Alaska Sablefish Assessment for 2004

By

Michael F. Sigler, Chris R. Lunsford, Jeffrey T. Fujioka, and Sandra A. Lowe

3.0 Executive Summary

3.0.1 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 2003 longline survey, relative abundance and length data from the 2002 longline fishery, and age data from the 2002 longline survey and longline fishery were added to the assessment model.

Assessment results: Sablefish abundance increased during the mid-1960s due to strong year classes from the late 1950's and 1960's. Abundance subsequently dropped during the 1970s 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 as these exceptional year classes died off.

The survey abundance index decreased 7% from 2002 to 2003. This decrease follows recent increases, so that relative abundance in 2003 is 10% higher than in 2000. The fishery abundance index also generally increased and is 6% higher in 2002 than in 2000 (2003 data isn't available yet).

Spawning biomass is projected to decrease slightly (<1%) from 2003 to 2004. **Sablefish abundance is moderate; projected 2004 spawning biomass is 40% of unfished biomass.** Abundance has increased from a low during 1998 to 2000. The 1997 year class is an important part of the total biomass and is projected to account for 31% of 2004 spawning biomass. Another year class likely is above average, the 1998 year class, although not as strong as the 1997 year class.

We have recommended recent ABCs less than the maximum permissible because sablefish abundance has been low. Abundance now has increased to a moderate level. Abundance increased due to conservative quotas in previous years and the strong 1997 year class. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is 25,400 mt for 2004 and 20,700 mt for 2005. However the 2004 ABC represents a substantial increase (22%) while abundance is projected to decrease slightly (1%). Further the probability that maximum permissible yield will reduce spawning biomass below the benchmark $B_{30\%}$ in five years is 0.27. **We recommend a 2004 ABC less than the maximum permissible, either 23,000 mt or 20,700 mt for the combined stock.** The 23,000 mt ABC is a moderate increase (10%) compared with the maximum permissible ABC. This ABC increase represents a balance between a stock now at the target abundance but also projected to decline. This ABC increase appears to be sufficiently risk-averse given that next year's assessment will re-evaluate the stock status. The 20,700 mt ABC is similar to the 2003 ABC of 20,900 mt. This ABC is more risk-averse because it is consistent with the abundance trend. Abundance is projected to decline slightly in 2004 and continue decreasing thereafter.

In December 1999, the Council allocated the 2000 ABC based on survey and fishery data. We used the same algorithm to allocate the 2004 ABC. The combined 2004 ABC was apportioned to regions based on a 5-year exponential weighting of the survey and fishery abundance indices. The apportionment of 2004 ABC equal 23,000 mt is Bering Sea 3,006 mt, Aleutian Islands 3,449 mt and Gulf of Alaska 16,545 mt, which is further apportioned Western 2,927 mt, Central 7,300 mt, West Yakutat 2,348 mt, and East Yakutat/Southeast 3,970 mt. The ABCs increase for all areas. The apportionment of 2004 ABC equal 20,700 is Bering Sea 2,705 mt, Aleutian Islands 3,104 mt and Gulf of Alaska 14,891 mt, which is further apportioned Western 2,634 mt, Central 6,570 mt, West Yakutat 2,114 mt, and East Yakutat/Southeast

3,573 mt. The ABCs increase for Western and Central Gulf of Alaska, stay about the same for Aleutians and East Yakutat/Southeast, and decrease for the Bering Sea and West Yakutat areas. The OFL of 30,800 mt is apportioned using the same method as for the ABC: Bering Sea - 4,020 mt, Aleutian Islands - 4,620 mt, and Gulf of Alaska - 22,160 mt..

3.0.2 Responses to Council, SSC, and Plan Teams comments

The Plan Teams and SSC recommended that the decision analysis consider policies that are in concert with Council-established policy, such that adjustments to maximum permissible ABC utilize harvest policies like the biomass-based policy established by the Council. This year our decision analysis adjusts catch with abundance when projecting abundance and analyzing the effect of catch on projected abundance (section 3.5).

The SSC recommended that the analysts reevaluate whether to exclude the 1977-1981 year-classes from the calculation of unfished biomass and reference biomass $B_{40\%}$. In fact the 1977-1981 year classes always have been included in calculation of reference biomass and biomass has been projected both excluding and including these year classes. Nevertheless we reexamined whether it was reasonable to project biomass excluding these year classes (section 3.5).

3.1 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 gullies, 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 population and a southern population, based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). The northern 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.

Northern 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). Average spawning date based on otolith analysis is March 30 (Sigler et al. 2001). During surveys of the outer continental shelf, most young-of-the-year sablefish are caught in the central and eastern Gulf of Alaska (Sigler et al. 2001). 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 because trawl fisheries usually occur on the continental shelf and shelf break inhabited by younger fish.

Growth and maturity: Sablefish grow rapidly in early life, growing 1.2 mm d^{-1} during their first spring and summer (Sigler et al. 2001). Within 100 days after first increment formation, they average 120 mm. They reach average maximum lengths and weights of 69 cm and 3.4 kg for males and 83 cm and 6.2 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 5 years for males (Table 3.1). The length (L)-age (t) functions are $L = 68.8 (1- e^{-0.167 (t - -5.8)})$ for males and $L = 82.8 (1- e^{-0.120 (t - -6.3)})$ for females (Sigler et al. 1997). The weight (W) - length function is $W = 0.0000474 L^{3.19}$ (Sasaki 1985, all areas). The maturity (M) - length function is $M = 1 / (1 + e^{-0.40 (L - 57)})$ for males and $M = 1 / (1 + e^{-0.40 (L - 65)})$ for females. Maturity at age was computed using logistic equations fit to the length/maturity relationships shown in Sasaki (1985, Figure 23, Gulf of Alaska). A value of 0.4 is used for the slope parameter for maturity at length (cm) of 50 percent maturity.

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=0.112 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. The estimated value is about 0.10.

Prey and predators: Young-of-the-year sablefish diet was mostly euphausiids (Sigler et al. 2001). For juvenile and adult sablefish, sablefish < 60 cm FL consumed more euphausiids, shrimp, and cephalopods and sablefish > 60 cm FL consumed more fish (Yang and Nelson 2000). Juvenile and adult sablefish are opportunistic feeders. Fish constituted 3/4 of stomach content weight, with the remainder invertebrates, in the Gulf of Alaska sablefish diet study (Yang and Nelson 2000). 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 euphausiids 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 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). The only other fish species reported to prey on sablefish in the Gulf of Alaska is Pacific halibut; sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999). Fish are an important part of sperm whale diet in some parts of the world, including the northeastern Pacific Ocean (Kawakami 1980). Cephalopods were important in the western Aleutians and Bering Sea but fish became more important in the eastern Aleutians and Gulf of Alaska. The fish species was not identified in the Alaska sperm whale diets, but sablefish were found in 8.3% of sperm whale stomachs off California and 0.0% off British Columbia.

