorten in 1984. By the late 1980's, the average season length decreased to one to two months. In some areas, this open-access fishery was as short as 10 days, warranting the label “derby” fishery.

Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Season length (months)	12	7.6	3.0	1.5	1.2	1.8	1.5	1.3	0.9	0.7	0.5	0.3	8

Season length continued to decrease until Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels in 1995 along with an 8-month season. The season runs from March 15-November 15, concurrent with the halibut IFQ fishery.

The expansion of the U.S. fishery was helped by exceptional recruitment during the late 1970's. This exceptional recruitment fueled an increase in abundance for the population which had been heavily fished during the 1970's. Increased abundance led to relaxation of fishing quotas and catches peaked again in 1988 at about 70% of the 1972 peak. Abundance has since fallen as the exceptional late 1970's year classes have died off. Catches also have fallen and in 1999, were about 35% of the 1988 peak.

The directed fishery primarily is a hook-and-line fishery. Sablefish also are caught as bycatch during directed trawl fisheries for other species groups such as rockfish and deepwater flatfish. Five state fisheries also land sablefish outside the IFQ program; the major fisheries in the Prince William Sound, Chatham Strait, and Clarence Strait and the minor fisheries in the northern Gulf of Alaska and Aleutian Islands. For Federal and State sablefish fisheries combined, the number of longline vessels targeting sablefish (Greig et al. 1998) and number of hooks deployed were:

Year	1993	1994	1995	1996	1997	1998
Vessels	871	1,078	613	578	504	na
Hooks (millions)	92.2	112.5	53.9	46.9	38.3	40.4

The number of hooks deployed in Federal fishery alone were:

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Hooks (millions)	96.9	78.0	76.2	86.7	81.5	49.7	44.7	34.4	35.0

Longline gear in Alaska is fished on-bottom. In the 1996 directed fishery for sablefish, average set length was 9 km and average hook spacing was 1.2 m. The gear is baited by hand or by machine, with smaller boats generally baiting by hand and larger boats generally baiting by machine. Circle hooks usually are used, except for modified J-hooks on some boats with machine baiters. The gear usually is deployed from the vessel stern with the vessel traveling at 5-7 knots. Some vessels attach weights to the longline, especially on rough or steep bottom, so that the longline stays in place and lays on-bottom.

Catch

Annual catches in Alaska averaged about 1,700 mt from 1930 to 1957 and exploitation rates remained low until Japanese vessels began fishing for sablefish in the Bering Sea in 1959 and the Gulf of Alaska in 1963. Catches rapidly escalated during the mid-1960's. Annual catches in Alaska reached peaks in 1962, 1972, and 1988 (Table 2). The 1972 catch was the all-time high, at 53,080 mt, and the 1962 and 1988 catches were 50% and 72% of the 1972 catch. Evidence of declining stock abundance led to significant fishery restrictions from 1978 to 1985, and total catches were reduced substantially. Catches averaged about 12,200 mt during this time. Exceptional recruitment fueled increased abundance and increased catches during the late 1980's. The domestic fishery also expanded during the 1980's, harvesting 100% of the catch in the Gulf of Alaska by 1985 and in the Bering Sea and Aleutians by 1988. Catches have declined during the 1990's. Catches peaked at 38,406 mt in 1988 and have fallen to about 14,000 mt currently due to reduced quotas.

Bycatch and discards

The percent of sablefish catch discarded during 1994 to 1997 averaged 2.1% in the directed Alaska-wide sablefish longline fishery, 32.2% in the Bering Sea/Aleutian Islands Greenland turbot longline fishery, and 33.6% in the Bering Sea/Aleutian Islands Pacific cod longline fishery. Sablefish discard averaged 16.1% in Alaska-wide rockfish trawl fisheries and 39.5% in flatfish trawl fisheries (Table 3). The average discard from 1994 to 1997 was 3% for all longline fisheries and 27% for all trawl fisheries.

Previous management actions

Quota allocation: Amendment 14 to the Gulf of Alaska Fishery Management Plan, allocated the sablefish quota by gear type: 80% to hook-and-line gear and 20% to trawl in the Western and Central Gulf of Alaska and 95% to hook-and-line gear and 5% to trawl in the Eastern Gulf of Alaska, effective 1985. Amendment 13 to the Bering Sea/Aleutian Islands Fishery Management Plan, allocated the sablefish quota by gear type, 50% to fixed gear and 50% to trawl in the eastern Bering Sea, and 75% to fixed gear and 25% to trawl gear in the Aleutians, effective January 1, 1990.

IFQ management: Amendment 20 to the Gulf of Alaska Fishery Management Plan and 15 to the Bering Sea/Aleutian Islands Fishery Management Plan established IFQ management for sablefish beginning in 1995. These amendments also allocated 20% of the fixed gear allocation of sablefish to a CDQ reserve for the Bering Sea and Aleutian Islands.

Maximum retainable bycatch: Maximum retainable bycatch percentages for sablefish were revised in the Gulf of Alaska by a regulatory amendment, effective 4/10/97. The percentage depends on the basis species: pollock 1%, Pacific cod 1%, deep flatfish 7%, rex sole 7%, flathead sole 7%, shallow flatfish 1%, arrowtooth flounder 0%, Pacific ocean perch 7%, shortraker and rougheye rockfish 7%, other rockfish 7%, northern rockfish 7%, pelagic rockfish 7%, demersal shelf rockfish in the Southeast Outside district 7%, thornyhead 7%, Atka mackerel 1%, other species 1%, and aggregated amount of non-groundfish species 1%.

Allowable gear: Amendment 12 to the Gulf of Alaska Fishery Management Plan banned the use of pots for fishing for sablefish in the Gulf of Alaska and Bering Sea, effective 1982. The prohibition on sablefish longline pot gear use was removed for the Bering Sea, except from June 1 to 30 to prevent gear conflicts with trawlers during that month, effective 9/12/96. Sablefish longline pot gear are allowed in the Aleutian Islands.

Management areas: Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish, effective 1980.

Data

Source	Data	Dates
Fisheries	Catch	1960-1999
Japanese longline fishery	Effort	1964-1981
	Length	1963-1980
Japanese trawl fishery	Length	1964-1971
U.S. longline fishery	Effort, length, discards	1990-1999
U.S. trawl fisheries	Length	1990,1991,1999
	Discards	1990-1999
Japan-U.S. cooperative longline survey	Catch, effort, length	1979-1994
	Age	1981, 1983, 1987, 1989, 1991, 1993
Domestic longline survey	Catch, effort, length	1990-2000
	Age	1996-1999

Fishery

Catch, effort, and length data are collected from sablefish fisheries. The catch data covers several decades. Length and effort data were collected from the Japanese and U.S. longline fisheries (Table 4). Length data were collected from the Japanese and U.S. trawl fisheries. The Japanese data were collected by fishermen trained by Japanese scientists (L-L. Low, Alaska Fisheries Science Center, 25 August 1999). The U.S. fishery data were collected by at-sea and plant observers. No age data were systematically collected from the fisheries until 1999 because of the difficulty of obtaining representative samples from the fishery and because a limited number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A.

Some catches probably were not reported during the late 1980's (Kinoshita et al 1995). Unreported catches could account for the Japan-U.S. cooperative longline survey index's sharp drop from 1989-90 (Figures 2 and 3, Table 5). We tried to estimate the amount of unreported catches by comparing reported catch to another measure of sablefish catch, sablefish imports to Japan, the primary buyer of sablefish. However the trends of reported catch and imports were similar, so we decided to change our approach for catch reporting in the 1999 assessment. We assumed that non-reporting is due to at-sea discards and apply discard estimates from 1994 to 1997 to inflate U.S. reported catches before 1994 (2.9% for hook-and-line and 26.6% for trawl).

One problem with the fishery data has been low length sample sizes for the trawl fishery. From 1992 to 1998, few lengths were collected each year and the resultant length frequencies were ragged and could not be used in the assessment model. The problem was that sablefish often are caught with other species like rockfish and deepwater flatfish, but are not the predominant species. The observer sampling protocol called for sampling the predominant species, so sablefish were poorly sampled. We communicated this problem to the observer program and together worked out revised sampling protocols. The revision greatly improved the sample size, so that the 1999 length data for the trawl fishery can be used for the assessment. We appreciate the efforts of the Observer Program, notably Sarah Gaichas, to improve fishery sampling.

Longline surveys

Catch, effort, age, length, weight, and maturity data are collected during sablefish longline surveys. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000). Japan and the United States conducted a cooperative longline survey for sablefish in the Gulf of Alaska annually from 1978 to 1994 (Sasaki 1985, Sigler and Fujioka 1988). The survey was expanded to include the Aleutian Islands region in 1980 and the Eastern Bering Sea in 1982. Since 1987, the Alaska Fisheries Science Center has conducted annual longline surveys of the upper continental slope, referred to as domestic longline surveys, designed to continue the time series of the Japan-U.S. cooperative survey (Sigler and Zenger 1989). The domestic longline survey began annual sampling of the Gulf of Alaska in 1987, biennial sampling of the Aleutian Islands in 1996, and biennial sampling of the eastern Bering Sea in 1997 (Rutecki et al 1997). The domestic survey also samples major gullies of the Gulf of Alaska in addition to sampling the upper continental slope. Longline survey catches are tabled in appendix E.

Length data were collected for all survey years and sablefish otoliths were collected for most survey years. Only a subset of these otoliths were aged until 1996, when annual ageing of samples began. Otolith collections were length-stratified from 1979-94 and random thereafter.

The order in which areas are surveyed was changed in 1998 to avoid surveying areas during times when short, intense fisheries were occurring to minimize the potential for interactions between fishing and survey sampling. The survey order has been: Aleutians and/or Bering Sea, Western Gulf, Central Gulf, Eastern Gulf, but in 1998 the Eastern area was surveyed before the Central area. Starting in 1998, the Eastern area was surveyed about one month earlier and the Central area about one month later compared to 1979-97.

Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 5.5). It is not clear why the two surveys showed divergent trends from 1989 to 1990; Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

Killer whale depredation of the survey's sablefish catches has been a problem in the Bering Sea since the beginning of the survey (Sasaki, 1987). The problem occurred mainly east of 170° W in the eastern Bering Sea and to a lesser extent in the northeast Aleutians between 170° W and 175° W. The 1983 (Sasaki 1984), 1986 and 1987 (T. Sasaki, Far Seas Fisheries Research Laboratory) and 1988 Bering Sea abundance indices likely were underestimated, although sablefish catches were lower at all stations in 1987 compared to 1986, regardless of whether killer whales were present. Killer whale depredation has been fairly consistent since 1988. An analysis is planned as time permits to exclude killer whale affected stations from abundance calculations with the cooperative longline survey data. Portions of the gear affected by killer whale depredation during domestic longline surveys already are excluded from the analysis of the survey data.

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted approximately triennially since 1979 in the Bering Sea, 1980 in the Aleutians, and 1984 in the Gulf of Alaska. Trawl surveys of the Eastern Bering Sea shelf are conducted annually, but sablefish have never occurred on the shelf in large numbers except for juveniles of the 1977 year class which showed up in large numbers in 1978. The slope trawl surveys are not considered good indicators of the sablefish relative abundance over time because of differences in net types used each year, depths sampled, and high sampling variation and so are not used in the sablefish assessment. Trawl survey catches are tabled in appendix E.

Recruitment data

Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. The appearance of large numbers of juveniles widespread in inside waters of southeastern Alaska likely indicates a strong year class. Juvenile sablefish were common during the summers of about 1960 (J. Fujioka, Auke Bay Laboratory, 15 August 1999; H. Zenger, Alaska Fisheries Science Center, 2 August 2000), 1978 (Bracken 1983), 1981, 1985, and 1999, corresponding to strong year classes in about 1959, 1977, 1980, 1984, and 1998. Juvenile sablefish also were common in Prince William Sound in 1998 (W. Bechtol, Alaska Department of Fish and Game, 22 September 1999; M. Miller, Alaska Department of Fish and Game, 19 October 1999) and 1999 (M. Miller, Alaska Department of Fish and Game, 19 October 1999) and around Kodiak Island in 1999 (D. Jackson, Alaska Department of Fish and Game, 7 October 1999), but not around Dutch Harbor in 1999 (R. Gish, Alaska Department of Fish and Game, 1 September 1999).

Catch, effort, age, length, and diet data for young-of-the-year and age-1+ sablefish are collected from surface gillnet surveys of the Aleutian Islands, Bering Sea, and Gulf of Alaska. Surface gillnet surveys have been conducted annually since 1995 generally near the edge of the continental shelf. Catch rates of young-of-the-year sablefish from gillnet surveys were above average in 1995, 1997, and 1998 and below average in 1996, 1999, and 2000, implying that the 1995, 1997, and 1998 year classes are above average within this 6-year period.

Age data from the longline survey and longline fishery also indicate that the 1995 and 1997 year classes are above average. The 1995 year class is the dominant year class in the 1999 fishery age data for the Aleutians, Bering, and Western Gulf of Alaska areas (and much less common in the Central and Eastern Gulf of Alaska). The 1997 year class appears as the largest proportion of 2-year olds in longline survey age data since the appearance of the 1981 year class in the 1983 longline survey age data.

Relative abundance data summary

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 5, Figure 2). The post-1970 decrease likely is due to heavy fishing. The 1985 peak likely is due to the exceptional late 1970's year classes. Since 1988, relative abundance has decreased substantially. Regionally, abundance has decreased faster in the Eastern Bering Sea and Aleutian Islands and more slowly in the Gulf of Alaska. These latter areas may be the outer edges of sablefish distribution and less favored habitat than the apparent center of sablefish abundance, the Gulf of Alaska.

Analytic approach

Model

Model structure

The analysis generally follows the approach described by Kimura (1990) for age-structured population analysis. This approach also was tested for sablefish by Sigler (1999). The analysis was completed using AD model builder software, a C++ based software for development and fitting of general nonlinear statistical models (Otter Research 1996). Details of the model structure are shown in Appendix B.

The sablefish population in Alaska is represented with an age-structured model. Numbers at age for ages 2 to 30, pooled age 31, and years 1960 to 1999 were estimated with the age-structured model.

Sablefish are difficult to age, especially those older than eight years (Kimura and Lyons 1991, Table 6) and sablefish often are misaged. An ageing error matrix based on known-age otoliths was used to account for ageing error (Heifetz et al. 1999). An age-length transition matrix was used to translate age into length.

Selectivity is represented using a function and is separately estimated for longline surveys, longline fisheries, and trawl fisheries. Selectivity for longline surveys and longline fisheries is restricted to be asymptotic. Selectivity for trawl fisheries is allowed to be dome-shaped. The age of 50% availability for longline fisheries is allowed to vary with season length. Fishermen may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the pre-1995 “derby” fishery, when fishermen reportedly often fished in less productive depths due to crowding. In choosing their ground, they presumably target bigger, older fish.

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, and the U.S. longline fishery. Information is available to link these estimates of catchability. Kimura and Zenger (1997) analyzed the relationship between the cooperative and domestic longline surveys. We used their results to create a prior distribution which linked catchability estimates for the two surveys. Sasaki, Sigler, and Lunsford conducted hook spacing experiments. The fishery and survey data differ in their hook spacing but otherwise are similar. We used the hook spacing data to create prior distributions which linked the catchability estimates for the surveys and fisheries.

A natural mortality rate of M=0.10 was assumed for assessments before 1999. Since then, natural mortality is estimated in the assessment model.

Some information used in the assessment model was estimated independently of the assessment model. The parameters and equations describing growth and maturity were estimated independently of the assessment modeling, then were incorporated into the assessment model as fixed values.

Annual tag releases from 1978 to 1994 during the Japan-U.S. cooperative longline survey and tag recoveries from 1979 to 1997 were included in preliminary model analyses. This analysis is not finished and so will not be used in this year's assessment.

Sablefish-specific population projections

A set of population projections were completed that are specific to the Alaska sablefish population. These sablefish-specific projections are used in the Bayesian and decision analyses which are described in a later section of the assessment. The method of projecting the population is similar to the standard set of projections described in the next section, except that a different harvest policy is tested in the sablefish-specific projections.

The modeled population was projected forward 5 years. Future recruitment was sampled with replacement from the estimated recruitments for the 1982-1996 year classes. Each stochastic projection was repeated 250 times. Earlier year classes were not included because estimated recruitments for the 1977-1981 year classes were higher and may not recur in the next five years. The 1997 and 1998 year classes also were not included because these year classes have been observed only one or two times and are only partially recruited (estimated less than 20% selected).

Sixteen harvest levels were tested, 10,000, 11,000, ... , 25,000 mt in the projections. For example, the modeled population was projected forward 5 years with a catch of 10,000 mt each year. The purpose of testing several harvest levels was to determine the harvest level which kept future abundance the same.

Standard set of population projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2000 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2001 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2000. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2001, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2001 recommended in the assessment to the *max* F_{ABC} for 2001. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1995-1999 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2001 and above its MSY level in 2011 under this scenario, then the stock is not overfished.)

Scenario 7: In 2001 and 2002, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2013 under this scenario, then the stock is not approaching an overfished condition.)

Bayesian analysis

Previous sablefish assessments assumed that the value of natural mortality was known exactly. This assessment incorporates uncertainty in the value of natural mortality as well as survey catchability using the same approach as the Pacific cod assessments. Other population parameters are uncertain, but uncertainty in only these two parameters was examined because they are the most important parameters determining the value of abundance.

The likelihood surface was mapped over a grid of M and q-values. Equally spaced M and q-values were examined. The natural mortality values and survey catchability values were paired to create a grid of M - q pairs. The remaining population parameters were estimated with the population model given each M - q pair. The resulting likelihood values are an estimate of the likelihood surface given M and q. Each M - q pair was assumed to have equal prior probability, so the posterior probabilities were computed by normalizing the likelihoods so their sum was 1.0. One concern with mapping the likelihood is that the choice of the grid boundaries can have an impact on the results. However we made sure that the boundaries of the grid extended past nearly all of the probability of the normalized likelihood, so that the choice of the grid boundaries can not affect the shape of the posterior.