3.1.1 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 3.2, Figure 3.1). 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 land-based 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 land-based 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**
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

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 ran from March 15-November 15 until 2003, when the starting date was changed to March 1 to extend the season to 8-1/2 months. The sablefish IFQ fishery is 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 2000, were about 42% of the 1988 peak.

IFQ management has increased fishery catch rate and decreased the harvest of immature fish (Sigler and Lunsford 2001). Catching efficiency increased 1.8 times with the change from an open-access to an IFQ fishery. The improved catching efficiency of the IFQ fishery reduced variable costs to catch the quota from eight to five percent of landed value, a savings averaging US$3.1 million annually. Decreased harvest of immature fish improved the chance that individual fish will reproduce at least once. Spawning potential of sablefish, expressed as spawning biomass per recruit, increased nine percent for the IFQ fishery.

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 (Hiatt and Terry 2002) was:

Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Vessels	871	1,078	613	578	504	450	446	436	438	421

The numbers of hooks deployed in the Federal fishery alone were:

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Hooks (millions)	96.9	78.0	84.9	86.7	81.5	50.1	45.1	34.4	35.0	33.2	43.4	39.5	44.5

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 3.2). 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 15,000 mt currently due to reduced quotas.

Bycatch and discards

Sablefish discards averaged 526 mt (3.7% of total catch) in longline fisheries and 560 mt (29.8%) in trawl fisheries during the last five years (Table 3.3). By longline fishery, discards averaged 380 mt (2.8%) in the sablefish fishery, 63 mt (29.7%, BSAI) in the Greenland turbot fishery, and 32 mt (44.4%, BSAI) in the Pacific cod fishery (Table 3.3). By trawl fishery, discard averaged 225 mt (20.8%) in rockfish fisheries and 285 mt (41.1%) in flatfish 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 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 10 April 1997. The percentage depends on the basis species: 1% for pollock, Pacific cod, Atka mackerel, “other species”, and aggregated amount of non-groundfish species. Fisheries targeting deep flatfish, rex sole, flathead sole, shallow flatfish, Pacific ocean perch, shortraker and rougheye rockfish, other rockfish, northern rockfish, pelagic rockfish, demersal shelf rockfish in the Southeast Outside district, and thornyheads are allowed 7%. Arrowtooth flounder fisheries are not allowed to retain any sablefish.

Allowable gear: Amendment 14 to the Gulf of Alaska Fishery Management Plan banned the use of pots for fishing for sablefish in the Gulf of Alaska, effective 18 November 1985, starting in the Eastern area in 1986, in the Central area in 1987, and in the Western area in 1989. An earlier regulatory amendment was approved in 1985 for 3 months (27 March - 25 June 1985) until Amendment 14 was effective. A later regulatory amendment in 1992 prohibited longline pot gear in the Bering Sea (57 FR 37906). The prohibition on sablefish longline pot gear use was removed for the Bering Sea, except from 1 to 30 June

to prevent gear conflicts with trawlers during that month, effective 12 September 1996. Sablefish longline pot gear is 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.

3.1.2 Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1960-2002
Japanese longline fishery	Effort	1964-1981
	Length	1963-1980
Japanese trawl fishery	Length	1964-1971
U.S. longline fishery	Effort, length, discards	1990-2002
	Age	1999-2002
U.S. trawl fisheries	Length	1990,1991,1999
	Discards	1990-2002
Japan-U.S. cooperative longline survey	Catch, effort, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	Catch, effort, length	1990-2003
	Age	1996-2002

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 3.4). 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 the 2002 SAFE, Appendix A).

The catches used in this assessment (Table 3.2) include catches from minor state waters fisheries in the northern Gulf of Alaska and in the Aleutian Islands region. These minor state fisheries were established by the State of Alaska in 1995, the same time as the Federal Government established the IFQ fishery. The state established these fisheries primarily to provide open-access fisheries to fishermen who could not participate in the IFQ fishery. Fish caught in these state waters are reported using the area code of the adjacent Federal waters in Alaska Regional Office catch reporting system (G. Tromble, 12 July 1999), the source of the catch data used in this assessment. Minor state fisheries catches averaged 180 mt from 1995-1998 (ADFG), about 1% of the average total catch of 16,890 mt. Most of the catch (80%) is from the Aleutian Islands region. The effect of including these state waters catches in the assessment is to

overestimate biomass by about 1%, a negligible error considering statistical variation in other data used in this assessment.

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 3.2 and 3.3, Table 3.5). 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. Unfortunately the sample size decreased in 2000, falling from 1,268 lengths to 472 lengths, and the subsequent length compositions can not be used for the assessment. Small sample sizes for the trawl fishery continue to be a problem.

Longline fishery catch rate

Steady declines in longline 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 from the observer program and logbooks. We computed fishery catch rates based on observer and logbook data and compared these fishery catch rates to longline survey data. We checked and did not find any substantial changes in fishery effort by season or area. Such changes may cause fishery catch rates to be unrepresentative of abundance. 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 an incorrect interpretation of fishery catch rates: assessment scientists did not realize that the area occupied by the stock was diminishing while the fishery catch rates remained level (Rose and Kulka 1999).

Fishery data is recorded by observers and in voluntary and required logbooks. Vessels over 60 feet carry an observer 30% of the time if less than 125 feet and 100% of the time if over 125 feet. Logbooks are required for vessels over 60 feet. Some captains of vessels less than 60 feet participate in a voluntary logbook program initiated in 1997.

Only sets targeting sablefish are included, defined as a set where sablefish were at least 50% of the catch by weight. 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 was standardized to a 39 inch (1m) spacing following the method used for standardizing halibut catch rates (Skud and Hamley, 1978; Sigler and Lunsford, 2001). 39 and 42 inch spacings were the most common spacings in the directed sablefish fishery (64% of all sets from 1990 to 1999). Each set's catch rate was calculated by dividing the catch in weight by the standardized number of hooks, then used to compute average catch rates by vessel and NPFMC region. The observer and voluntary logbook

data were combined when computing average catch rates. The required logbook data were available for the first time in 1999. Currently they are treated as a separate data set and are not included in the assessment model.