Decision analysis

The general approach of recommending recent sablefish ABC's has been to consider current abundance and trend relative to historical cycles. Current abundance is estimated as low and stable, so the ABC should not decrease abundance because abundance is low. Thus a reasonable criteria for choosing ABC is a catch level that does not decrease abundance. Five-year projected abundance was compared to next year's projected abundance. The posterior probability from the Bayesian analysis was used to compute the probability of decreasing abundance, that 2005 abundance will be less than 2001 abundance, for several values of catch. Five years was chosen for the projection time frame because, compared to longer time frame projections, projected abundance is only slightly influenced by the assumed value of future stock productivity.

Model evaluation

Data fits

The model fit the observed abundance indices, survey and fishery length data, and survey age data (Figures 2, 3, and 4 [the length fits are not shown for brevity]).

Results

5.7.1 Model

Annual estimated recruitment varies widely, with strong year classes estimated for 1959, 1963, 1967, 1974, 1977, 1980, 1981, 1984, 1988, 1990, 1994, 1995, and 1997 (Figure 5). Intervening year classes are relatively weak. Two recent strong year classes are the 1995 and 1997 year classes. The 1998 year class also may be strong, see Relative abundance data summary section for evidence, but appears relatively weak in the model estimates. However estimates of the strength of recent year classes strength are uncertain because these year classes have been observed only a few times and are only partially recruited. More reliable estimates of the strength of the 1998 year class will be available with 1-2 more years of survey data.

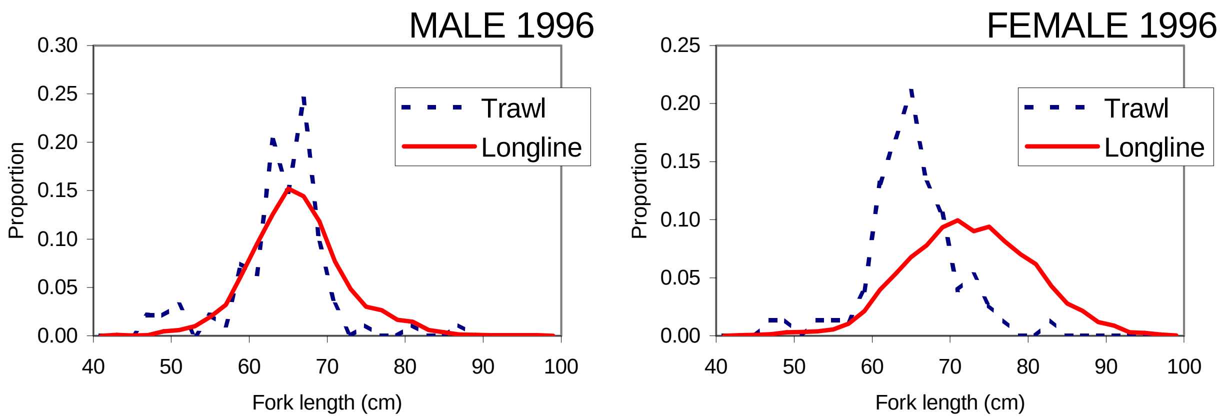
Sablefish abundance increased during the mid-1960's (Table 6, Figure 6) due to strong year classes from the late 1950's and 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 56,988 mt in 1972. The population recovered due to strong year classes from the late 1970's; spawning abundance peaked again in 1987. The population then decreased because these strong year classes are dying off.

Combined exploitable biomass for the Aleutian Islands, eastern Bering Sea, Gulf of Alaska increased 1.0% and spawning biomass decreased 0.4% from 1999 to 2000. Projected 2001 exploitable biomass is about 186,000 mt, spawning biomass 178,000 mt, increases of 2.7 and 3.9% from the estimated values for 2000. **Alaska sablefish abundance now appears low but stable.** This confirms the conclusion from last year's assessment that the abundance trend has changed from low and slowly decreasing to low and stable. Abundance is projected to continue to increase; the size of the increase depends on the actual strength of the above-average 1997 and 1998 year classes.

The 1977, 1980 and 1981 strong year classes appear to be exceptional year classes associated with the regime shift of 1976-1977. Subsequent year classes are weaker, but may be "normal" for the changed oceanographic state following the regime shift. A major change in the productivity of the stock appears to have occurred following these exceptional year classes.

Estimates of recruitment strength during the 1960's are uncertain because they depend on length rather than age data and because the abundance index is the fishery catch rate, which may be a biased measure of abundance. Late 1970's abundance may be overestimated; predicted mean weight is greater than observed mean weight, implying that predictions of how many fish survived the heavy fishing during the 1970's is overestimated. The observed population during the late 1970's appears to consist of more young fish than was predicted.

The age of 50% selection by the longline survey is about 4 years (Figure 7). The age of 50% selection is about 1 year later for the IFQ longline fishery, about the same for short open-access seasons ("derby" fishery), and about 1.5 years earlier for the trawl fishery. Selectivity is asymptotic for the longline survey and fishery and dome-shaped for the trawl fishery. Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishermen were pushed to fish shallower water that young fish inhabit. Young fish are more vulnerable and older fish are less vulnerable to the trawl fishery (see following figure [only 1996 data shown for brevity]) because trawling often occurs on the continental shelf and < 300 m water of the continental slope that young sablefish inhabit.



Catch rate data were available from 1990-present. Catchability was separately estimated for the "derby" (through 1994) and IFQ (1995 and later) fisheries. On average fishery catchability was 38% less during the "derby" fishery. Like the selectivity effect, this likely occurred due to crowding of the fishing grounds, so that fishermen were pushed to fish areas where sablefish densities were less. Fishermen also fished the same area repeatedly, with associated decrease in catch rate due to "fishing down" the area.

A value of 0.098 was estimated for natural mortality in this year's assessment, similar to the assumed value of 0.10 used in previous assessments.

Fishery catch rates often are biased estimates of relative abundance (e.g. Crecco and Overholtz 1990). We examined possible biases in US fishery catch rate data; see Appendix C. The assessment results shown in this section used both survey and fishery catch rates as measures of sablefish relative abundance. Because of the potential bias of sablefish fishery catch rates, we tested the effect of the sablefish fishery catch rates. Both Japan and US fishery catch rate data are used in the assessment, but we only tested the effect of US fishery catch rate data because there was no alternative abundance index during most years of the Japanese longline fishery, unlike the US fishery, which overlaps longline surveys. We found that US fishery catch rates have little effect on spawning biomass estimates. Their inclusion in the assessment model decreased spawning biomass estimates by no more than 1.6% for 1990-1999, the years of US fishery catch rate data.

Comparison to last year's model

The scale and the trend of the spawning and exploitable biomass estimates are similar between the November 1999 and 2000 assessments, except for minor differences (Figure 8). The 2000 assessment changes birth year by one year for 2 strong year classes about 1960. This likely is due to adding age data from the 1981 longline survey to the assessment model, which provides some information on the strength and timing of these year classes. The 2000 assessment increased the estimate of the 1997 year class. Estimated strengths of recent year classes often change as additional years' data are collected.

Projections and harvest alternatives

Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2001 spawning biomass estimate, are shown in Table 7. Reference biomass values were computed for recruitment equal to average recruitment from the 1977-95 year classes. Projected 2001 spawning biomass is 34% of unfished spawning biomass and 84% of $B_{40\%}$. A downward adjustment to the reference fishing mortality rates is required to set the maximum Acceptable Biological Catch under Tier 3b.

Maximum sustainable yield

A spawner-recruit relationship has not been determined for sablefish, thus estimates of maximum sustainable yield are unavailable.

Population projections

Projected 2001 exploitable biomass is about 186,000 mt for Aleutian Islands, eastern Bering Sea, Gulf of Alaska combined, spawning (male and female) biomass 178,000 mt. Spawning biomass currently is less than 35% of the unfished value. What happens next depends on future average recruitment and fishing mortality (Figure 9). If catch is about 17,000 mt, then abundance is projected to slowly increase through 2004, then decrease if future average recruitment equals 1982-1996 average recruitment. With the same catch and future average recruitment equal to 1977-1996 average recruitment, then abundance is projected to increase through 2005. The latter recruitment scenario is more optimistic because it includes the exceptional 1977-1981 year classes. Spawning biomass is projected to increase above 35% of the unfished value only if future recruitment equals the more optimistic recruitment level or if fishing mortality is substantially reduced. Projected abundances for maximum permissible fishing mortality and 5-year average fishing mortality are similar to projected abundances for catch of 17,000 mt. Abundance generally will increase in 2001 and later if fishing mortality is half maximum permissible or zero.

We also projected yields based on recruitment estimates from the whole time series of 1957+, in addition to the abundance and yield projections described in the previous paragraph for 1977+ and 1982+; abundance and yield projections for 1957+ are similar to 1977+ because average recruitment for both time intervals is similar, about 19 million 2-year old sablefish per year, compared to 12 million for 1982+.

Spawning biomass, fishing mortality, and yield also are tabulated for the seven standard projection scenarios (Table 8).

Status determination

Alaska sablefish are not overfished nor are they approaching an overfished condition (Table 5.8).

Bayesian analysis

The parameters natural mortality and survey catchability are well-defined by the available data. Most of the probability lies between M of 0.07 and 0.15 and q of 5.2 and 12.2 (Figure 10). The probability changes smoothly and is well-mapped by the chosen values for the q-M grid. We plan to test an algorithm such as

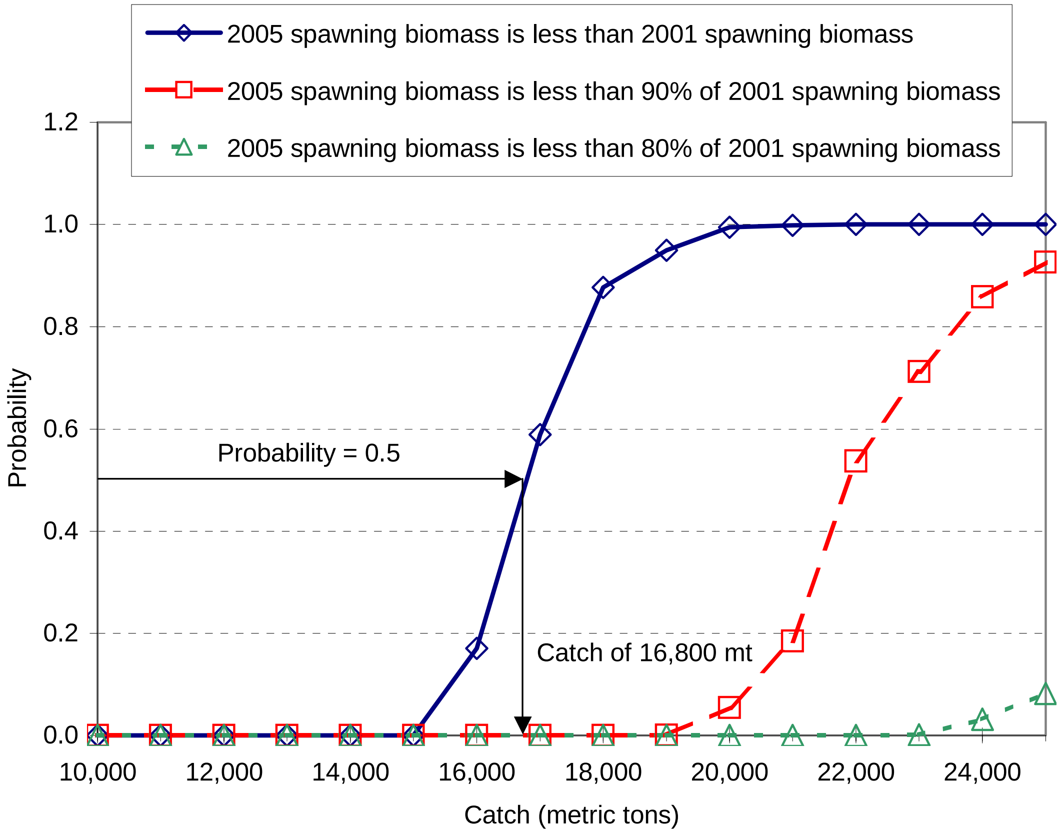
MCMC to integrate the posterior probability over all possible combinations of q and M when time allows.

More informative priors than the uniform priors on M and q could be used. Adding more informative priors should narrow the posterior. We tested a more informative prior for natural mortality and as expected, the posterior was narrower. The amount of narrowing depended on the variance assumed for the prior. Adding more informative priors also should reduce the estimates of the probability that spawning biomass will decrease in the future. This probability forms the basis of the decision analysis used to recommend the 2001 ABC and described in the next section. Therefore if the prior is "too" informative, the probability of a given catch level decreasing sablefish abundance will be underestimated, e.g. for catch of 21,000 mt, the probability that 2005 abundance will be less than 90% of 2001 abundance will be 0.1 rather than 0.2. One basis for adding a more informative prior is sablefish biologists' opinion of the value of natural mortality. However our opinion primarily is based on age-structured modeling. Adding an opinion-based prior to the age-structured model essentially is double-counting the information used to estimate natural mortality. Therefore we did not add more informative priors based on our opinion of natural mortality.

Another approach for adding more informative priors which does not depend on sablefish data alone is a meta-analysis based on the value of natural mortality for other species, if the analysis includes long-lived species of the Scorpaeniformes (which includes sablefish and rockfish) or a meta-analysis that uses other life history relationships such as natural mortality and the growth parameter k. During development of the Bayes and decision analyses we considered using meta-analysis priors for natural mortality as well as stock-recruitment relationship "steepness" and may add these priors to future sablefish assessments.

Decision analysis

The decision analysis asks the question: What is the probability that spawning biomass will decrease in the future? The years 2001 and 2005 were compared. The spawning biomass most likely will be the same in 2001 and 2005 for catch of 16,800 mt each year (the catch where probability equals 0.5 that 2005 spawning biomass is less than 2001 spawning biomass in the figure following this paragraph). The probability that this catch will reduce 2005 spawning biomass to less than 90% of 2001 spawning biomass is near zero.


2005 spawning biomass is less than 2001 spawning biomass
2005 spawning biomass is less than 90% of 2001 spawning biomass
2005 spawning biomass is less than 80% of 2001 spawning biomass
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Probability
Probability = 0.5
Catch of 16,800 mt
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
Catch (metric tons)

Acceptable biological catch

Biomass estimates have changed between assessments in some previous assessments and may not result in a consistent series of ABC's when an $F_{40\%}$ strategy is applied. Given the low abundance of sablefish (spawning biomass is 34% of unfished value), we feel that prior ABC's and the abundance trend should be considered to recommend ABC. The approach we used to recommend the 1997, 1998, and 1999 acceptable biological catches (ABC) consisted of two steps: 1) compute the short-term equilibrium yield, then 2) recommend 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 mt, the short-term equilibrium yield projected in the 1998 assessment was 16,000 mt, so the 1998 ABC recommendation was 16,800 mt for the combined stock. The short-term equilibrium yield was used to recommend ABC because the yield calculated from an adjusted $F_{40\%}$ strategy in the 1997 and 1998 assessments represented an increase over recent ABC's. Increasing ABC was inconsistent with declining stock trend. Rather than increasing ABC then reducing thereafter toward the predicted short-term equilibrium yield, in the 1997 and 1998 assessments we recommended an incremental adjustment of ABC toward the short-term equilibrium yield. An incremental adjustment was used to recommend ABC to spread out the change from current ABC to short-term equilibrium yield over 3 years and because estimates of short-term equilibrium yield may change as new data become available and we use new methods of estimating short-term equilibrium yield.

We recommend choosing the 2001 ABC based on the same concerns for abundance trend and low abundance. The decision analysis presented in the previous section addresses this concern using more sophisticated methods of estimating the risk of decreasing abundance and also was used to recommend the 2000 ABC. The decision analysis indicates that a yield of 16,800 mt most likely will keep spawning biomass the same and has near-zero probability of reducing 2005 spawning biomass to less than 90% of 2001 spawning biomass. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is 16,900 mt. Based on these results, **we recommend a 2001 ABC of 16,900 mt for the combined stock**, similar to the 2000 ABC of 17,300 mt (2% decrease).

Similar 2000 and 2001 ABCs is consistent with a sablefish abundance trend that appears low and stable. Exploitable and spawning biomass are projected to increase 3 and 4%, respectively, from 2000 to 2001. The survey abundance index decreased 10% in numbers and 8% in weight from 1999 to 2000. These decreases follow increases from 1998 to 1999 in the survey abundance index of 10% in numbers and 5% in weight and in the fishery abundance index of 7% in weight, so that relative abundance in 2000 is similar to 1998 (Table 5). Fishery abundance data for 2000 were not analyzed because the fishery remains open.

The current approach of considering the risk of decreasing abundance for recommending ABC is appropriate for a population which is decreasing or stable and at low abundance. If abundance increases substantially, well away from the current low abundance, the opportunity will arise to consider other objectives and concerns. If abundance were to increase, then increased emphasis on yield maximization will be appropriate. Another concern which is more a TAC concern, is considering that abundance may increase, then subsequently decrease as has occurred twice in the last forty years. A TAC strategy for increasing abundance might consider how best to manage through this cycle, including bringing in market and economic considerations such as expansion and subsequent contraction of the supply of sablefish over a 10- to 20-year period.

Regional and area apportionment

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of interannual changes in the allocation. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of biomass distribution, while adapting to current information about biomass distribution. However mixing rates for sablefish are sufficiently high and fishing rates sufficiently low that moderate variations of the biomass based apportionment would not significantly change overall sablefish yield unless there are strong areal differences in recruitment, growth, and survival (Heifetz et al 1997). The 1993 TAC was apportioned using a 5 year running average with emphasis doubled for the current year survey abundance index in weight (relative population weight or RPW). Since 1995, the ABC was allocated using an exponential weighting of regional RPW's. This method of determining weighting values depends on the assumed ratio between measurement (survey variance) to process error (recruitment, natural mortality, and migration variability). If survey variability is 1/N-th of total variability, the weighting factor is reduced 1/N-th each previous year. The sablefish longline surveys are assumed fairly accurate relative to many other surveys and probably survey variability is no more than ½ of total variability. A $(1/2)^x$ weighting scheme reduced annual fluctuations in ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model, where x is the year index (J. Heifetz, Auke Bay Lab, pers. comm.). The weights are year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000.