The Central Gulf region has the most sets observed and the Bering Sea the least (Table 3.6). The voluntary logbook data is an important supplement to the observer data, especially in the West Yakutat and East Yakutat/Southeast areas. More sets were reported for required logbook data than observer data, especially in the Bering Sea and East Yakutat/Southeast areas.

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 3.4). Catch rates increased in all areas between 1994 and 1995 due to implementation of the Individual Fishing Quota (IFQ) system. The major discrepancy between fishery and survey trends is West Yakutat, where survey catch rates decreased steadily since 1992 except for an increase in 2002. Fishery catch rates increased between 1997 and 2000. Catch rates for both the survey and the fishery decreased in 2001 and increased in 2002.

Required logbook fishery catch rates are similar to observer fishery catch rates in the Aleutian Islands, Western Gulf, and East Yakutat/Southeast and especially Central Gulf (Figure 3.4), the area with the highest sample size (Table 3.6). Catch rates are probably significantly different for the Bering Sea in 1999 and West Yakutat in 2000, since the confidence intervals do not include the means (Figure 3.5). Targeting of Greenland turbot, which co-occur with sablefish in the Bering Sea, may add variability to fishery catch rates. Collection of logbook data will continue in the future, increasing the number of data points and allowing more detailed comparisons with the logbook and observer fishery catch rates.

At their December 2001 meeting, the SSC requested an examination of the qualification value for directed fishing, currently 50%. They stated that "For example, the use of a 50% qualifying value (targeted catches only) may bias estimated declines in fish stocks. Typically fishery CPUE declines will be less, as larger qualification values are used, posing the question of "what qualification value should be used?" We examined the proportion of sablefish in observed sets for Gulf of Alaska data in 2001, excluding sets where sablefish composed less than 10% of the catch by weight. Sablefish are a large proportion of the catch for most sets: 72% of sets are at least 80% sablefish, 91% of sets are at least 50% sablefish, and 98% are at least 20% sablefish.

Percent of sablefish in set	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
Number of sets	48	54	57	85	125	128	222	425	1,430

The qualification value potentially has a complicated effect on the quality of sablefish CPUE. The abundance of species other than sablefish may affect its quality. For example, if Pacific cod abundance increases, then the number of qualified sablefish sets will decrease. The effect's magnitude depends on the overlap of sablefish with other species. This effect likely is small on the upper continental slope where most sablefish fishing occurs because sablefish are the primary species caught. The effect may be larger on the continental shelf where other fisheries occur and juvenile sablefish primarily are bycatch.

How sablefish abundance affects their spatial distribution also may affect the quality of the sablefish CPUE. If density-dependent habitat selection occurs and some locations have high densities regardless of total abundance, then declines in fishery CPUE will be less as larger qualification values are used. Density-dependent habitat selection likely occurs on an Alaska-size scale. The central and eastern Gulf of Alaska is favored sablefish habitat. Sablefish density declined slower in these areas than the western Gulf of Alaska, Aleutian Islands, and eastern Bering Sea when overall sablefish abundance decreased during the 1990s. We account for large-scale habitat selection by stratifying of the CPUE data by area. As for smaller scales, we have no evidence that density-dependent habitat selection occurs on a smaller scale.

Fishery effort by location within area hasn't changed substantially (SAFE 2000, Sablefish, Appendix C, Figure 2).

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, adding the Aleutians Islands region in 1980 and the eastern Bering Sea in 1982 (Sasaki 1985, Sigler and Fujioka 1988). 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. The order in which areas are surveyed was changed in 1998 to reduce interactions between survey sampling and short, intense fisheries. Before 1998, the order was Aleutians and/or Bering Sea, Western Gulf, Central Gulf, Eastern Gulf. Starting in 1998, the Eastern area was surveyed before the Central area. Longline survey catches are tabled in appendix B.

Length data were collected for all survey years and sablefish otoliths were collected for most survey years. Not all otoliths collections were aged until 1996, when annual ageing of samples began. Otolith collections were length-stratified from 1979-94 and random thereafter.

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 3.5). 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.

Sperm whale depredation may affect longline catches. Data on apparent sperm whale depredation has been recorded since the 1998 longline survey (Table 3.7). Apparent sperm whale depredation is defined as sperm whales are present and damaged sablefish are retrieved. Sperm whales also are present when fish are retrieved undamaged (about 45% of the time), in which case the sperm whales apparently feed off discard. The number of stations with sperm whale depredation was four in 1998, twelve in 1999, five in 2000, and five in 2001. The number of damaged sablefish retrieved averaged eight per station. Sablefish catches were significantly less at affected stations. Standard residuals of relative population number (RPN) by station were significantly less at the affected stations (Mann-Whitney test (a nonparametric rank test), one-sided test, $p = 0.035$). The median standard residual for stations with depredation was -0.147 compared to 0.106 for unaffected stations, implying sperm whales removed twenty-three percent of the sablefish at stations where depredation occurred. Unlike our analysis, an earlier study found no significant effect (Hill et al. 1999). The earlier study compared longline fishery catches between sets with

sperm whales present and absent. The likely reason they could not find a significant effect was that their analysis included all sperm whales sighted near the vessel, whether depredation occurred or not, thus tending to mask any effect.

The longline survey catch rates were not adjusted for sperm whale depredation because we don't know when significant depredation began. Current abundance is unbiased if depredation has consistently occurred over time. If significant depredation began recently, then current biomass is underestimated because the relationship between the survey index and biomass has changed. However if we adjust recent catch rates for sperm whale depredation when in fact it has happened all along, then current biomass will be overestimated. We do not plan to adjust longline survey catch rates for sperm whale depredation. We will continue to monitor sperm whale depredation of survey catches for changes in the level of depredation.

Interactions between longline fishery and survey are described in Appendix A.

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 B.

Recruitment trends

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. Widespread, abundant age-1 juveniles likely indicate a strong year class. Abundant age-1 juveniles were reported for the 1960 (J. Fujioka & H. Zenger, NMFS, approximate year), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, ADFG), and the 1998 year class near Kodiak Island (D. Jackson, ADFG).

Catch, effort, age, length, and diet data for young-of-the-year sablefish have been collected since 1995 during annual surface gillnet surveys of the Aleutian Islands, Bering Sea, and Gulf of Alaska. Catch rates of young-of-the-year sablefish imply that the 1995, 1997, and 1998 year classes are above average. Longline survey catch rates in the western areas (Bering Sea, Aleutian Islands, and Western Gulf of Alaska) for the 1998 year class at age four are about 40% of the catch rates for the 1997 year class, implying that the strength of the 1998 year class is about 40% of the 1997 year class.

Sablefish recruitment varies greatly from year to year (Figure 3.9), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success also is related to recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1960 and 1977 year classes were strong and the 1984 year class was above average (Figure 3.9). The synchronous strong year classes occurred during a warm era, three (1961, 1970, 1977) took place on the first occasion when winter NEPI (northeast Pacific pressure index) values

were more than one standard deviation above the mean, and three (1970, 1977, 1984) were associated with El Nino events (Hollowed and Wooster 1992).

Some of the largest year classes of sablefish occurred when abundance was near the historic low, the 1977-1978 and 1980-1981 year classes. These strong year classes followed the 1976/1977 North Pacific regime shift. The 1977 year class was associated with the Pacific Decadal Oscillation (PDO) phase change and the 1977 and 1981 year classes were associated with warm water and unusually strong northeast Pacific pressure index (NEPI, Hollowed and Wooster 1992). Some species such as walleye pollock and sablefish exhibit increased production at the beginning of a new environmental regime, when bottom up forcing prevails and high turnover species compete for dominance, which later shifts to top down forcing once dominance is established (Bailey 2001; Rice 2001; Hunt 2002). The large year classes of sablefish indicate that the population, though low, still was able to take advantage of favorable environmental conditions and produce large year classes.

Relative abundance trends

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 3.5, Figures 3.2 and 3.3). 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 decreased faster in the Eastern Bering Sea, Aleutian Islands, and western Gulf of Alaska and more slowly in the central and eastern Gulf of Alaska (Figure 3.6). These regional abundance changes likely are due to size-dependent migration. Small sablefish typically migrate westward, while large sablefish typically migrate eastward (Heifetz and Fujioka 1991). The recruitment of the strong late 1970s year classes accounted for the sharp increase in overall abundance during the early 1980s. During the late 1980s as sablefish moved eastward, abundance fell quickly in the western areas, fell slowly in the Central area, and remained stable in the Eastern area. The size-dependent migration and pattern of regional abundance changes indicate that the western areas are the outer edges of sablefish distribution and less favored habitat than the apparent center of sablefish abundance, the central and eastern Gulf of Alaska.

Above average year classes typically are first abundant in the western areas, another consequence of size-dependent migration. For example, an above average 1995 year class first became an important year class in western areas at age 4 (1999 plot), but not until age 7 (2002 plot) in the central and eastern areas (Figure 3.7). Overall, above average year classes became abundant in the western areas at ages 4-5, in the central area at ages 4-9, and in the eastern area at ages 4-7 (Table 3.8a). The strongest year classes (1977 and 1997) appear in the central and eastern areas at the earliest age (4), whereas the remaining above average year classes appear in these areas at later ages (6-9).

The 1998 year class now is apparent in the western areas and is predicted to appear in the central and eastern areas in 2003-2004 (Table 3b). Based on survey abundance at age four, the size of the 1998 year class is predicted to be 40% of the 1997 year class (Figure 3.7)

In the East Yakutat/Southeast area, sablefish abundance decreased for many years until 2002, when both the fishery and survey indices increased (Figure 3.4). The increase was due to the above average 1995 and 1997 year classes (Figure 3.7). The survey index decreased again in 2003. This long-term decline in abundance for this area that is considered a part of the main spawning area (central and eastern Gulf of Alaska) is a serious concern.

3.2 Analytic approach

3.2.1 Model structure

The sablefish population is represented with an age-structured model. The analysis follows the approach described by Kimura (1990) for age-structured population analysis. This approach also was described and 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).

Parameters estimated independently

Maturity parameters were estimated independently of the assessment model and then incorporated into the assessment model as fixed values. The parameter values are listed in section 3.1, growth and maturity. Sablefish are difficult to age, especially those older than eight years (Kimura and Lyons 1991). To compensate, we use an ageing error matrix based on known-age otoliths (Heifetz et al. 1999). An age-length transition matrix also was used to translate predicted age frequencies into predicted length frequencies.

Parameters estimated conditionally

The age range for the model is 2 to 31, where 31 is a pooled group including all ages 31 and greater. Abundances for years 1960 to 2003 are estimated.

Selectivity is represented using a function and is separately estimated for longline survey, longline fishery, and trawl fishery. Selectivity for longline survey and longline fishery is restricted to be asymptotic. Selectivity for trawl fishery is allowed to be dome-shaped. The age of 50% availability for longline fisheries is allowed to differ with season length. Fishermen may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the 1985-1994 “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 (1979) and Sigler and Lunsford (2001) 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 has been estimated in the assessment model.

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 Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2003 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2004 using the schedules of natural

mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2003. 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 1,000 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 2004, 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 2004 recommended in the assessment to the *max* F_{ABC} for 2003. (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 1999-2003 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 2004 and above its MSY level in 2014 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2004 and 2005, 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 2016 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. Since the 1999 assessment, we incorporated 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 regularly spaced M and q-values. The remaining

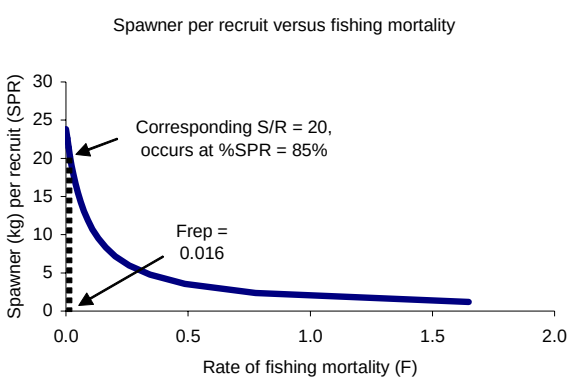
population parameters were estimated with the population model given each *M* - *q* pair. The resulting likelihood values are an estimate of the likelihood surface given *M* and *q*. Each *M* - *q* pair was assumed to have equal prior probability, so the posterior probabilities were simply equal to the normalized likelihoods. We examined the probability density along the grid boundaries to ensure adequate coverage of the likelihood surface. The probabilities at the grid boundaries were less than 1/500th of the maximum probability.