Previously, the Council approved allocations of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an allocation based on survey and fishery data. We also used survey and fishery data to allocate the 2001 ABC.

The fishery and survey information were combined to allocate ABC using the following method. The RPW based on the fishery data were weighted with the same exponential weights used to weight the survey data (year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000). The fishery and survey data were combined by computing a weighted average of the survey and fishery estimates, with the weight inversely proportional to the variability of each data source. The variance for the fishery data is about twice that for the survey data, so the survey data was weighted twice as much as the fishery data.

This method of combining the fishery and survey data appears reasonable, but using equal exponential weights for the fishery and survey data is not consistent with the theory used to determine the exponential weights. Weighting the survey data twice as much as the fishery data when combining the data, as described above, fits the theory. However using the same exponential weights for the fishery and survey data does not. More study is needed to resolve this inconsistency.

Apportionments are based on survey and fishery information	2000 ABC Apportion ment	2000 Survey RPW	1999 Fishery RPW	2001 ABC Apportion ment	2000 ABC	2001 ABC	change
Total					17,230	**16,900**	-2%
Bering Sea	9%	8%	9%	9%	1,470	**1,560**	6%
Aleutians	14%	16%	15%	15%	2,430	**2,500**	3%
Gulf of Alaska	77%	76%	77%	76%	13,330	**12,840**	-4%
Western	14%	20%	14%	16%	1,840	**2,010**	9%
Central	43%	42%	39%	42%	5,730	**5,410**	-6%
W. Yakutat	15%	13%	19%	15%	2,020	**1,880**	-7%
E. Yakutat / Southeast	28%	25%	29%	28%	3,740	**3,540**	-5%

The 2001 apportionment percentages generally match both the survey and fishery regional estimates of abundance for the Bering Sea, Aleutians, and Gulf of Alaska. For example for the Gulf of Alaska, the 2001 ABC percentage is 76%, the 2000 survey RPW is 76% and the 1999 fishery RPW is 77%. Within the Gulf of Alaska, the survey and fishery percentages are less consistent, with the survey indicating more fish in the Western and Central Gulf of Alaska and fewer fish in the eastern Gulf of Alaska than the fishery. This occurs because survey catch rates are higher than fishery catch rates in the Western and Central Gulf of Alaska, whereas survey and fishery catch rates are similar in the eastern Gulf of Alaska (Appendix C, Figure 5).
Regional estimates of age-4+ biomass are tabulated in Table 9.

Overfishing level

Applying an adjusted $F_{35\%}$ as prescribed for Over Fishing Level (OFL) in Tier 3b results in a value of 20,700 mt for the combined stock. The OFL is apportioned by region, Bering Sea (1,910 mt), Aleutian Islands (3,070 mt), and Gulf of Alaska (15,720 mt), by the same method as the survey-based ABC apportionment.

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Table 1.--Sablefish fork length (cm), weight (kg), and proportion mature by age and sex. Maturity at age was computed using logistic equations fit to the length/maturity relationships shown in Sasaki (1985, Figure 23). A value of 0.4 is used for the slope parameter for maturity at length (cm) of 50 percent maturity.

	Fork length (cm)		**Weight (kg)**		**Fraction mature**	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2	50	52	1.2	1.4	0.059	0.006
3	53	56	1.5	1.7	0.165	0.024
4	55	59	1.7	2.1	0.343	0.077
5	57	62	1.9	2.4	0.543	0.198
6	59	64	2.1	2.7	0.704	0.394
7	61	66	2.3	3.0	0.811	0.604
8	62	68	2.4	3.3	0.876	0.765
9	63	70	2.6	3.6	0.915	0.865
10	64	71	2.7	3.9	0.939	0.921
11	65	72	2.8	4.1	0.954	0.952
12	65	74	2.9	4.3	0.964	0.969
13	66	75	3.0	4.5	0.971	0.979
14	66	76	3.1	4.7	0.976	0.986
15	67	76	3.1	4.9	0.979	0.990
16	67	77	3.2	5.1	0.982	0.992
17	67	78	3.2	5.2	0.984	0.994
18	67	78	3.2	5.3	0.985	0.995
19	68	79	3.3	5.4	0.986	0.996
20	68	79	3.3	5.5	0.987	0.997
21	68	80	3.3	5.6	0.988	0.997
22	68	80	3.3	5.7	0.988	0.998
23	68	80	3.4	5.8	0.989	0.998
24	68	81	3.4	5.9	0.989	0.998
25	68	81	3.4	5.9	0.989	0.998
26	68	81	3.4	6.0	0.990	0.998
27	68	81	3.4	6.0	0.990	0.999
28	69	81	3.4	6.1	0.990	0.999
29	69	82	3.4	6.1	0.990	0.999
30	69	82	3.4	6.1	0.990	0.999

Table 2--Alaska sablefish catch, 1956-1999. The values include landed catch and discard estimates. For years where discard estimates were not available from observer data (before 1993), discards were estimated for U.S. fisheries by multiplying reported catch by 2.9% for fixed gear and 26.9% for trawl gear.

		BY AREA								BY GEAR	
Year	GRAND TOTAL	Bering Sea	Aleutians	Western	Central	Eastern	West Yakutat	E. Yakutat/ Southeast	Un-known	Fixed	Trawl
1956	773	0	0	0	0	773			0	773	0
1957	2,059	0	0	0	0	2,059			0	2,059	0
1958	477	6	0	0	0	471			0	477	0
1959	910	289	0	0	0	621			0	910	0
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,433	668	2,080	739	11,971	9,975	4,619	5,356	0	22,912	2,521
1994	23,760	694	1,726	555	9,495	11,290	4,497	6,793	0	20,797	2,963
1995	20,954	990	1,333	1,747	7,673	9,211	3,866	5,345	0	18,342	2,612
1996	17,577	697	905	1,648	6,772	7,555	2,899	4,656	0	15,390	2,187
1997	14,922	728	929	1,374	6,237	5,653	1,928	3,725	0	13,287	1,635
1998	14,108	614	734	1,435	5,877	5,448	1,969	3,479	0	12,644	1,464
1999	13,575	677	671	1,487	5,873	4,867	1,709	3,158	0	11,590	1,985

Table 3--Discarded catches of sablefish (amount [mt] and percent of total catch) by target fishery, gear (H&L=hook & line, TWL=trawl), and management area for 1994 to 1999.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (H&L)	1994	7	4	16	1	11	2	75	1	39	1	66	1
	1995	5	1	8	1	40	2	111	2	71	2	132	2
	1996	7	2	9	1	33	2	137	3	56	2	79	2
	1997	8	4	19	3	41	3	116	2	88	5	123	3
	1998	6	4	5	1	91	6	210	5	46	2	184	5
	1999	2	1	34	6	38	3	124	3	27	2	68	2
Greenland	1994	1	1	2	3	0	-	0	-	0	-	0	-
turbot (H&L)	1995	82	48	40	53	0	-	0	-	0	-	0	-
	1996	75	41	5	17	0	-	0	-	0	-	0	-
	1997	92	40	1	11	0	-	0	-	0	-	0	-
	1998	85	31	7	5	0	-	0	-	0	-	0	-
	1999	45	24	13	19	0	-	0	-	0	-	0	-
Pacific cod (H&L)	1994	7	15	1	2	1	23	0	-	0	-	0	-
	1995	15	37	2	18	2	96	4	11	0	-	0	-
	1996	15	64	13	19	0	-	0	-	0	-	0	-
	1997	15	71	5	16	8	75	114	89	0	-	0	-
	1998	9	63	4	31	0	-	5	46	0	2	0	-
	1999	9	61	2	12	0	-	1	6	0	-	0	-
All other (H&L)	1994	0	0	0	0	0	-	0	-	4	72	0	-
	1995	0	0	3	83	0	-	0	-	0	-	0	7
	1996	0	57	0	6	0	-	0	-	0	-	0	-
	1997	1	39	0	-	0	-	0	-	0	-	0	-
	1998	2	90	0	-	0	-	3	36	0	5	6	48
	1999	0	5	0	0	0	4	1	61	1	26	6	48
Total H&L	1994	14	5	19	1	11	3	75	1	44	1	66	1
	1995	102	16	52	5	42	3	115	2	71	2	132	2
	1996	98	19	27	4	33	2	137	3	56	2	79	2
	1997	117	24	25	3	49	4	230	5	88	5	123	3
	1998	101	22	16	3	91	6	218	5	46	2	190	5
	1999	57	15	48	7	38	3	126	3	28	2	74	2

Table 3 cont.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (TWL)	1994	13	28	0	-	0	-	10	15	0	-	0	-
	1995	0	-	1	10	0	-	62	61	0	-	0	-
	1996	0	1	0	-	0	-	1	2	2	3	0	-
	1997	0	-	0	-	0	-	0	-	0	-	0	-
	1998	0	-	0	-	0	-	0	-	0	-	0	-
	1999	0	-	0	-	0	-	0	-	0	-	0	-
Rockfish (TWL)	1994	1	-	9	12	1	1	54	8	28	13	0	-
	1995	0	-	1	4	2	4	167	21	57	25	0	-
	1996	0	5	0	2	0	-	208	19	28	13	0	-
	1997	0	-	1	5	0	5	159	19	5	13	0	-
	1998	0	-	0	1	0	-	67	9	0	-	0	-
	1999	0	-	0	-	1	1	250	30	2	1	0	-
Arrowtooth (TWL)	1994	0	-	0	-	0	-	20	42	0	-	0	-
	1995	0	-	0	-	0	-	286	75	0	-	0	-
	1996	0	-	0	-	1	36	133	76	0	-	0	-
	1997	0	-	0	-	0	-	24	47	0	-	0	-
	1998	5	21	0	-	13	62	62	96	0	-	0	-
	1999	6	13	0	-	32	78	53	81	0	-	0	-
Deepwater flatfish (TWL)	1994	0	-	0	-	0	-	180	40	12	26	47	73
	1995	0	-	0	-	0	-	76	41	7	22	0	-
	1996	0	-	0	-	0	-	66	39	6	23	0	-
	1997	0	-	0	-	0	-	117	47	3	49	93	59
	1998	0	-	0	-	0	-	71	35	1	29	0	-
	1999	0	-	0	-	0	-	130	65	33	61	0	-
Shallow water flatfish (TWL)	1994	0	-	0	-	0	-	9	8	0	-	0	-
	1995	0	-	0	-	0	-	18	33	0	-	0	-
	1996	0	-	0	-	0	-	7	23	0	-	0	-
	1997	0	-	0	-	0	-	11	32	0	-	0	-
	1998	0	-	0	-	0	-	32	84	0	-	0	-
	1999	0	-	0	-	0	-	0	-	0	-	0	-
Rex sole (TWL)	1994	0	-	0	-	0	-	137	30	0	-	0	-
	1995	0	-	0	-	0	-	36	16	6	94	0	-
	1996	0	-	0	-	0	-	32	24	42	-	0	-
	1997	0	-	0	-	0	3	5	13	16	77	0	-
	1998	0	-	0	-	3	34	6	11	0	-	0	-
	1999	0	-	0	-	32	64	18	24	0	-	0	-
Greenland turbot (TWL)	1994	35	12	10	18	0	-	0	-	0	-	0	-
	1995	7	3	16	22	0	-	0	-	0	-	0	-
	1996	3	6	0	-	0	-	0	-	0	-	0	-
	1997	0	1	0	-	0	-	0	-	0	-	0	-
	1998	1	1	0	-	0	-	0	-	0	-	0	-
	1999	6	5	0	-	0	-	0	-	0	-	0	-
All other (TWL)	1994	17	48	0	4	3	54	35	25	0	-	0	-
	1995	13	61	3	49	8	70	18	20	0	-	0	-
	1996	16	26	10	77	2	13	1	13	0	-	0	-
	1997	11	37	0	23	1	15	44	48	0	-	0	-
	1998	7	11	4	43	4	62	56	54	1	39	0	-
	1999	37	29	0	-	39	99	122	86	0	-	0	-
Total TWL	1994	66	17	18	12	4	4	445	23	40	15	47	63
	1995	20	7	20	19	10	13	663	36	70	26	0	-
	1996	19	14	10	41	3	11	448	27	77	22	0	-
	1997	11	20	1	6	2	8	360	28	23	35	93	55
	1998	12	9	4	21	20	44	294	24	2	3	0	-
	1999	48	17	0	-	103	59	572	43	35	18	0	-
Grand total	1994	80	12	38	2	15	3	520	6	83	2	112	2
	1995	122	13	72	7	53	3	777	10	141	4	132	2
	1996	117	18	36	5	35	2	585	9	133	5	79	2
	1997	128	23	26	3	51	4	589	9	111	6	216	6
	1998	114	19	20	3	111	8	512	9	48	2	190	5
	1999	109	16	49	7	141	9	703	12	63	4	74	2

Table 4.--Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data. Survey sample sizes are approximate; exact values will be tabulated for the next year's assessment.

	LENGTH						AGE	
	Japanese fishery		U.S. fishery		Cooperative longline survey	Domestic longline survey	Cooperative longline survey	Domestic longline survey
Year	Trawl	Longline	Trawl	Longline				
1963		30,562						
1964	3,337	11,377						
1965	6,267	9,631						
1966	27,459	13,802						
1967	31,868	12,700						
1968	17,727							
1969	3,843							
1970	3,456							
1971	5,848	19,653						
1972	1,560	8,217						
1973	1,678	16,332						
1974		3,330						
1975								
1976		7,704						
1977		1,079						
1978		9,985						
1979		1,292			100,000			
1980		1,944			100,000			
1981					100,000		1,200	
1982					100,000			
1983					100,000		1,200	
1984					100,000			
1985					100,000			
1986					100,000			
1987					100,000		1,200	
1988					100,000			
1989					100,000		1,200	
1990			1,229	33,822	100,000	60,000		
1991			721	29,615	100,000	60,000	1,200	
1992			0	21,000	100,000	60,000		
1993			468	23,884	100,000	60,000	1,200	
1994			89	13,614	100,000	60,000		
1995			87	18,174		60,000		
1996			239	15,213		60,000		1,200
1997			0	20,311		60,000		1,200
1998			35	8,900		60,000		1,200
1999			1,268	26,662		60,000		1,200
2000						60,000		

Table 5.--Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. One or two indices of population abundance were computed: catch per effort in numbers weighted by respective strata areas to produce a relative population number (RPN) and catch per effort measured in weight multiplied by strata areas, to produce a relative population weight (RPW). Indices were extrapolated for unsampled survey areas: Aleutian Islands 1979, 1995, 1997, 1999; Bering Sea 1979-1981, 1995, 1996, 1998.

	RPN		RPW			
Year	**Cooperative longline survey**	**Domestic longline survey**	**Japanese longline fishery**	**Cooperative longline survey**	**Domestic longline survey**	**U.S. fishery**
1964			1,452			
1965			1,806			
1966			2,462			
1967			2,855			
1968			2,336			
1969			2,443			
1970			2,912			
1971			2,401			
1972			2,247			
1973			2,318			
1974			2,295			
1975			1,953			
1976			1,780			
1977			1,511			
1978			942			
1979	413		809	1,075		
1980	388		1,040	968		
1981	460		1,343	1,153		
1982	613			1,572		
1983	621			1,632		
1984	685			1,822		
1985	903			2,569		
1986	838			2,456		
1987	667			2,068		
1988	707			2,088		
1989	661			2,178		
1990	450	649		1,454	2,141	1,201
1991	386	593		1,321	2,071	1,066
1992	402	511		1,390	1,758	908
1993	395	563		1,318	1,894	904
1994	366	489		1,288	1,882	822
1995		501			1,803	1,243
1996		520			2,017	1,201
1997		491			1,764	1,341
1998		466			1,662	1,130
1999		511			1,740	1,209
2000		461			1,597	na

Table 6.--Sablefish age 4+ biomass, exploitable biomass, spawning biomass, and catch (thousands mt) by year. Projected values assume catch for adjusted $F_{40\%}$ and recruitment based on average for 1982-1996 year classes.

Year	Age 4+ biomass	Exploitable biomass	Spawning biomass	Catch	Catch / Age 4+ biomass
1960	282	246	245	3.1	0.011
1961	270	244	241	16.1	0.060
1962	245	228	226	26.4	0.108
1963	244	199	210	16.9	0.069
1964	395	193	226	7.3	0.018
1965	398	232	272	8.7	0.022
1966	393	315	319	15.6	0.040
1967	387	348	341	19.2	0.050
1968	475	336	340	31.0	0.065
1969	443	333	348	36.8	0.083
1970	397	344	345	37.8	0.095
1971	447	334	337	43.5	0.097
1972	405	303	313	53.0	0.131
1973	358	299	298	36.9	0.103
1974	320	285	277	34.6	0.108
1975	271	252	243	29.9	0.110
1976	226	217	208	31.7	0.140
1977	184	178	175	21.4	0.117
1978	203	151	155	10.4	0.051
1979	189	142	151	11.9	0.063
1980	177	151	158	10.4	0.059
1981	289	157	174	12.6	0.044
1982	290	169	199	12.0	0.041
1983	324	222	237	11.8	0.036
1984	387	291	275	14.1	0.036
1985	433	366	301	14.5	0.033
1986	421	404	332	28.9	0.069
1987	389	383	333	35.2	0.091
1988	387	356	316	38.4	0.099
1989	341	326	282	34.8	0.102
1990	310	298	263	32.1	0.104
1991	266	265	238	27.0	0.101
1992	262	242	214	24.9	0.095
1993	235	231	201	25.4	0.108
1994	243	222	189	23.8	0.098
1995	234	192	184	20.9	0.089
1996	224	191	179	17.6	0.079
1997	209	187	176	14.9	0.071
1998	212	181	173	14.1	0.067
1999	224	179	172	13.6	0.061
2000	206	181	171	13.6	0.066
2001	246	186	178	16.9	0.069
2002			179	17.2	
2003			185	18.8	
2004			189	19.2	
2005			190	19.3	

Table 7--Alaska sablefish harvest information.

M	0.098
Age at 50% selection for survey	4.1
Age at 50% selection for "derby" fishery	4.1
Age at 50% selection for IFQ fishery	5.1
Equilibrium unfished spawning biomass	532
Reference point spawning biomass, $B_{40\%}$	213
Reference point spawning biomass, $B_{35\%}$	186
2001 exploitable biomass	186
2001 spawning biomass	178
Ratio 2001 : unfished spawning biomass	0.34
HARVEST ALTERNATIVES	
Maximum permissible fishing level	
$F_{40\%}$	0.120
2001 $F_{40\%\ adj}$	0.100
2001 $F_{40\%\ adj}$ Yield	16.9
Overfishing level	
$F_{35\%}$	0.149
2000 $F_{35\%\ adj}$	0.124
2000 $F_{35\%\ adj}$ Yield	20.7
Authors' recommendation	
2001 F	0.100
2001 ABC	16.9

Table 8--Alaska sablefish spawning biomass, fishing mortality, and yield for seven harvest scenarios. The reference spawning biomass used to determine if the population is overfished, $B_{35\%}$, is 186 thousand mt, which sablefish are projected to reach by 2007, so Alaska sablefish are not classified as overfished. Projections are based on the 1977 to 1996 year classes.

Year	Maximum permissible F	Fraction maximum F	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass							
2000	171	171	171	171	171	171	172
2001	178	178	178	178	178	178	180
2002	179	179	186	180	194	175	183
2003	185	185	199	187	215	179	195
2004	189	189	210	193	236	181	200
2005	190	190	216	195	251	180	199
2006	196	196	228	203	272	185	200
2007	199	199	234	206	287	186	198
2008	205	205	245	214	308	191	200
2009	206	206	250	216	321	191	199
2010	212	212	260	223	342	196	201
2011	213	213	265	226	355	197	201
2012	216	216	271	230	370	198	201
2013	217	217	276	232	383	199	200
Fishing mortality							
2000	0.082	0.082	0.082	0.082	0.082	0.082	0.082
2001	0.100	0.100	0.050	0.093	0.000	0.124	0.101
2002	0.100	0.100	0.052	0.093	0.000	0.122	0.103
2003	0.104	0.104	0.056	0.093	0.000	0.124	0.134
2004	0.105	0.105	0.058	0.093	0.000	0.125	0.135
2005	0.104	0.104	0.057	0.093	0.000	0.122	0.131
2006	0.105	0.105	0.058	0.093	0.000	0.123	0.130
2007	0.104	0.104	0.057	0.093	0.000	0.123	0.128
2008	0.105	0.105	0.058	0.093	0.000	0.124	0.129
2009	0.105	0.105	0.058	0.093	0.000	0.124	0.128
2010	0.107	0.107	0.058	0.093	0.000	0.126	0.128
2011	0.107	0.107	0.058	0.093	0.000	0.126	0.128
2012	0.108	0.108	0.059	0.093	0.000	0.127	0.128
2013	0.108	0.108	0.059	0.093	0.000	0.127	0.128
Yield							
2000	13.6	13.6	13.6	13.6	13.6	13.6	13.6
2001	16.9	16.9	8.6	15.8	0.0	20.7	17.1
2002	17.2	17.2	9.5	16.2	0.0	20.3	17.9
2003	18.8	18.8	11.1	17.1	0.0	21.5	25.3
2004	19.2	19.2	11.9	17.3	0.0	21.6	26.1
2005	19.3	19.3	12.3	17.6	0.0	21.5	25.5
2006	20.3	20.3	13.0	18.4	0.0	22.4	25.4
2007	20.5	20.5	13.4	18.7	0.0	22.7	25.1
2008	21.4	21.4	14.1	19.4	0.0	23.5	25.4
2009	21.7	21.7	14.5	19.7	0.0	23.7	25.2
2010	22.5	22.5	15.1	20.2	0.0	24.5	25.5
2011	22.8	22.8	15.5	20.6	0.0	24.7	25.5
2012	23.1	23.1	15.8	20.9	0.0	25.0	25.5
2013	23.3	23.3	16.1	21.1	0.0	25.1	25.4

Table 9.--Regional estimates of sablefish age-4+ biomass. Age 4+ biomass was estimated by year and region by applying only survey-based weights, similar to the method used to allocate the ABC (except that the ABC allocation also used fishery data).

Year	Bering Sea	Aleutian Islands	Gulf of Alaska	Alaska
1979	33	37	119	189
1980	31	34	111	177
1981	49	68	172	289
1982	50	66	175	290
1983	55	65	203	324
1984	69	79	239	387
1985	79	94	260	433
1986	81	89	251	421
1987	77	77	235	389
1988	57	82	249	387
1989	42	64	235	341
1990	42	61	207	310
1991	36	44	186	266
1992	25	40	197	262
1993	20	33	183	235
1994	14	33	196	243
1995	17	31	185	234
1996	17	31	176	224
1997	18	24	167	209
1998	18	22	171	212
1999	20	30	174	224
2000	17	31	158	206
2001	20	38	188	246

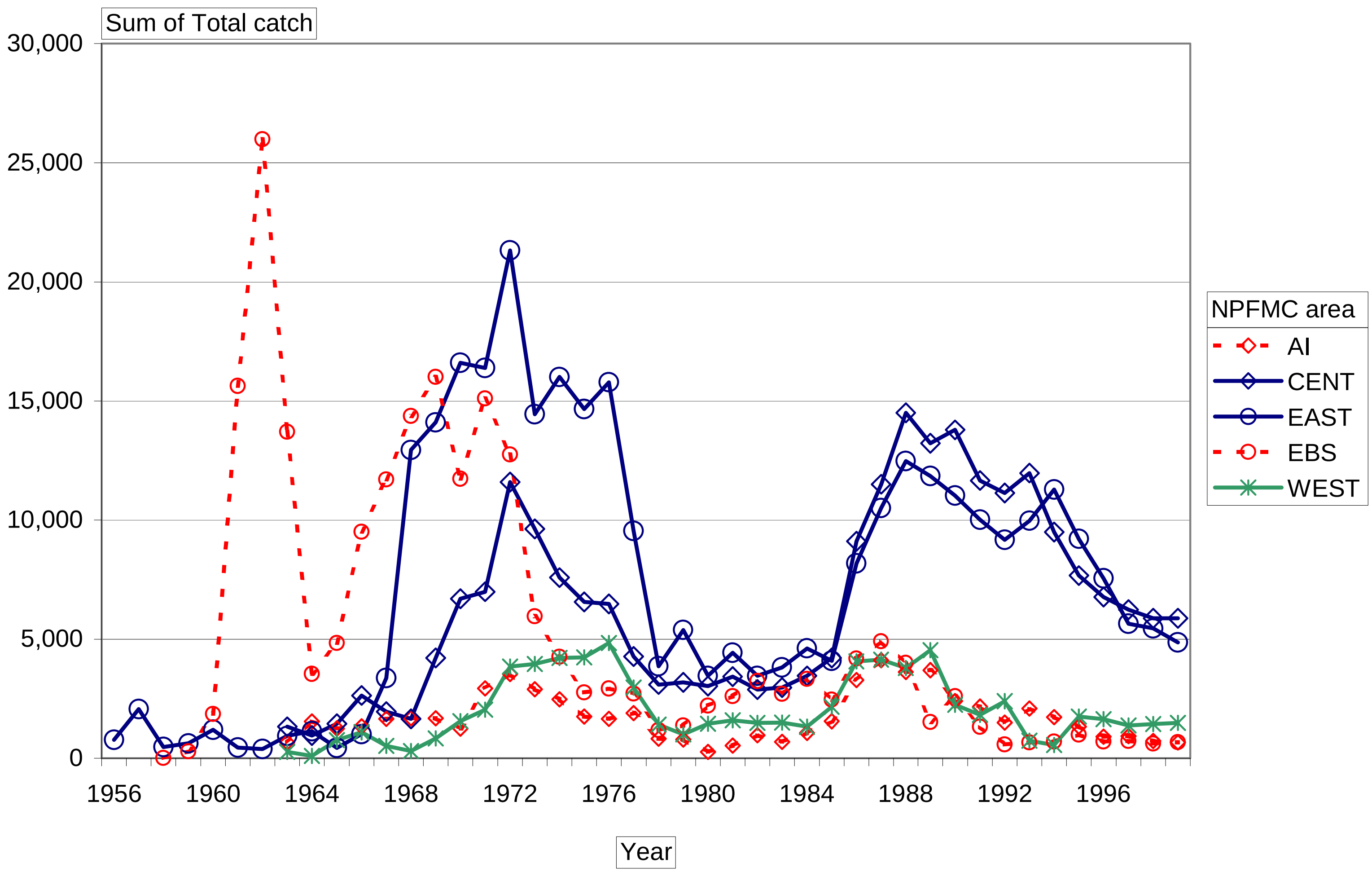

Figure 1--Sablefish fishery total reported catch (mt) by area and year.

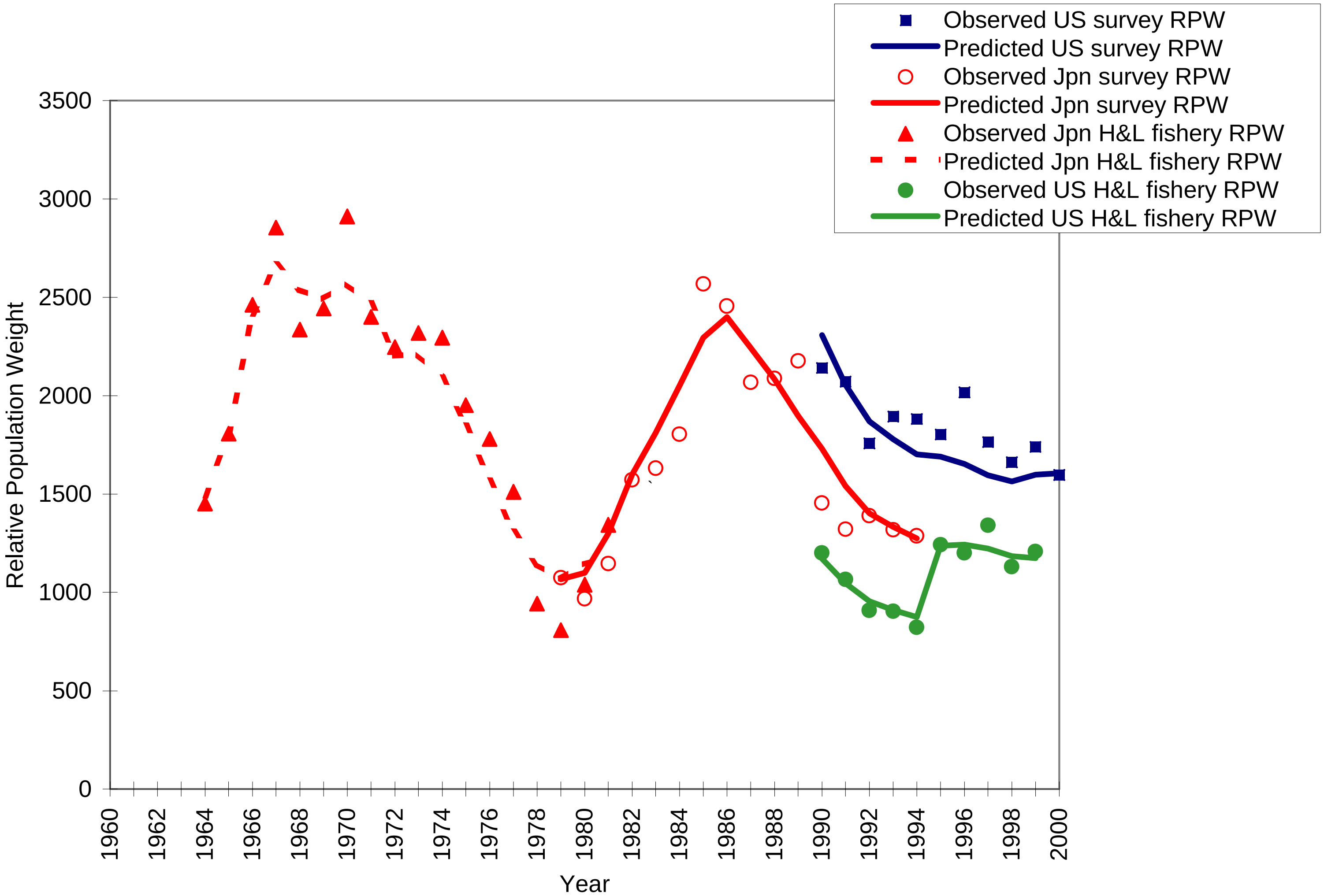

Figure 2.--Observed and predicted sablefish relative population weight versus year.

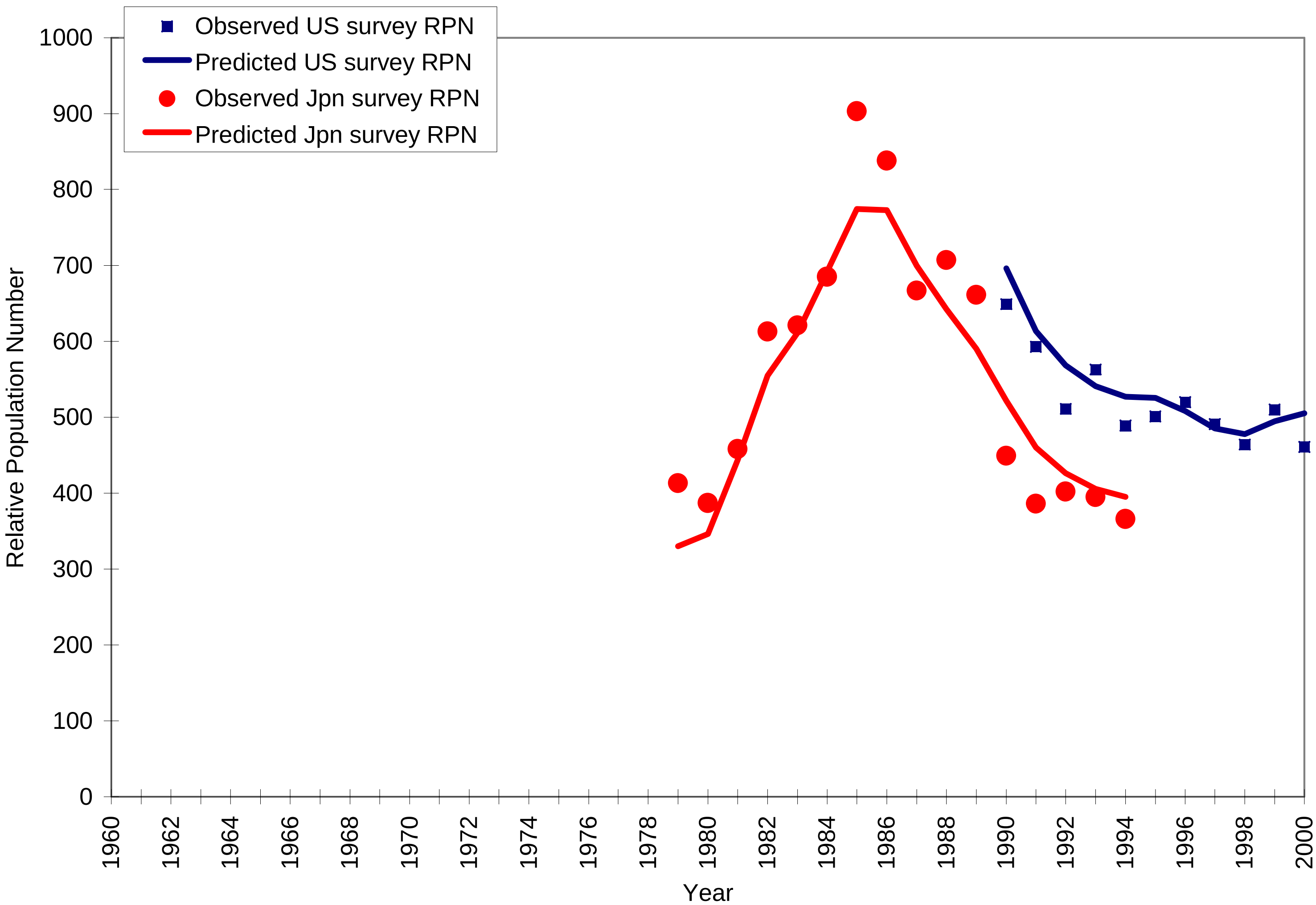

Figure 3.--Observed and predicted sablefish relative population number versus year.