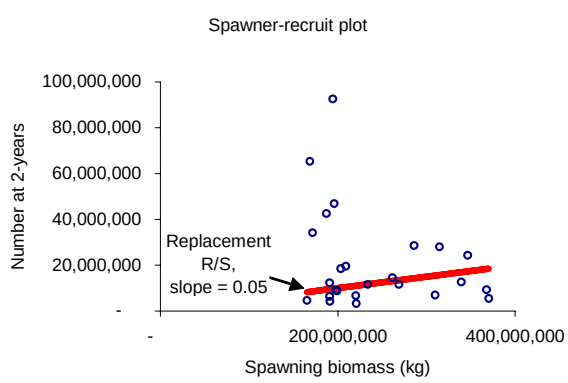
Decision analysis

We estimated the probability that projected abundance will fall below thresholds of 20, 25, 30, and 35% of the unfished spawning biomass based on the posterior probability estimates. Abundance was projected for 14 years over 20 scenarios with proportions of maximum fishing mortality of 0.05, 0.10 ... 1.00. A proportion of 0.50 is half of the maximum permissible fishing mortality (adjustable $F_{40\%}$ strategy of the Tier 3 rule). A proportion of 1.00 is the maximum permissible fishing mortality. Each scenario was repeated 1,000 times, resampling from the estimated year classes from 1977-1998.

The choice of threshold depends on a determination of how much spawning per recruit is enough for successive generations to replace or surpass each other on average (Mace and Sissenwine 1993). Mace and Sissenwine (1993) described three methods of estimating overfishing thresholds. In the following discussion for sablefish, percent spawner per recruit (%SPR) and percent of unfished biomass are equivalent.

1) The threshold can be estimated from spawner-recruit data (Mace and Sissenwine 1993, Figure 1). The replacement spawner per recruit (20) was estimated as the inverse of the median survival ratio (0.05) from the spawner-recruit plot. The corresponding estimate of replacement fishing mortality (0.016) was then obtained from the spawners per recruit versus fishing mortality curve. The estimate of percent spawn per recruit (85%) is high because there are no observations of recruitment at very low stock sizes where recruitment is reduced due to low abundance (historic low was about 30% of unfished value). The estimate is unrealistic because the sablefish stock has been fished at much higher rates and been sustainable. This estimate is not used further.





2) The threshold can be estimated from regression relationships for other well-studied fisheries (Mace and Sissenwine 1993, Table 6). An estimate for replacement SPR = 18% was obtained for sablefish values of maximum weight of 5.3 kg, weight at 50% maturity of 2.4 kg, unfished biomass of 525,000 mt, and natural mortality of 0.107, and the regression coefficients in Mace and Sissenwine (1993, Table 6). The sablefish estimate of 18% is similar to the other species analyzed by Mace and Sissenwine (1993), which found a mean value of 18.7% and a median

value of 17.2%. This value also is similar to 17.5%, the value to determine whether a stock is overfished for NPFMC Tier 3 stocks.

3) A default threshold of 30% is recommended by Mace and Sissenwine (1993) when there is no other basis for estimating the replacement level. They found that a 30% level was enough for 80% of the fish stocks considered, but may be overly-conservative for an "average" stock.

Mace (1994) conducted a theoretical examination of the relationship of commonly used thresholds and life history values. The theoretical study supports the previous recommendation by Mace and Sissenwine (1993), who recommended 20% of pristine biomass for stocks with at least average resilience (compensatory recruitment at low abundance) and 30% of pristine biomass for little-known stocks. Thompson (1993) provided additional guidance on threshold stock size and maximum fishing mortality rate: biomass should remain above $B_{20\%}$ (based on the stock-recruitment curve, not average historic recruitment); fishing mortality rate should remain below $F_{30\%}$.

In previous assessments, the recruitment time series used to project abundance and recommend ABC has been the 1982 and onward year classes. We excluded the 1977-1981 year classes because these strong year classes were much stronger than successive year classes until the 1997 year class appeared. The average year class strength (number at age 2) is 47 million for the 1977-1981 year classes and 14 million for the 1982-1996 year classes. The strong 1997 year class weakens the rationale for excluding the 1977-1981 year classes. The 1997 year class is tied for third in year class strength during 1977-1998 and is twice as strong as the average of the 1977-1998 year classes. However, the abundance of the 1997 year class is only 51% and 72% of the first (1977) and second (1980) year classes respectively, and only slightly greater (10%) than the fourth (1981) year class. Further, the 1977, 1980, and 1981 year classes were grouped with three strong year classes occurring within five years, whereas the 1997 year class is not associated with any other strong year classes (the 1998 year class may be above average but likely is weaker than the 1997 year class). Recent recruitments (1982 and onward) appear to constitute a different recruitment era than before 1982. Section 3.2, Recruitment trends provides some biological explanation for why year classes immediately following the 1976/1977 regime shift are a different magnitude than later year classes. Continued use of the 1982 and onward year classes to project abundance and recommend ABC appears reasonable. This recruitment time series covers the 1982-1999 year classes and therefore includes the strong 1997 year class in abundance projections.

3.3 Model evaluation

The model fit the observed abundance indices, survey and fishery length data, and survey age data (Figures 3.2, 3.3, and 3.8 [the length fits are not shown for brevity]).

Abundance estimates from this assessment and last year's (2002) assessment are very similar (Figure 3.12). For example, estimated 2002 spawning biomass was 204,000 in the 2002 assessment and 205,000 in the 2003 assessment, a 0.2% difference. The reference point $B_{40\%}$ also is similar, 216,000 mt in the 2002 assessment and 211,000 mt in the 2003 assessment, a 2% difference.

3.4 Model results

Annual estimated recruitment varies widely, with strong year classes estimated for 1960, 1964, 1967, 1974, 1977, 1980, 1981, 1984, 1988, 1990, 1994, 1995, and 1997 (Figure 3.9). 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 section 3.1.2 for evidence, but appears relatively weak in the model estimates.