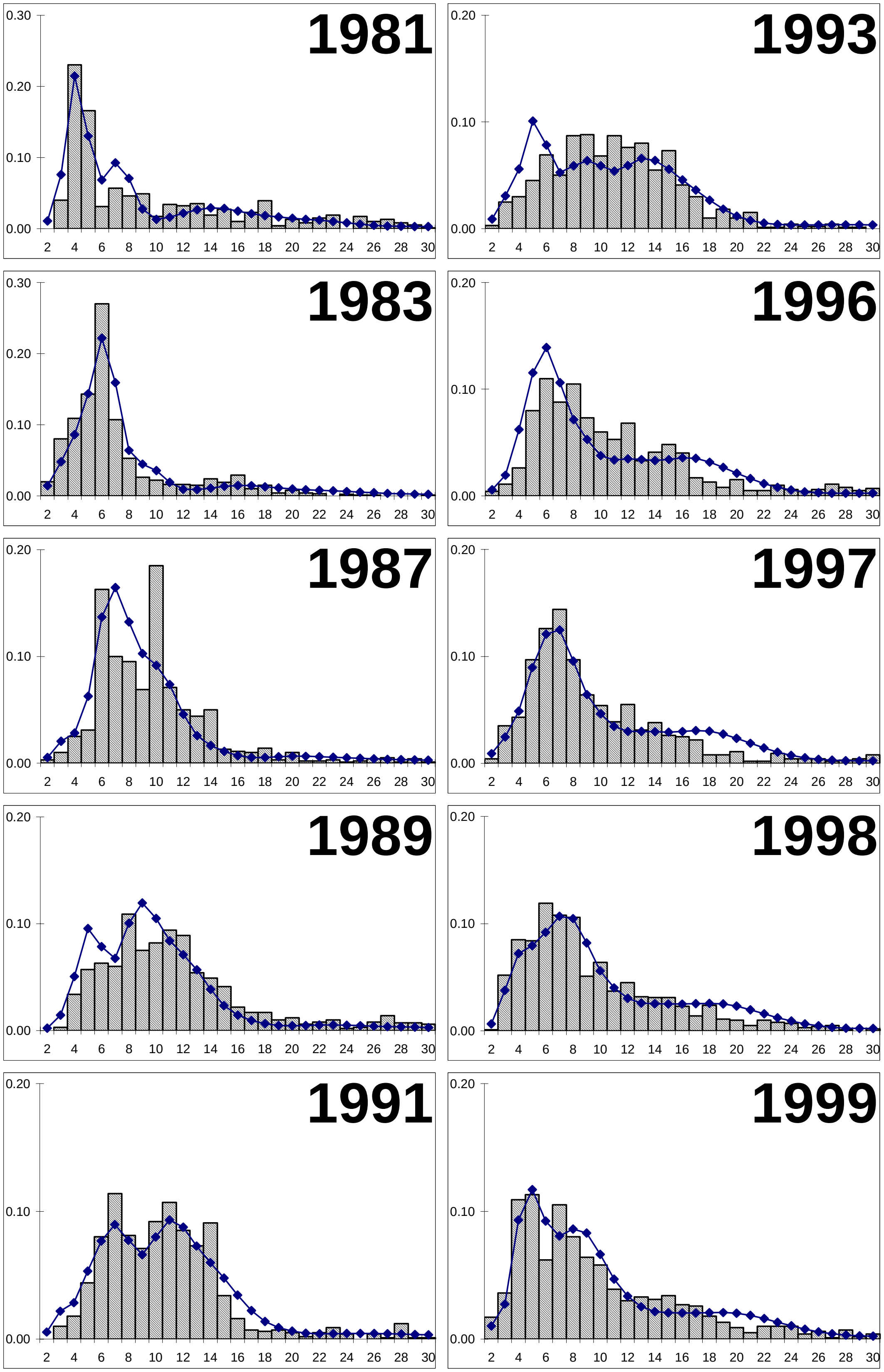

Figure 4 Observed (bar) and predicted (line) sablefish survey age frequency by age group and year.

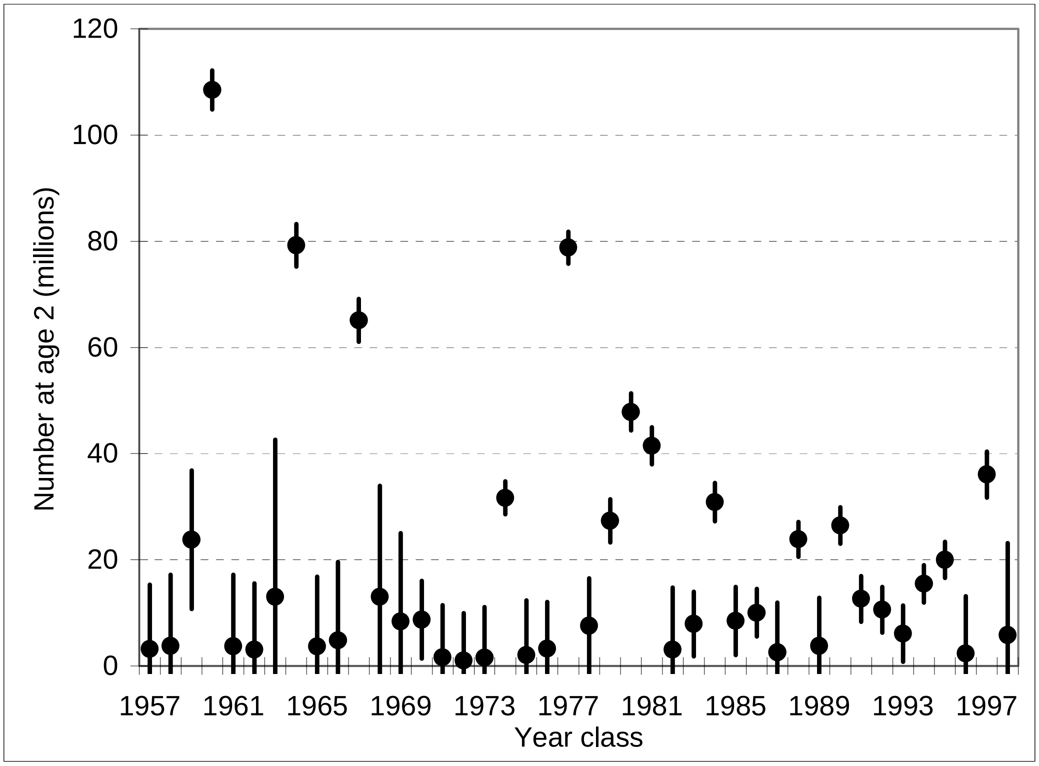

Figure 5 Model estimates of the number of age-2 sablefish (millions) +/- 2 standard errors by year class. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated.

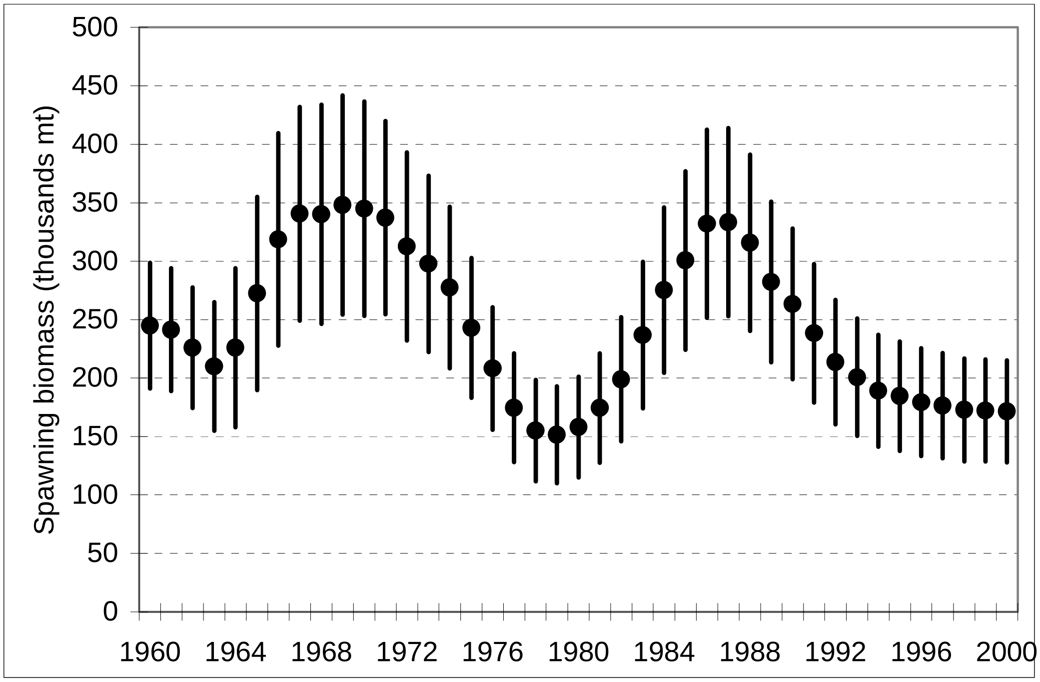

Figure 6 Model estimates of male and female spawning biomass (thousands mt) +/- 2 standard errors by year. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated..

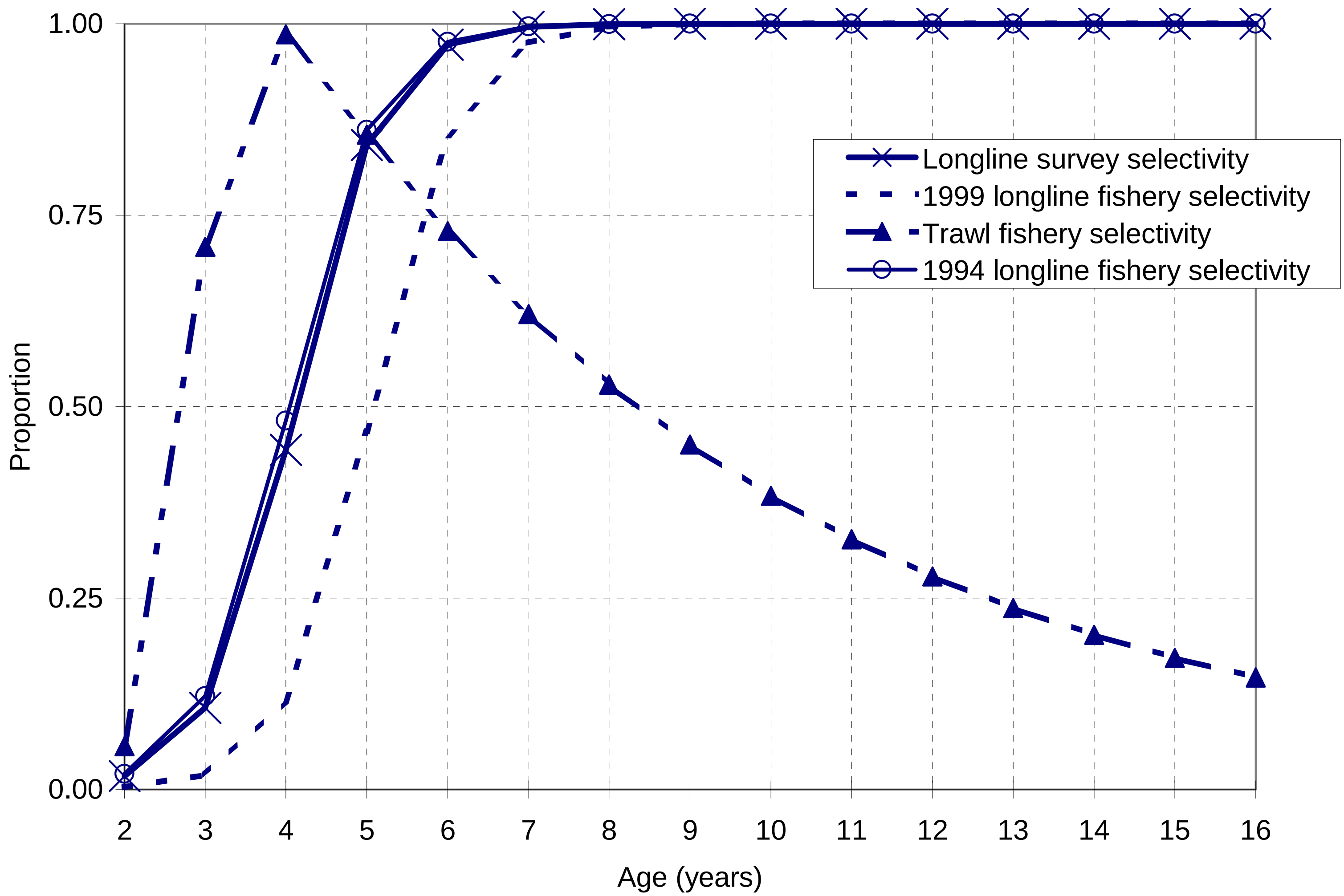

Figure 7 Sablefish survey, longline fishery, and trawl fishery selectivity functions. We chose to display the 1994 and 1999 longline selectivity functions because they are representative of the selectivity functions for the short open-access seasons ("derby" fishery) and IFQ seasons respectively.

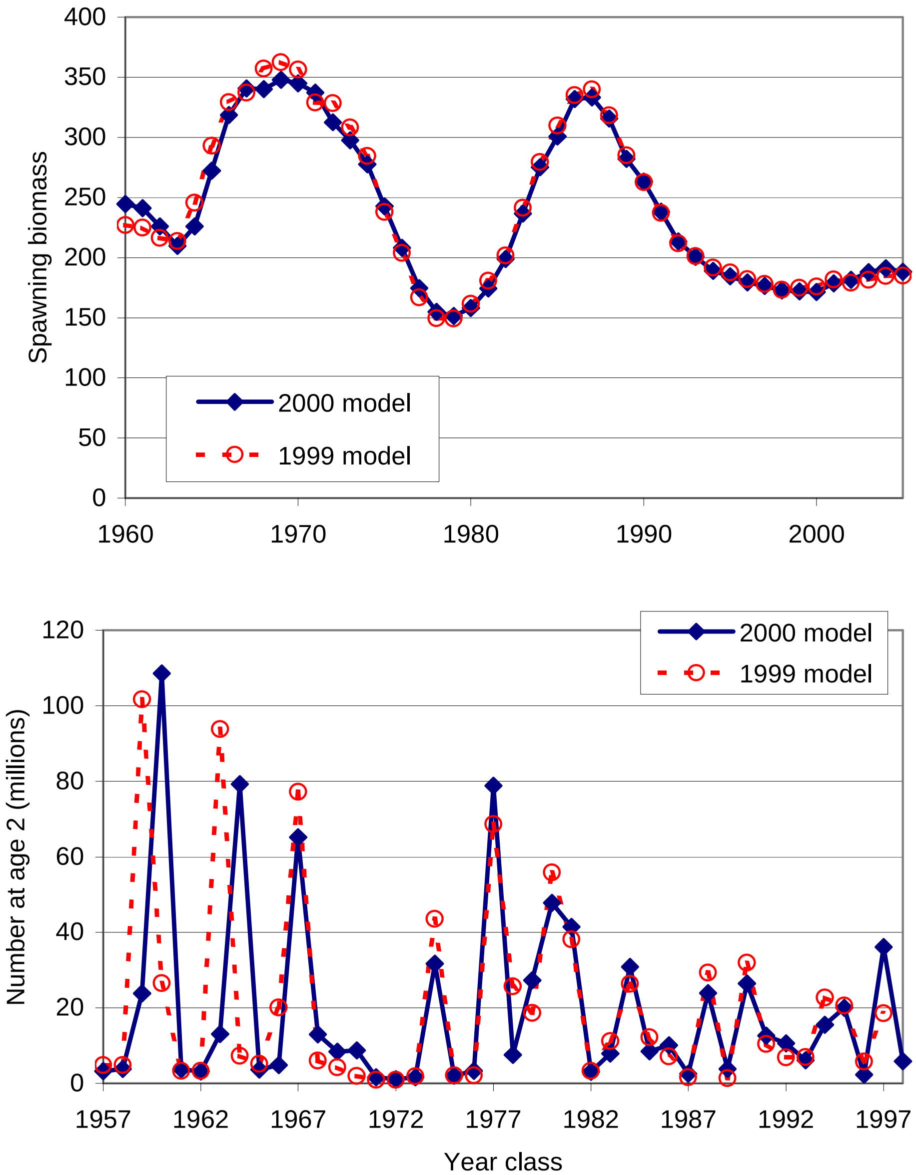

Figure 8 Estimated and projected sablefish spawning biomass (thousands mt) versus year and estimated recruitment (number at age 2, millions) for the 1999 and 2000 assessments.

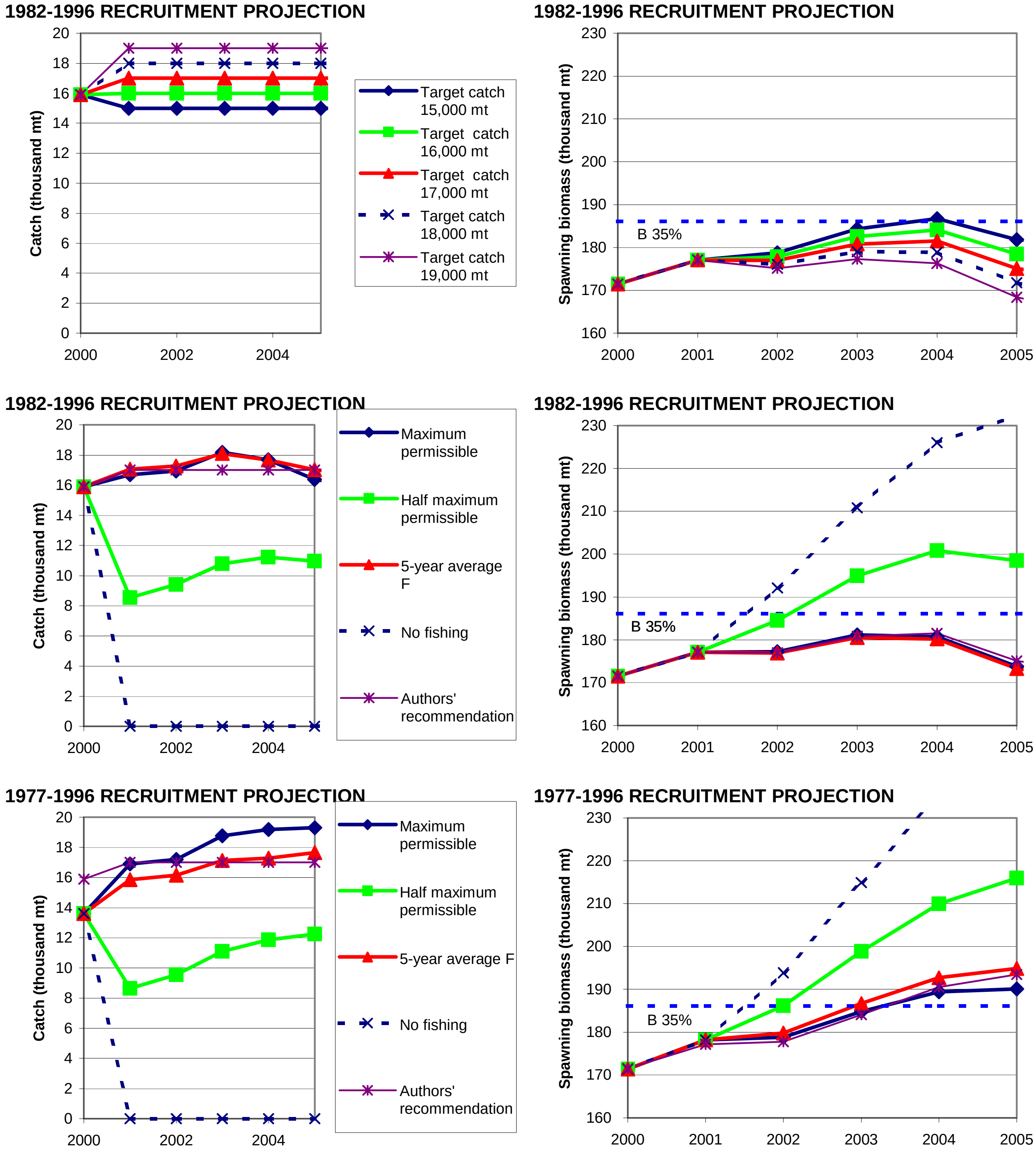

Figure 9--Sablefish spawning biomass and catch (thousands mt) for two recruitment scenarios and several harvest alternatives. Recruitment is projected using average recruitment for the 1982-1996 year classes or for the 1977-1996 year classes, which includes the exceptional 1977-1981 year classes. The harvest alternatives are described in section 5.1, *Sablefish-specific population projections* and *Standard set of population projections*. The authors' recommended ABC is 16,900 mt.