Sablefish abundance increased during the mid-1960's (Table 3.9, Figure 3.10) due to strong year classes from the 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches

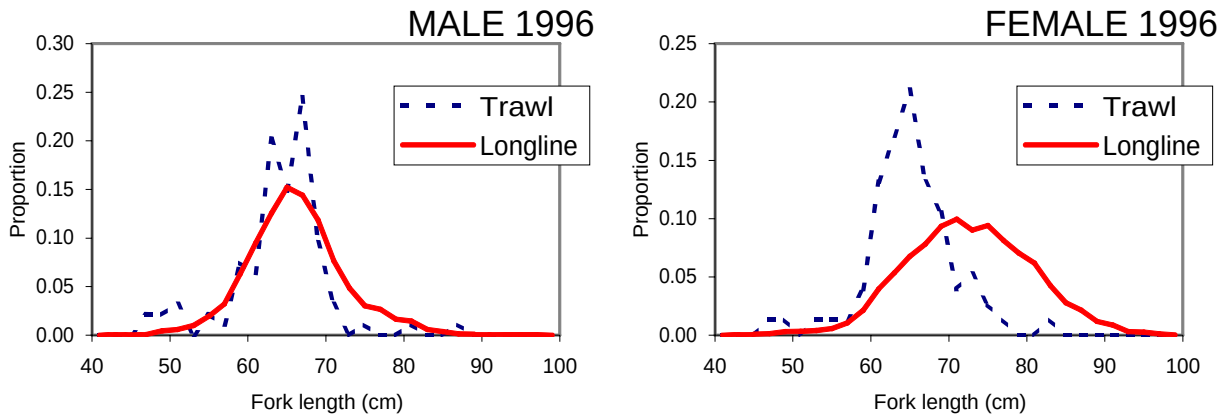
peaked at 56,988 mt in 1972. The population recovered due to strong year classes from the late 1970's; spawning abundance peaked again in 1987. The population then decreased because these strong year classes are dying off.

Spawning biomass is projected to decrease slightly (<1%) from 2003 to 2004. Projected 2004 spawning biomass is 210,000 mt and exploitable biomass is 221,000 mt (Table 3.9). **Sablefish abundance is moderate; projected 2004 spawning biomass is 40% of unfished biomass.** Abundance has increased from a low during 1998 to 2000 due to the strong 1997 year class. This year class is an important part of the total biomass and is projected to account for 31% of 2004 spawning biomass. The 1998 year class is likely to be above average, but not as strong as the 1997 year class.

Average recruitment for the 1977-1999 year classes is 23 million 2-year old sablefish per year, slightly higher than the 22 million for the 1957-1999 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.

Estimated natural mortality was 0.107. Some variation in estimates of natural mortality is not unusual. The value of 0.107 for this year's assessment is similar to 0.106 estimated for the 2002 assessment, 0.104 estimated for the 2001 assessment, 0.098 estimated for the 2000 assessment, 0.102 estimated for the 1999 assessment, and 0.10 assumed for previous assessments. The estimate will continue to vary in future assessments as data is collected and added to the population model each year.

The age of 50% selection is 4.3 years for the longline survey and short open-access seasons ("derby" fishery), 5.2 years for the IFQ longline fishery, and 2.9 years for the trawl fishery (Figure 3.11). 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 (Sigler and Lunsford 2001). 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 are available from 1990-2002. Catchability was separately estimated for the "derby" (through 1994) and IFQ (1995 and later) fisheries. On average, fishery catchability is 1.8 times greater during the IFQ fishery, the same as estimated in an independent analysis of the effects of individual quotas on catching efficiency in the fishery (Sigler and Lunsford 2001). Like the selectivity effect, lower catching efficiency during the "derby" fishery 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 decreases in catch rates due to "fishing down" the area.

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 section 3.1.2. We also tested the effect of including fishery catch rates in the assessment model. Both Japan and US fishery catch rate data are used in the assessment model. However 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 the longline surveys. Including US fishery catch rates has little effect on spawning biomass estimates, increasing spawning biomass estimates from 0.6% to 1.5% for 1990-2002, the years of US fishery catch rate data.

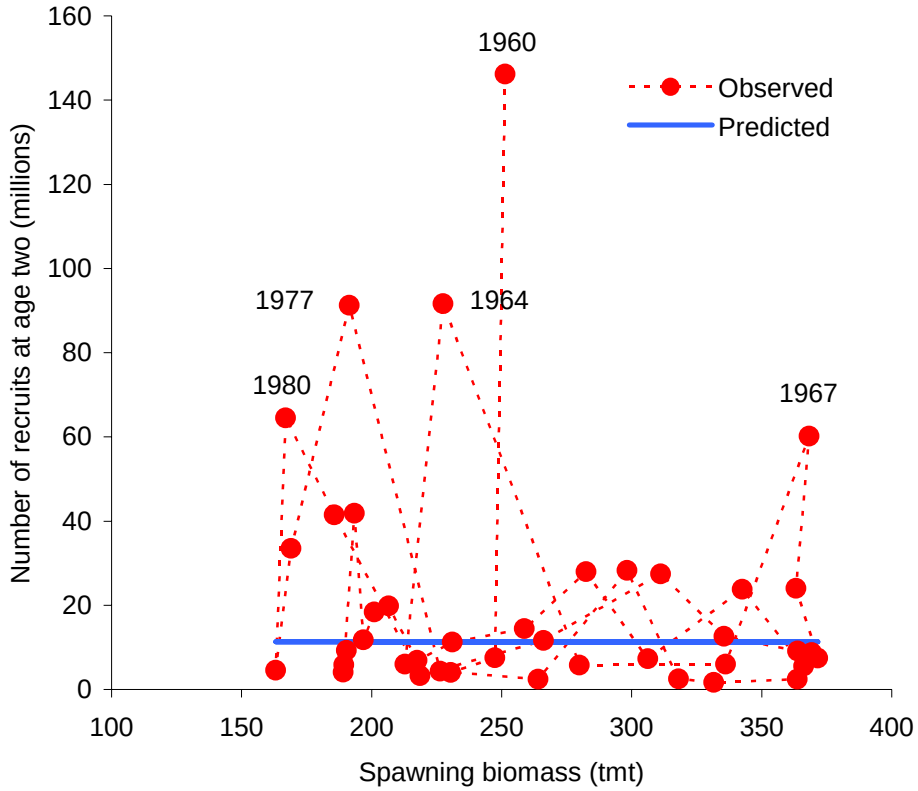
3.5 Projections and harvest alternatives

Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2004 spawning biomass, are shown in the summary table, section 3.7. Reference biomass values were always computed using the average recruitment from the 1977-1999 year classes. Projected 2004 spawning biomass is 40% of unfished spawning biomass and 99.5% of $B_{40\%}$. A downward adjustment to the reference fishing mortality rates is required to set the maximum Acceptable Biological Catch under Tier 3b. Reference point values for fishing mortality are similar to recent assessments. For example, $F_{40\%}$ is 0.131 for the 2003 assessment and 0.133 for both the 2001 and 2002 assessments.

Maximum sustainable yield

At their December 2001 meeting, the SSC requested an examination of the sablefish stock-recruitment relationship by fitting a curve through the stock and recruitment estimates. We fit a Beverton-Holt curve assuming a log-normal distribution for recruitment. The predicted values are plotted only for the observed range of spawning biomass because the shape of the relationship below the historic low biomass is unknown.