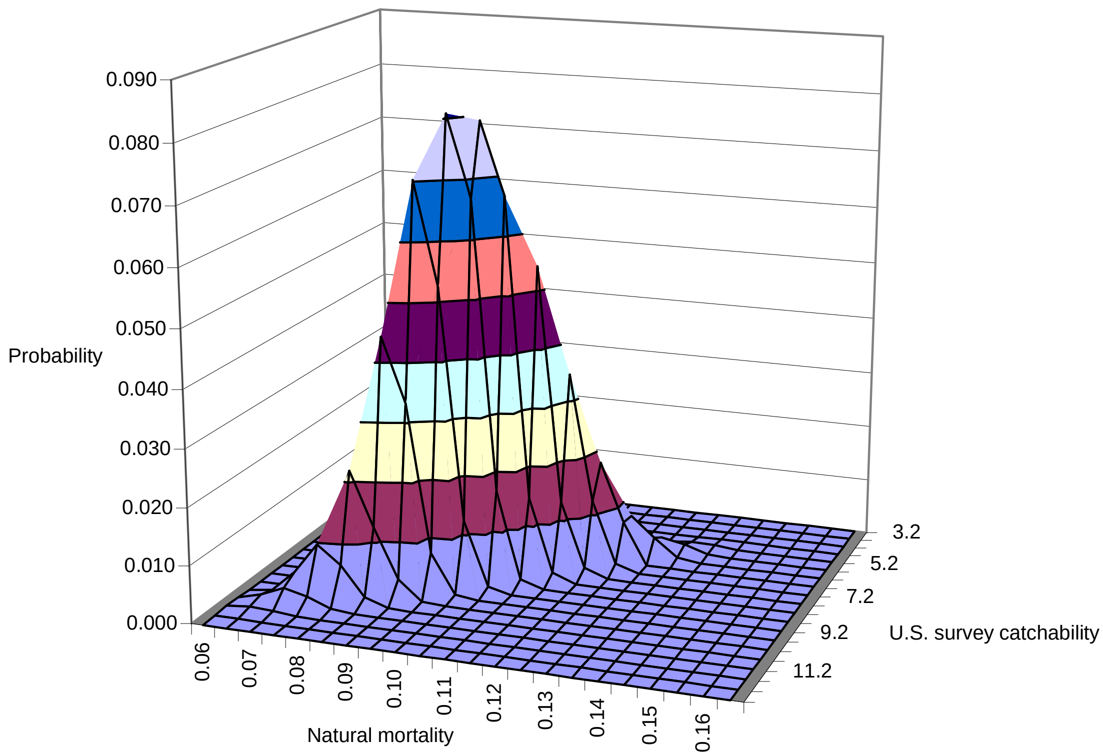

Figure 10.--Posterior probability versus catchability and natural mortality.

Appendix A.--The equations listed below were used to compile the fishery and survey data used in the assessment. Some notes about the data are: The strata for U.S. fisheries data are Bering, Aleutians, Western, Central, West Yakutat, East Yakutat / Southeast, but are coarser for the Japanese fisheries: Bering Sea and Aleutians combined and Western, Central, West Yakutat, East Yakutat / Southeast combined, i.e. Gulf of Alaska.

Fishery data

For all years, let

w_k = weight at length k,

A_m = Areal size of strata.

For each year, let

Y_m = catch in weight for strata m,

Y_{mn} = catch in weight for strata m and set n,

E_{mn} = effort in number of hooks for strata m and set n,

f_{km} = proportion for length k and strata m,

then

$U_m \equiv \frac{\sum_n Y_{mn}/E_{mn}}{N}$ = Catch per hook for strata m,

$RPW_m \equiv U_m A_m$ = Relative population weight for strata m,

$\overline{w}_m \equiv \sum_k f_{km} w_k$ = mean weight

$c_m \equiv y_m / \overline{w}_m$ = catch in number

$f_k \equiv \sum_m f_{km} c_m / \sum_m c_m$ = proportion at length for Alaska

Length frequencies by statistical area were used to "randomize" the earlier age collections and compute an age frequency representative of the area's surveyed population (Kimura 1977). The age frequencies by area were weighted by the area RPN, then summed across area to obtain an RPN weighted age frequency for Alaska.

Appendix B.--The equations listed below were used to represent the sablefish population in Alaska.

Let $i = 1, \ldots y$ be the year index, and $j = 1, \ldots a$ be the age index. Let

c_i = the observed catch in numbers,
μ_i = the exploitation rate for fully vulnerable ages (i.e., ages for which $s_j = 1$),
s_j = the selectivity for age j fish such that the assumption of "separability" holds, i.e.,
$\mu_{ij} = \mu_i s_j$ = the exploitation fraction of age j fish during year i,
N_{ij} = the total number at age,
$N^f_{ij} = s_j N_{ij}$ = the fishable number at age, and

$$N_i^f = \sum_{j=1}^{a} N_{ij}^f \quad \text{= the fishable number.}$$

$U_{ij} = F_{ij} / (M + F_{ij})\ (1 - \exp(-M - F_{ij}))$ is the exploitation rate on age j fish in year i, assuming an instantaneous natural mortality rate of M. It follows that

$$N_{i+1,j+1} = N_{ij}\, e^{-M-F_{ij}}$$

and predicted catch would be $\hat{c}_{ij} = U_{ij} N_{ij}$.

A function which can describe either asymptotic or dome-shaped selectivity is the "exponential-logistic" function (Thompson 1994):

$$s_j = \left(\frac{1}{1-\gamma}\right)\left(\frac{1-\gamma}{\gamma}\right)^{\gamma}\left(\frac{e^{\beta\gamma(A_{50}-j)}}{1+e^{\beta(A_{50}-j)}}\right)$$

This function's advantages are that it automatically scales maximum vulnerability to 1.0, reduces to an asymptotic function of age as γ approaches zero, and A_{50} and β have biological meaning when $\gamma = 0$: A_{50} is the age where 50% of the population is vulnerable and β is the slope of the function at A_{50}.

We allowed A_{50} to vary with season length,

$$A_{50}^{s} = A_{50}\frac{1}{1+e^{-\beta(s-m_{50})}}$$

where s is season length in months, and A_{50}, β, and m_{50} are estimated.

A predicted abundance index in numbers is

$$\hat{S}_i = \hat{q}\hat{N}_i^{f}$$

where q is survey catchability and quantities predicted with the model are denoted with "hats." A predicted abundance index in weight is computed by multiplying the predicted abundance index in numbers by the predicted mean weight of the available population.

An ageing error matrix based on known-age otoliths (Heifetz et al 1999) was used to account for ageing error. Known-age otoliths were obtained in the following manner. Age-1+ sablefish have been tagged and released in nearshore waters of southeast Alaska annually since 1985. Otoliths sometimes were collectd with recoveries. These known-age fish were read in a blind test, where the age reader did not know the true age. The assigned ages were used to compute how often the true age was assigned, and if they differed, by how much. For example, of true age 3 fish, 0.15 were assigned age 2, 0.61 age 3, 0.23 age 4, and 0.01 age 5. The resultant matrix was used in the population model to convert predicted true age to predicted reader age. The known-age ageing error matrix was not available for last year's assessment and instead, age data were aggregated over several ages {2, 3, 4, 5, 6, 7, 8, 9-10, 11-15, 16+}, as suggested by Deriso et al. (1989) if errors are present in age compositions.

An age-length transition matrix also was calculated from the survey results, where l_{jk} = the probability that a fish sampled of age class j will be of length class k. The predicted length distributions are

$$\hat{f}_{ik} = \sum_j \hat{p}_{ij} l_{jk}$$

The length data were aggregated into 2-cm length classes by sex: {40-41, 42-43, . . . 98-99 cm fork length}.

Parameters can be estimated by assuming the probability distributions of the sampled abundnace indices, age, and length data are known. Fournier and Archibald (1982) suggested multinomial errors for age data and log-normal errors for catch data. Log-normal errors were assumed for the abundance indices and multinomial errors for the age and length data. The log-likelihood incorporating the sablefish data is (not all data is shown for brevity)

$$L = \sum_{ij} m_i p_{ij} \log \frac{\hat{p}_{ij}}{p_{ij}} + \sum_{ik} n_i f_{ik} \log \frac{\hat{f}_{ik}}{f_{ik}} - \frac{1}{2\sigma^2} \sum_i (\log(S_i) - \log(\hat{q}\hat{N}_i^f))^2$$

where m_i and n_i are the number of ages and lengths sampled in year i and σ^2 is the variance of the observed abundance index. Maximum likelihood estimates for the parameters can be found by maximizing L. As noted by Kimura (1989, 1990), reliability in the estimation process is improved if the log-parameters rather than parameters on the original scale are estimated. This makes the parameters more similar in magnitude, and probably reduces parameter-effects non-linearity (Ratkowsky 1983).

Data weighting

The variances of the age data and the survey index were estimated independently of the population modeling (Kimura 1977, Sigler and Fujioka 1988) and were used to weight the likelihood components of the population model. The estimated c.v. for the survey index is 0.05 and for the age data is 0.6. The effective sample size assuming a multinomial distribution was computed from the variance of the age data. Variances of the age and length data were assumed equal.

Appendix C.--Using fishery catch rates in the sablefish assessment

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6 October 2000

Introduction

Since 1979, annual longline surveys of the upper continental slope in the Gulf of Alaska, Aleutian Islands, and eastern Bering Sea have been conducted. Data from these surveys are used to index sablefish (*Anoplopoma fimbria*) abundance in Alaska. The survey abundance index is used in two ways, to estimate sablefish abundance with population models and to allocate the fishery quota among areas. Steady declines in survey catch rates of sablefish have led to reduced fishery quotas in recent years. Some fishermen are concerned that their catch rates have remained strong in some areas despite the decline in longline survey catch rates. Extensive fishery information is available through data collected by the domestic observer program and logbook data reported by fishermen. In this report, we compute fishery catch rates based on observer and logbook data and compare these fishery catch rates to survey data. We check for changes in fishery effort by season or area because fishery catch rates may not be representative of abundance because gear configurations and fishing patterns may vary. For example, fishermen sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). Overfishing of northern (Newfoundland) cod likely was made worse by incorrect interpretation of fishery catch rates: assessment scientists did not realize that the area occupied by the stock was diminishing while fishery catch rate remained level (Rose and Kulka 1999). The purpose of this paper is to demonstrate that use of catch rates for the sablefish assessment is reasonable.

Methods

Fishery data collection

Observers recorded data from 17,518 sablefish target longline sets from 1990 to 1999. Only data through 1999 are included in this analysis because the fishing season is not complete. Fishermen also recorded data from 538 sablefish target longline sets for a voluntary sablefish logbook program initiated in 1997. The latter program collects data from smaller boats not required to carry an observer. Only sets targeting sablefish are included. A sablefish targeted set was defined as a set where sablefish were at least 50% of the catch by weight.

Individual Fishery Quota (IFQ) management began in 1995 with fishing open from March 15 to November 15 and replaced short open access “derby” fisheries. Data collected from November 16 to March 14 since 1995 were excluded from the analysis because directed longline fishing for sablefish was closed, whereas data collected during this time period before 1995 were included since directed longline fisheries sometimes occurred throughout the year.

The logbook reported weights usually are approximate because vessel captains typically estimate and record catch for each set in the logbook while at sea and without an accurate scale measurement. An accurate weight for the entire trip is measured at landing and recorded as the IFQ landing report. We adjusted the captain’s estimate of catch per set using the ratio of IFQ landing report and logbook reported weight.

Hook spacing adjustment

Catch rates were standardized to account for differences in hook spacing. Thirty-nine and forty-two inch spacings are the most common spacings used in the directed sablefish longline fishery, accounting for 64% of all observed sets from 1990 to 1999 (Figure 1). We chose the 39 inch (1 m) spacing as the standard because it most matches one of the spacings tested in sablefish hook spacing experiments that we've conducted.

The hook spacing effect was measured for sablefish in three hook spacing experiments. One experiment was conducted in Chatham Strait near Tenakee Inlet from 4-13 July 1986 from the NOAA R/V John N. Cobb (Sigler 1986). Circle hooks (size equivalent to 13/0) baited with herring were used. Three hook spacings were tested, 1, 2, and 4 m; all three hook spacings were tested in each set. A second experiment was conducted from 25-26 July 1999 in the Gulf of Alaska off Icy Bay from the F/V Ocean Prowler. A third experiment was conducted from 25-26 July 2000 in the Gulf of Alaska off Yakutat Bay from the F/V Alaskan Leader. Circle hooks (size 13/0) baited with squid were used in the second and third experiments and four hook spacings were tested, 0.5, 1, 2, and 4 m. Catch rate per hook increased as hook spacing increased for all three experiments.

Skud and Hamley (1978) developed a method for standardizing halibut longline catch rates for hook spacing. This method continues to be applied by the Halibut Commission (Sullivan et al. 1999). They used an asymptotic function,

$$CPUE_h \ / \ CPUE_s = C_\infty (1 - \exp(-k\,h))$$

where *CPUE* is catch per hook, *h* is some hook spacing, *s* is the standard hook spacing, C_∞ is the maximum relative catch per hook and *k* is a measure of how fast this maximum is reached. This equation implies that catch per hook increases with hook-spacing, but at a rate less than proportional to hook-spacing. Skud and Hamley (1978) estimated the parameters of the equation for halibut longline gear from a series of hook spacing experiments. Similarly we estimated the parameters of the equation for sablefish longline gear from experimental data, finding estimates $C_\infty = 1.95$ and $k = 0.78$. The estimated asymptote is 1.95, only slightly larger than the relative catch per hook of 4-m gear. This implies that the relative catch per hook is near the maximum at this spacing.

Data used in this analysis were standardized for hook spacing differences using parameter estimates for the 1986 and 1999 experiments of $C_\infty = 2.2$ and $k = 0.57$, the standardization used in last year's sablefish assessment. The number of standardized hooks N_{std} was computed from the number of unstandardized hooks N_{unstd} and these parameter estimates

$$N_{std} = N_{unstd} \ 2.2 \ (1 - \exp(-0.57h)),$$

where *h* is expressed in meters. A standardized CPUE was calculated for each set by dividing the weight of the catch by the standardized number of hooks

$$CPUE_{std} = \frac{weight}{N_{std}}.$$

Computation of catch rate by area and year

The standardized catch rates by set were used to compute average catch rates by vessel for each North Pacific Fishery Management Council (NPFMC) region and year. The average catch rate by vessel were used to compute average catch rates by region and year. Standard errors of the mean and 95% confidence intervals also were computed. The observer and logbook data were combined when computing the average catch rates by region and year.

Check whether fishing patterns have changed

Fishery data were stratified by season to determine whether observed longline effort shifted between areas over time. The proportions of unstandardized hooks by year and season were computed. The seasons are winter (November 16 to March 14), spring (March 15 to May 31), summer (June 1 to August 31), and fall (September 1 to November 15). The start and end dates for the seasons were adjusted to correspond to the longline survey dates (about June 1 to August 31) and the IFQ season (March 15 to November 15).

Fishery data were stratified by latitude or longitude strips to determine whether observed longline effort shifted between among areas over time. For example, the amount of observed effort between 57 and 58 degrees N latitude was computed for the East Yakutat / Southeast area. The data were stratified by latitude where the coast generally runs from north to south (the eastern Bering Sea and Alaska east of 140 degrees W longitude) and were stratified by longitude where the coast generally runs from east to west (the Aleutian Islands region and Gulf of Alaska to 140 degrees W longitude).

Results and Discussion

Fishing patterns

The most sets were observed for the Central Gulf region (Table 1). Fewer sets were observed for the Bering Sea and for 1997 and 1998, the Aleutians. The voluntary logbook data is an important supplement to the observer data, especially in the West Yakutat and East Yakutat/Southeast areas. Observer data availability decreased overall between 1997 and 1998 whereas the amount of voluntary data increased with the involvement of more participating vessels (Table 2). For 1999, the number of observed vessels was identical to 1998 numbers but the number of observed sets increased.