Population projections

Projected 2004 exploitable biomass is 221,000 mt for Aleutian Islands, eastern Bering Sea, Gulf of Alaska combined, spawning (male and female) biomass 210,000 mt (Table 3.9). Spawning biomass currently equals 40% of the unfished value. Spawning biomass is projected to fall to 36% of the unfished level in 2005, 34% in 2006, and 33% in 2007 (Figure 3.14, maximum permissible fishing mortality, project with 1977-1999 year classes). Abundance is projected to fall because year classes following the strong 1997 year class are weaker than the 1997 year class. Since the 1998 year class may be above average, how much sablefish abundance will decline after the 2003 peak depends on the actual magnitude of this year class (the current estimate is 4.2 million). If for example, the 1998 year class strength instead equals the 1977-1999 average of 22.8 million, then spawning biomass is projected to fall to 36% of the unfished level in 2007 (rather than 33%).

Future sablefish abundance also depends on future average recruitment and fishing mortality. Abundance is projected to decrease if future average recruitment equals 1982-1998 average recruitment (maximum permissible fishing mortality). If future average recruitment equals 1977-1998 average recruitment, then abundance is projected to decrease until 2007, then increase. The latter recruitment scenario is more optimistic because it includes the exceptional 1977-1981 year classes. However, the short-term difference between the two recruitment scenarios is small; spawning biomasses projected 3-years ahead (2006) differ by only 2% (maximum permissible fishing mortality). Projected spawning biomass increases if fishing mortality is reduced, but not by much, even for substantial reductions in fishing mortality (Figure 3.14). For example, reducing fishing mortality to half the maximum permissible increases projected 2008 spawning biomass by only 18% (projected with 1977-1999 year classes).

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 3.10).

Status determination

Alaska sablefish are not overfished nor are they approaching an overfished condition (Table 3.10).

Bayesian analysis

The estimates of *M* and *q* appear to be well-defined by the available data. Most of the probability lies between *M* of 0.07 and 0.15 and *q* of 4.7 and 10.7 (Figure 3.13). The probability changes smoothly and is well-mapped by the chosen values for the *q*-*M* grid. Adding informative priors narrowed the posterior, depending on the prior variance. Using biologists' opinions of the value of natural mortality is one method to develop an informative prior distribution, but these opinions are often based on experience interpreting population model results and may fail to be independent from the data. Therefore, we chose to use non-informative prior distributions.

Another approach for adding informative priors is a meta-analysis of natural mortality values for other species. This approach is appropriate if long-lived species of the Scorpaeniformes (sablefish and rockfish are members) are included, or if the meta-analysis uses life history relationships such as natural mortality and the growth parameter *k*. During development of the Bayesian decision analyses we considered using meta-analytic priors for natural mortality and stock-recruitment parameters. We may add these priors to future sablefish assessments.

Decision analysis

The maximum permissible 2004 catch is 25,400 mt falling to 18,200 mt by 2007 (Table 3.10, projected with 1977-1999 year classes). The probability of abundance falling below $B_{35\%}$ in the next five years is 0.82, below $B_{30\%}$ is 0.10, and below $B_{25\%}$ is <0.002 (Figure 3.15). Reducing fishing mortality rate reduces

the probability of falling below these benchmarks. For example, the probability of abundance falling below $B_{30\%}$ is 0.04 at 0.8 of maximum permissible fishing mortality.

The recruitment scenario used to project abundance affects the estimated probability of abundance falling below the benchmarks. If future average recruitment equals 1982-1999 average recruitment, then the probability of abundance falling below $B_{35\%}$ in the next five years is 1.00, below $B_{30\%}$ is 0.27, and below $B_{25\%}$ is <0.003 (Figure 3.15)[1]. However, the choice of recruitment scenario has little effect in the short term. The probability of abundance falling below $B_{30\%}$ in the next three years is 0.09 if future average recruitment equals the 1977-1999 average and 0.10 if future average recruitment equals the 1982-1999 average.

The choice of threshold affects the determination of which ABC leaves enough spawning per recruit for successive generations to replace or surpass each other on average. A threshold of 18%SPR was estimated for sablefish; a default threshold of 30% SPR is recommended when there is no other basis for estimating the threshold level (section 3.2). The probability of falling below 18% SPR is nil even for maximum permissible catch (Figure 3.15), whereas the probability of falling below 30%SPR during the next three years is about 0.10 for projections at the maximum permissible fishing mortality (regardless of the year classes used in the projection).

The probability of falling below $B_{30\%}$ can be substantially reduced by setting fishing mortality less than the maximum permissible value. For example, for a 5-year time horizon and projection with the 1982-1999 year classes, this probability decreases from 0.27 at maximum fishing mortality to 0.06 at 80% of maximum permissible fishing mortality. The equivalent 2004 catches are 25,400 mt and 20,700 mt. The equivalent 5-year average annual catches are 20,700 mt and 17,700 mt. The tradeoff for reducing the chance of falling below the default threshold to one in twenty is 3,700 mt in 2004 and 3,000 mt annual average during 2004-2008. The benefit is not as great if future average recruitment equals 1977-1999 average recruitment; the probability of falling below $B_{30\%}$ decreases from 0.10 at maximum fishing mortality to 0.04 at 0.8 of maximum fishing mortality (4-year time horizon).

The probability of falling below $B_{30\%}$ is small for shorter time horizons and also largely unaffected by recruitment scenario choice. This probability is about 0.1 for a 3-year time horizon (2006) regardless of recruitment scenario. Thus the benefits of fishing below the maximum permissible rate take several years to become apparent and whether the benefit is substantial depends on future average recruitment.

Acceptable biological catch

The maximum permissible yield from an adjusted $F_{40\%}$ strategy is 25,400 mt. The probability of spawning biomass falling below the estimated threshold (anytime in the next 12 years) of 18%SPR and the NMFS definition of MSST for a Tier 3 stock of 17.5%SPR is <0.003, regardless of recruitment scenario. Thus the risk that maximum permissible yield will reduce spawning biomass below the replacement level is low. The risk is low because abundance currently is near the target level of 40% of unfished biomass (all reference levels are calculated using the 1977-1999 year classes). Abundance has been near the target level the last two years, substantiating the increase in sablefish abundance from recent lows. Abundance increased due to conservative quotas in previous years and the strong 1997 year

[1] All reference levels are calculated using the 1977-1999 year classes, even though this abundance projection uses the 1982-1999 year classes. This approach is valid under the assumption that long-term recruitment is represented by the 1977-1999 year classes and short-term recruitment by the 1982-1999 year classes. This approach is not valid if one believes that long-term recruitment is better represented by the 1982-1999 year classes. We have chosen to consistently use the 1977-1999 year classes to compute the reference levels because these are the year classes used for all Alaska groundfish species. We would use the 1982-1999 year classes to compute reference levels if there were consistent agreement from the Plan Teams that the 1982-1999 year classes represent the long-term recruitment trend for sablefish.

class. (Council-approved quotas during the last seven years on average have been 14% less than the maximum permissible values.)