Since 1995, the majority of effort has occurred in the spring and summer with approximately a tenth of the overall effort occurring in the fall (Table 3). These proportions did not change much from 1995 to 1999. Because of this similarity, seasons were combined, i.e. all data within a year were pooled, and the remainder of this analysis assumes that effort distribution by season is similar among years.

Effort distribution by latitude or longitude strip did not change much from 1995 to 1999, except for the Bering Sea (Figure 2). This is especially true in the East Yakutat/Southeast area where most effort occurred around 57.5N latitude, the area near Sitka, Alaska. In the Bering Sea, observed effort distribution varied and extended from 52.5N to 57.0N latitude. In the Gulf of Alaska, observed effort was similar among years and is greatest around 147 degrees W longitude and substantial from 175-180, 147-165, and 142-143 degrees W longitude. Because of this similarity from 1995 to 1999, latitude and longitude strips were combined within each NPFMC area and the remainder of our analysis assumes that effort distribution by location is similar among years.

Fishery Catch Rates

Fishery catch rates were highest in West Yakutat, and East Yakutat/Southeast, closely followed by the Central Gulf, and substantially more than Western Gulf, Bering Sea, and Aleutian Islands (Figure 3, Table 4). Catch rates generally declined from 1990 to 1994 in the Bering Sea, Aleutian Islands and Western Gulf and generally were similar in Central Gulf, West Yakutat and East Yakutat/Southeast. Catch rates generally declined from 1995 to 1999 in the eastern Bering Sea and generally were similar in the Aleutian Islands, Western Gulf, Central Gulf, and East Yakutat/Southeast. The remaining area, West Yakutat, increased; the 1996 to 1997 change probably is significantly different because the 1996 confidence interval does not include the 1997 mean. Catch rates decreased in all regions from 1997 to 1998, but only the Bering Sea and East Yakutat/Southeast catch rates decreased from 1998-1999.

Comparison of fishery and survey catch rates

The Bering Sea, Aleutians Islands, and Western Gulf, have lower catch rates than the other areas, just like the fishery data. The sablefish longline fishery likely depressed the longline survey catch rate for the Western Gulf in 1992. The rockfish trawl fishery in the Central Gulf likely depressed the longline survey catch rate in 1995.

Considering the period 1990 to 1999, survey catch rates in the Gulf of Alaska decreased overall in Western Gulf and Central Gulf since 1990, West Yakutat since 1992, and East Yakutat/Southeast since 1991 (Figure 4). Focusing on the period since 1995, survey catch rates generally decreased for only the West Yakutat area and generally were similar for the other regions of the Gulf of Alaska .

Survey catch rates generally are higher than fishery catch rates except in the Bering Sea and Aleutians (Figures 4,5; Table 5). The fishery and survey catch rate trends from 1995 to 1999 are similar in all Gulf of Alaska areas except West Yakutat. In West Yakutat, survey catch rate declined steadily since 1996. Fishery catch rate, however, increased in 1997 followed by a slight decrease in 1998, and a large increase in 1999. The survey catch rate in East Yakutat/Southeast has steadily declined since 1991, whereas the fishery catch rate from 1995 to 1999 appears steady. However from 1995 to 1999, the survey decrease is slight enough that it is indistinguishable from the fishery. In the Central Gulf, the survey catch rate has declined since 1996 but the fishery catch rate has remained steady resulting in similar catch rates for 1998. In 1999, both the fishery and survey catch rates increased in the Central Gulf. In the Western Gulf, no major changes are distinguishable between data sets from 1995 to 1998, but in 1999 the catch rates were similar due to a increase in the fishery catch rate and a decrease in the survey rate.

Derby fishery vs. IFQ fishery

Fishery catch rates increased dramatically from 1994 to 1995 in all Gulf of Alaska regions, probably due to the change from a “derby” to an IFQ fishery (Figure 3; Table 5). The fishing grounds were crowded during the “derby” fisheries in the Gulf of Alaska; the IFQ season is much longer, spreading effort over time. Fishery catch rates did not increase dramatically from 1994 to 1995 in the Bering Sea and Aleutian Islands region, probably because seasons in these areas never were as short as in the Gulf of Alaska and the fishing grounds were uncrowded. As a result, fishery catch rates from 1990 to 1994 and from 1995 to 1999 appear comparable in the Bering Sea and Aleutian Islands, but not in the Gulf of Alaska.

How the fishery abundance index is used to estimate sablefish abundance with population models

The fishery catch rates are used along with survey catch rates to estimate sablefish abundance with population models. An assumption of the population modeling is that the relationship between catch rate and abundance is linear, that is, a 10% increase in catch rate represents a 10% change in abundance. This assumption appears reasonable for sablefish longline gear (Sigler 2000).

An important part of population modeling is determining how much weight to give each data type. The data type given the most weight has the greatest influence over the population modeling results. If two data types indicate different representations of the population, then the population modeling results will look most like the representation implied by the data type with the most weight. For example if one abundance index indicates decreasing abundance and another abundance index indicates increasing abundance, then if the first abundance receives greater weight, estimated abundance from the population model will be decreasing.

Both the survey and fishery catch rates provide relatively precise indices of abundance. The coefficient of variation for the survey catch rates is 0.05 (Sigler and Fujioka 1988) and that for the fishery catch rates is 0.10. The survey catch rates appear more precise than the fishery catch and so receive greater weight in the population model.

The definition of catchability used in the sablefish population model is the ratio between catch rate and abundance. Catchability is separately estimated for the two phases of the U.S. longline fishery, the open-access fishery and the IFQ fishery. Catching efficiency doubled with the change from an open-access to an IFQ fishery (Sigler and Lunsford in review). This likely occurred due to crowding of the fishing grounds, so that fishermen were pushed to fish areas where sablefish densities were less. Fishermen also fished the same area repeatedly, with associated decrease in catch rate due to "fishing down" the area.

The 1999 and 2000 assessments use both survey and fishery catch rates as measures of sablefish relative abundance. Because of the potential bias of sablefish fishery catch rates, the effect of using sablefish fishery catch rates in the population model were tested. Fishery catch rates have little effect on spawning biomass estimates. Their inclusion in the 1999 assessment model increased spawning biomass estimates by no more than 1% for any year. For more detail on the population modeling, see Appendix B and Sigler (1999).

How the fishery abundance index is used to allocate the fishery quota among areas

The fishery catch rates are used along with survey catch rates to allocate the fishery quota among areas. Survey catch rates were used alone until the 2000 fishing year, when the Council approved quota allocations based on both fishery and survey catch rates.

The combined ABC has been apportioned to regions using weighted moving average methods; these methods reduce the magnitude of interannual changes in the allocation. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of biomass distribution, while adapting to current information about biomass distribution. However mixing rates for sablefish are sufficiently high and fishing rates sufficiently low that moderate variations of the biomass based apportionment would not significantly change overall sablefish yield unless there are strong areal differences in recruitment, growth, and survival (Heifetz et al 1997). The ABC has been allocated using an exponential weighting of regional RPW's. This method of determining weighting values depends on the assumed ratio between measurement (survey variance) to process error (recruitment, natural mortality, and migration variability). If survey variability is 1/N-th of total variability, the weighting factor is reduced 1/N-th each previous year. The sablefish longline surveys are assumed fairly accurate relative to many other surveys and probably survey variability is no more than ½ of total variability. A $(1/2)^x$ weighting scheme reduced annual fluctuations in ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model, where *x* is the year index (J. Heifetz, Auke Bay Lab, pers. comm.). The weights are year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000.

Members of the fishing industry requested, then received Council approval, for an allocation based on fishery in addition to survey catch rates for the 2000 quota. The fishery and survey information were combined to allocate ABC using the following method. The abundance indices based on the fishery data were weighted with the same exponential weights used to weight the survey data (year index 5: weight 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000). The fishery and survey data were combined by computing a weighted average of the survey and fishery estimates, with the weight inversely proportional to the variability of each data source. The coefficient of variation for the fishery data is about twice that for the survey data, so the survey data was weighted twice as much as the fishery data.

This method of combining the fishery and survey data appears reasonable, but using equal exponential weights for the fishery and survey data is not consistent with the theory used to determine the exponential weights. Weighting the survey data twice as much as the fishery data when combining the data, as described above, fits the theory. However, using the same exponential weights for the fishery and survey data does not. More study is needed to resolve this inconsistency.

Summary

The fishery and survey catch rate trends from 1995 to 1999 are similar in all Gulf of Alaska areas except West Yakutat, where the survey fishery catch rate is steadily declining while the fishery catch rate increased significantly from 1996 to 1997. The transition from a "derby" style fishery to an IFQ fishery has improved catch rates in the Gulf of Alaska. The voluntary logbook data is an important supplement to the observer data, especially in the West Yakutat and East Yakutat/Southeast areas. For the 2000 sablefish assessment, the fishery catch rates were used along with survey catch rates to estimate sablefish abundance with population models. Additionally, the fishery catch rates were used along with survey catch rates to allocate the fishery quota among areas for the 2000 fishery. Integrating fishery data into the assessment model adds another data component which may help to improve the assessment of sablefish in Alaska.

Using fishery data in the sablefish assessment appears reasonable. Changes in where fishermen fish have misled assessment scientists in the past, most notably for Newfoundland cod (Rose and Kulka 1999). However when and where sablefish fishing occurred remained similar during the years of IFQ management, so the fishery catch rates should not be biased by changes in these factors. The sablefish data also is adjusted for changes in fishing power through standardization of the catch rates for differences in hook spacing.

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TABLES

Table 1. The number of recorded sets used in the CPUE analysis. Numbers represent individual sets recorded by observers and the number of sets recorded in the voluntary logbook program.

	Bering Sea		Aleutians		Western Gulf		Central Gulf		W. Yakutat		E. Yakutat / SE	
	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook
1990	715		182		214		816		135		39	
1991	55		547		284		666		300		57	
1992	13		369		522		764		314		47	
1993	29		705		214		1191		515		40	
1994	8		405		78		474		124		5	
1995	60		345		508		749		267		164	
1996	51		251		302		599		284		185	
1997	30		157		375	9	519	48	147	24	131	126
1998	38		94		337		370	138	171	55	172	88
1999	49		369		377		338		117		135	

Table 2. Number of recorded vessels and longline sets used in th
analysis from the observer data and the voluntary logbook data.

	Observer Data		Voluntary Logbook	
	Vessels	Sets	Vessels	Sets
1997	72	1283	17	207
1998	58	1149	22	331
1999	58	1385		

Table 3. Proportion of unadjusted hooks (effort) for sablefish directed longline sets by season from observer and voluntary logbook data.

Year	Winter	Spring	Summer	Fall
1990		0.83	0.13	0.04
1991	0.08	0.50	0.37	0.06
1992	0.02	0.44	0.52	0.02
1993	0.11	0.15	0.73	0.01
1994	0.07	0.79	0.06	0.07
1995		0.33	0.42	0.25
1996		0.50	0.41	0.09
1997		0.47	0.42	0.10
1998		0.38	0.47	0.15
1999		0.41	0.46	0.13

Table 4. Average CPUE (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. Note: standard error not available when vessel equals one.

Bering Sea

Year	CPUE	SE	CV	Vessels
1990	0.37	0.07	0.10	39
1991	0.26	0.11	0.21	15
1992	0.15	0.06	0.20	6
1993	0.13	0.08	0.30	4
1994	0.32	0.36	0.57	4
1995	0.38	0.11	0.15	16
1996	0.44	0.16	0.19	17
1997	0.30	0.11	0.19	10
1998	0.24	0.10	0.21	10
1999	0.17	0.05	0.16	17

Aleutian Islands

Year	CPUE	SE	CV	Vessels
1990	0.51	0.20	0.20	7
1991	0.45	0.06	0.07	17
1992	0.39	0.07	0.09	11
1993	0.28	0.07	0.13	10
1994	0.29	0.08	0.14	22
1995	0.29	0.06	0.10	15
1996	0.23	0.04	0.08	18
1997	0.37	0.10	0.14	11
1998	0.23	0.06	0.13	10
1999	0.31	0.08	0.14	16

Western Gulf

Year	CPUE	SE	CV	Vessels
1990	0.54	0.23	0.21	10
1991	0.43	0.11	0.12	9
1992	0.32	0.04	0.07	25
1993	0.29	0.05	0.09	6
1994	0.29	0.07	0.12	5
1995	0.56	0.18	0.17	22
1996	0.53	0.09	0.09	22
1997	0.47	0.08	0.09	21
1998	0.46	0.05	0.05	15
1999	0.60	0.07	0.06	23

Central Gulf

Year	CPUE	SE	CV	Vessels
1990	0.59	0.10	0.08	51
1991	0.54	0.13	0.12	11
1992	0.56	0.09	0.08	41
1993	0.76	0.51	0.34	7
1994	0.53	0.13	0.12	25
1995	0.80	0.09	0.06	37
1996	0.85	0.10	0.06	59
1997	0.92	0.10	0.06	51
1998	0.85	0.09	0.05	39
1999	0.89	0.13	0.07	38

West Yakutat

Year	CPUE	SE	CV	Vessels
1990	0.65	0.16	0.13	19
1991	0.63	0.16	0.13	9
1992	0.54	0.21	0.20	20
1993	0.57	0.12	0.11	5
1994	0.55	0.29	0.27	8
1995	0.98	0.18	0.09	23
1996	0.90	0.13	0.07	33
1997	1.21	0.18	0.08	29
1998	1.11	0.16	0.07	32
1999	1.32	0.28	0.11	21

East Yakutat / Southeast

Year	CPUE	SE	CV	Vessels
1990	0.60	0.60	0.51	3
1991	0.69	0.27	0.20	5
1992	0.62	0.27	0.22	4
1993	0.80	0.03	0.02	2
1994	0.32			1
1995	1.21	0.32	0.14	18
1996	1.10	0.19	0.09	30
1997	1.26	0.24	0.10	38
1998	1.21	0.18	0.08	34
1999	1.09	0.17	0.08	18

Table 5. Average CPUE (pounds/hook) by region for survey and sablefish directed longline fishery data, 1990-2000.

	Bering Sea		Aleutians		Western Gulf		Central Gulf		W. Yakutat		E. Yakutat / SE	
	Survey	Fishery	Survey	Fishery	Survey	Fishery	Survey	Fishery	Survey	Fishery	Survey	Fishery
1990		0.37		0.51	0.87	0.54	1.27	0.59	1.52	0.65	1.22	0.60
1991		0.26		0.45	0.73	0.43	1.19	0.54	1.63	0.63	1.65	0.69
1992		0.15		0.39	0.34	0.32	1.05	0.56	1.79	0.54	1.47	0.62
1993		0.13		0.28	0.84	0.29	1.18	0.76	1.73	0.57	1.39	0.80
1994		0.32		0.29	0.63	0.29	1.12	0.53	1.56	0.55	1.35	0.32
1995		0.38		0.29	0.71	0.56	1.10	0.80	1.39	0.98	1.20	1.21
1996		0.44	0.13	0.23	0.76	0.53	1.45	0.85	1.41	0.90	1.21	1.10
1997	0.20	0.30		0.37	0.65	0.47	1.27	0.92	1.23	1.21	1.11	1.26
1998		0.24	0.19	0.23	0.73	0.46	0.96	0.85	1.01	1.11	1.08	1.21
1999	0.17	0.17		0.31	0.66	0.60	1.08	0.89	1.00	1.32	1.01	1.09
2000			0.19		0.87		0.94		0.90		0.94	

Figures

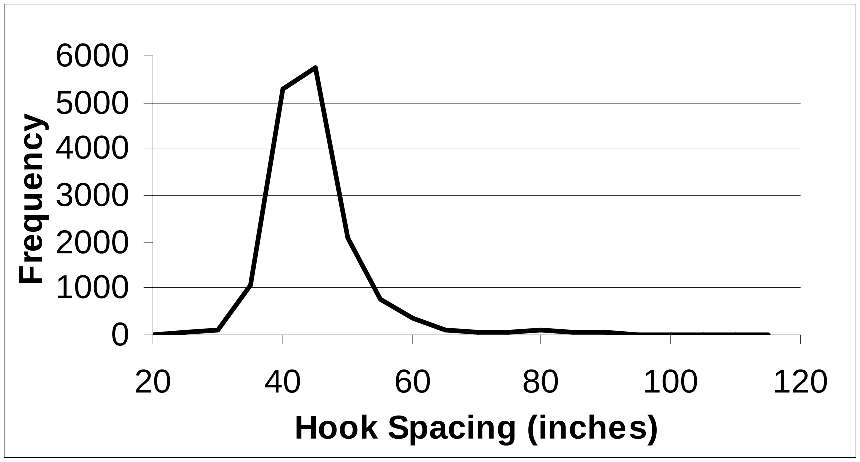


Figure 1. Number of observed sets and average hook spacings for the sablefish directed longline fishery, 1990-1999.

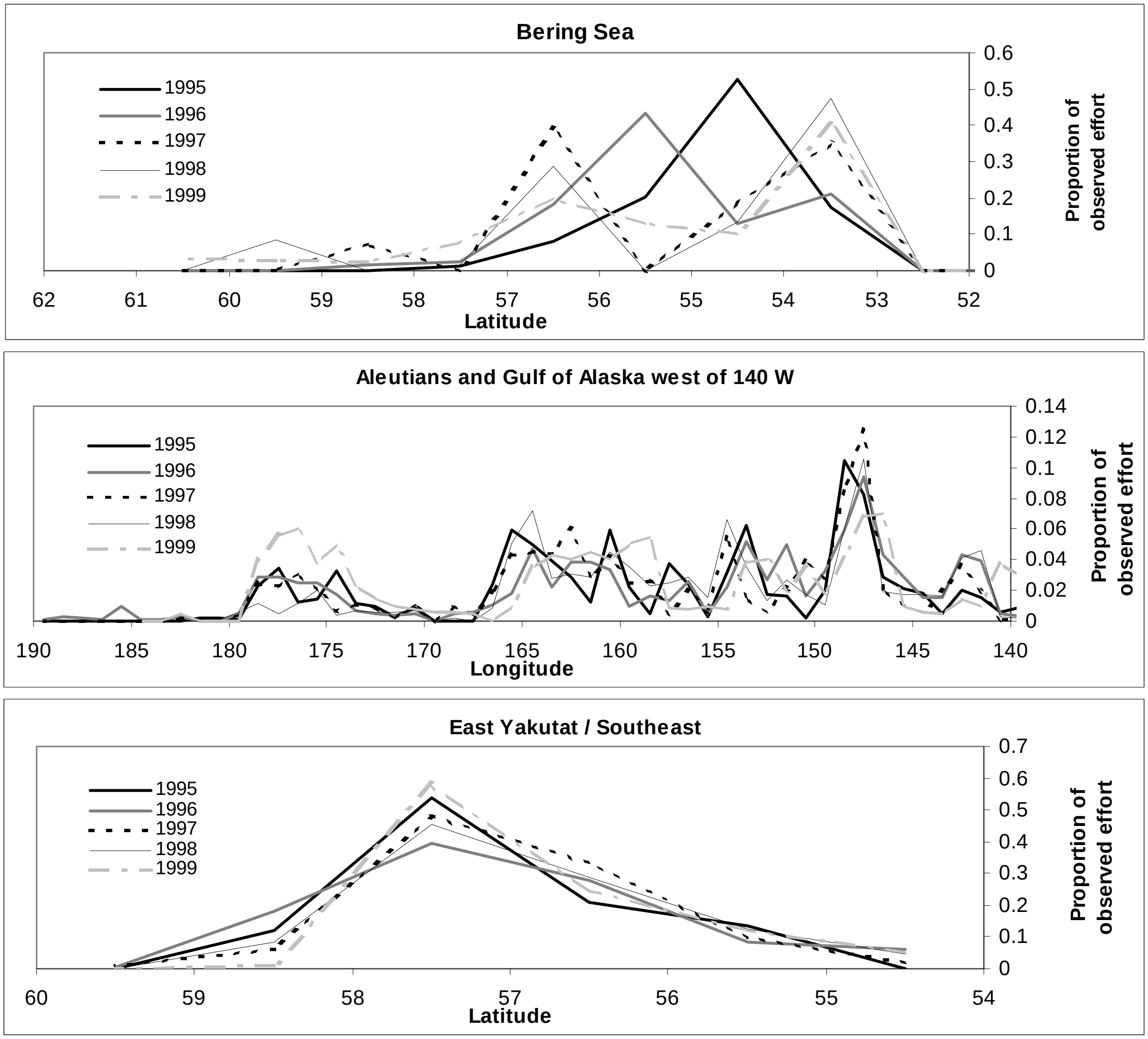


Figure 2. Proportion of observed effort for the fishery by year (1995-1999) for sablefish directed longline sets plotted against set location.

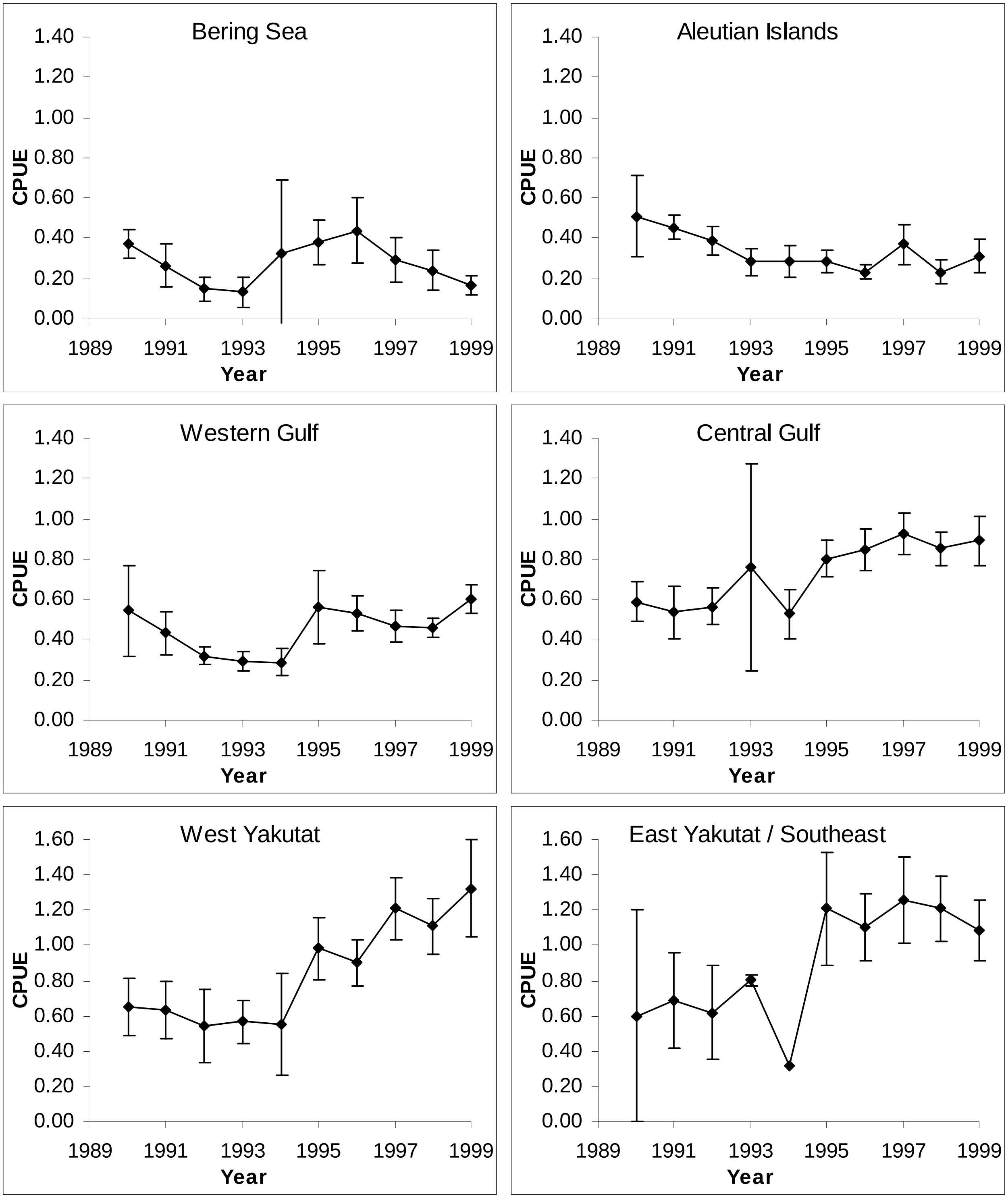
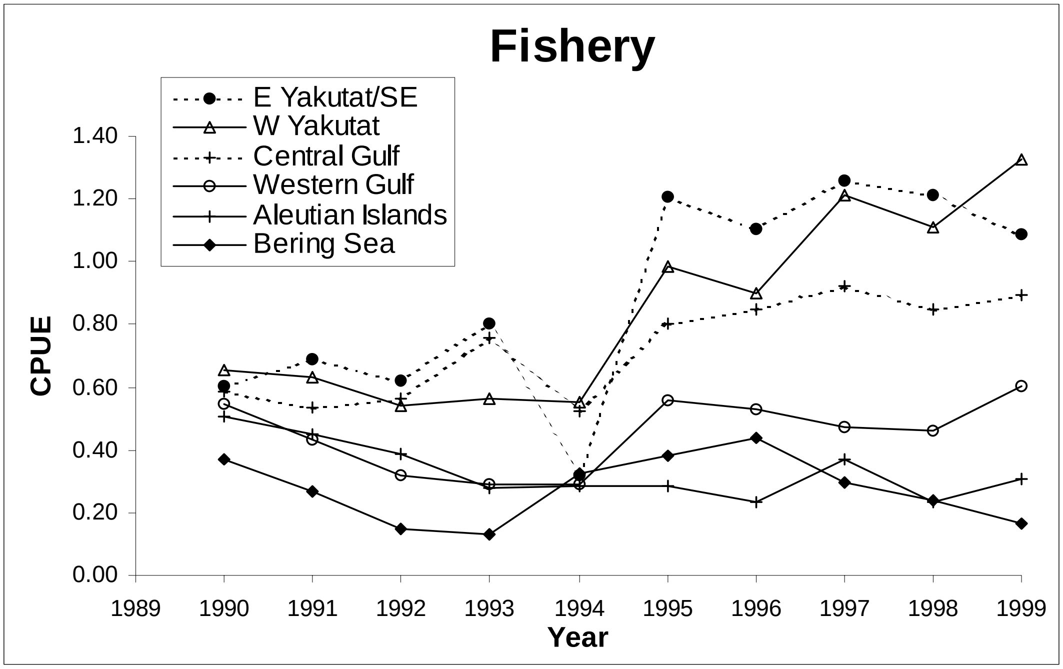


Figure 3. Average CPUE (pounds/hook) and associated 95% confidence intervals by region for sablefish directed longline fishery data, 1990-1999.



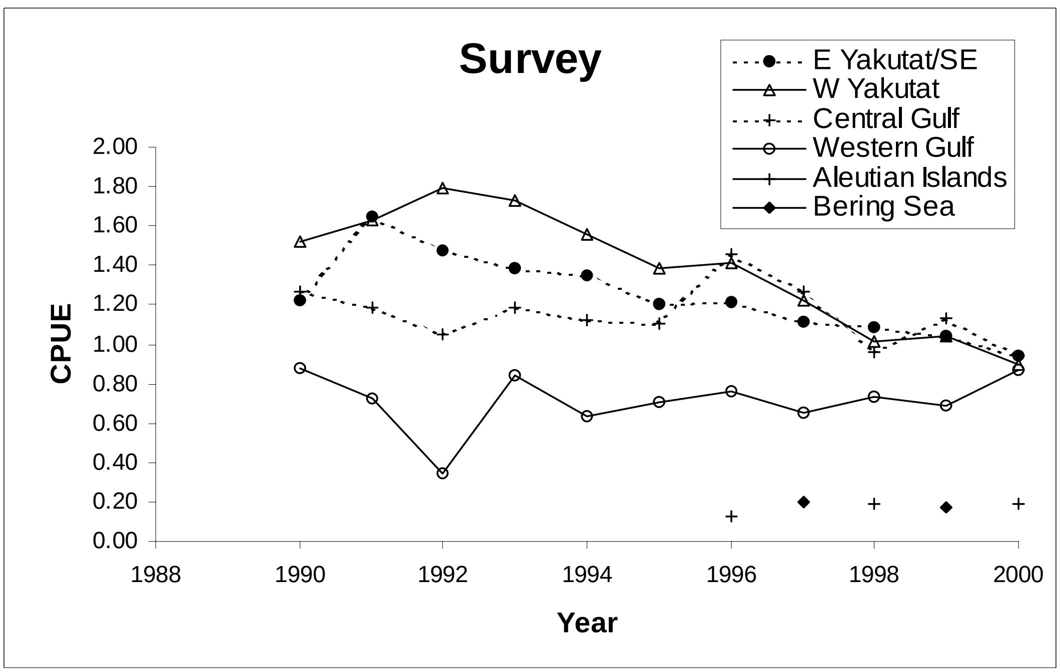


Figure 4. Average CPUE (pounds/hook) by region for survey and sablefish directed longine fishery data, 1990-1999.

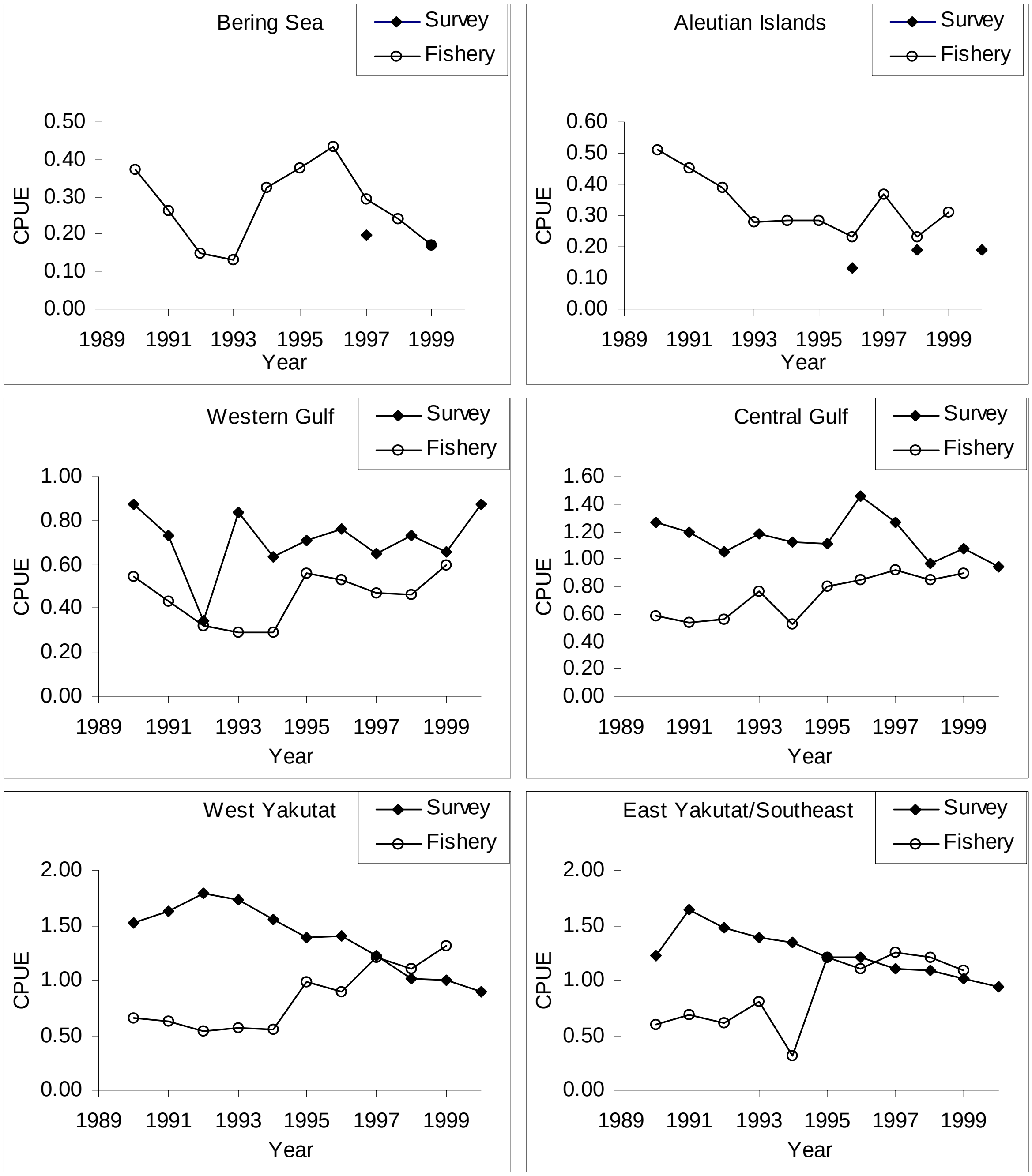


Figure 5. Average CPUE (pounds/hook) by region for survey and sablefish directed longline fishery data, 1990-2000.

Appendix D.--Sablefish longline survey - fishery interactions, 1995-2000

NMFS has requested the assistance of the fishing fleet to avoid the annual sablefish longline survey since the inception of sablefish IFQ management in 1995. We requested that fishermen stay at least five nautical miles away from each survey station for 7 days before and 3 days after the planned sampling date (3 days allowed for survey delays). Beginning in 1999, we also revised the longline survey schedule to avoid the July 1 rockfish trawl fishery opening as well as other short, but less intense fisheries.

History of interactions

Publicity, the revised longline survey schedule, and fishermen cooperation generally have been effective at reducing trawl fishery interactions. No interactions were reported in 2000. An increase in 1999 was due to one trawler during a reopening of the rockfish fishery and 5 trawlers during the new pollock "C" season.

Distribution of the survey schedule to all IFQ permit holders, radio announcements from the survey vessel, and the threat of a regulatory rolling closure generally have not been effective at reducing the annual number of longline fishery interactions, except for 1999. The number of fishing vessels has been about 10, except for 3 in 1999. Forty-nine different longline vessels have interacted with the survey vessel since 1995, about 10% of the fleet. One positive note is that no fishing vessels interacting in previous years repeated in 2000.

	Longline		Trawl		Total	
Year	Stations	Vessels	Stations	Vessels	Stations	Vessels
1995	8	7	9	15	17	22
1996	11	18	15	17	26	35
1997	8	8	8	7	16	15
1998	10	9	0	0	10	9
1999	3	3	2	6	5	9
2000	10	10	0	0	10	10

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl, but not longline fishery interactions generally have decreased. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance.

Michael Sigler and Chris Lunsford, Alaska Fisheries Science Center 6 October 2000

Appendix E.--Research survey catches (kg) by survey type, 1977-1999.

Year	Echo integration trawl	Trawl	Japan US longline survey	Domestic longline survey	Total
1977		3,126			3,126
1978	23	14,302			14,325
1979		27,274	103,839		131,113
1980		69,738	114,055		183,793
1981	813	87,268	150,372		238,452
1982		107,898	239,696		347,595
1983	44	45,780	235,983		281,807
1984		127,432	284,431		411,864
1985		185,692	390,202		575,894
1986	80	123,419	395,851		519,350
1987		116,821	349,424		466,245
1988		14,570	389,382	302,670	706,622
1989		3,711	392,624	367,156	763,491
1990	94	25,835	272,274	366,236	664,439
1991		3,307	255,057	386,212	644,576
1992	168	10	281,380	392,607	674,165
1993	34	39,275	280,939	407,839	728,088
1994	65	852	270,793	395,443	667,153
1995				386,169	386,169
1996	0	12,686		426,479	439,165
1997	0	1,080		396,266	397,347
1998	5	25,528		310,564	336,096
1999		na		295,459	295,459