The threshold for sablefish abundance of 18%SPR was estimated from regression relationships for other well-studied fisheries. However this estimate is uncertain because the regression relationship may not apply to sablefish. Further there are no observations on how sablefish recruitment will respond below about 30% of the unfished level, hence resiliency at low stock levels is of questionable predictability. A default threshold of 30%SPR is recommended when there is no other basis for estimating the replacement level (Mace and Sissenwine 1993) or the resiliency of the stock is unknown (Mace 1994). Thus we also need to consider the probability of falling below 30% of the unfished level.

The probability of falling below $B_{30\%}$ in three years is small (about 0.10) for maximum permissible fishing mortality and little affected by recruitment scenario.

A substantial risk reduction is possible with a longer time horizon if future average recruitment equals 1982-1999 recruitment (see footnote 1). Future average recruitment equal to 1982-1999 recruitment is possible (see section 3.2.3, Decision analysis). Thus we also need to consider future average recruitment equal 1982-1999 recruitment. The probability of falling below $B_{30\%}$ in five years is reduced from 0.27 at F_{ABC} to 0.06 at 0.8 of F_{ABC}. The corresponding 2004 ABC is 20,700 mt. Fishing at 0.9 of F_{ABC} reduces the probability of falling below $B_{30\%}$ to 0.15 with a corresponding 2004 ABC of 23,000.

Spawning biomass currently is at 40% of the unfished level, but is projected to fall to 34% of the unfished level in 2006 for maximum permissible fishing mortality. Abundance is projected to fall because year classes following the strong 1997 year class are weaker than the 1997 year class. The maximum permissible ABC also is projected to decline from 25,400 mt in 2004, to 20,700 mt in 2005 and 18,800 mt in 2006.

We propose three values for 2004 ABC:

1) 25,400 mt (maximum permissible),

2) 20,700 mt (0.8 of maximum permissible), and

3) 23,000 mt (0.9 of maximum permissible).

Reasons in support or against each choice are tabulated on the next page.

We have recommended recent ABCs less than the maximum permissible because sablefish abundance has been low. Abundance now has increased to a moderate level. Abundance increased due to conservative quotas in previous years and the strong 1997 year class. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is 25,400 mt for 2004 and 20,700 mt for 2005. However the 2004 ABC represents a substantial increase (22%) while abundance is projected to decrease slightly (1%). Further the probability that maximum permissible yield will reduce spawning biomass below the benchmark $B_{30\%}$ in five years is 0.27. **We recommend a 2004 ABC less than the maximum permissible, either 23,000 mt or 20,700 mt for the combined stock.** The 23,000 mt ABC is a moderate increase (10%) compared with the maximum permissible ABC. This ABC increase represents a balance between a stock now at the target abundance but also projected to decline. This ABC increase appears to be sufficiently risk-averse given that next year's assessment will re-evaluate the stock status. The 20,700 mt ABC is similar to the 2003 ABC of 20,900 mt. This ABC is more risk-averse because it is consistent with the abundance trend. Abundance is projected to decline slightly in 2004 and continue decreasing thereafter.

Maximum permissible: 25,400 mt	0.8 maximum permissible: 20,700 mt	0.9 maximum permissible: 23,000 mt
Con: Substantial ABC increase (22%) while abundance projected to decrease slightly (1%) next year (2004).	Pro: Stable to declining abundance trend is more consistent with a stable ABC level.	
Con: Substantial ABC increase (22%) while spawning abundance is projected to fall to $B_{34\%}$, even when projecting with the optimistic 1977-1999 year classes.	Pro: The projected decline in spawning abundance is lower.	Pro: The projected decline in spawning abundance is lower.
Con: The probability of falling below $B_{30\%}$ in five years is large enough to be a concern when projecting with the 1982-1999 year classes (0.27).	Pro: The probability of falling below $B_{30\%}$ in five years when projecting with the 1982-1999 year classes is reduced to 0.06.	Pro: The probability of falling below $B_{30\%}$ in five years when projecting with the 1982-1999 year classes is reduced to 0.15, but with less cost in terms of reduced ABC.
Con: This represents a 47% increase in ABC in the last two years.		
Con: No catches this high since early 1990s.		
Con: Population has been at about $B_{40\%}$ for only 2 years (2003 and 2004).		
Pro: Sablefish abundance is at the target level of abundance of 40% of the unfished value.	Pro: While abundance now is at the target level, it is projected to decline substantially again. This harvest level reduces the degree of decline. Abundance in the important spawning area of Southeast Alaska continues to decline.	Pro: A moderate increase in 2004 ABC balances abundance at $B_{40\%}$ yet projected to decrease. Appropriateness will be reevaluated in next year's assessment.
Pro: The stock would potentially be more fully utilized and reap a larger benefit in the near term, though future catches are projected to decline substantially.		Pro: ABCs less than the maximum permissible were recommended when sablefish abundance was less than maximum permissible and decreasing to prevent abundance from going lower. ABCs closer to the maximum permissible are reasonable because abundance is at the target level.
Pro: The probability of falling below $B_{30\%}$ in three years is small (about 0.10) and little affected by recruitment scenario.		

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Last year the Plan Teams and SSC recommended a 2003 ABC less than the maximum permissible ABC. We applied their methods for the 2003 ABC to compute corresponding 2004 values. The Plan Teams supported a 2003 ABC of 18,400 mt that was scaled to the observed abundance change. Spawning biomass is projected to decrease 0.4% from 2003 to 2004 (Table 3.10), implying a 2004 ABC of 18,300 mt. The SSC supported a 2003 ABC of 20,900 mt that was the 5-year average of catches under the $F_{40\%}$ policy, implying a 2004 ABC of 20,500 mt (Table 3.10).

Table.–Maximum permissible ABC (Tier 3, $F_{40\%}$ adjusted value) and ABCs recommended by the stock assessment authors, Plan Teams, SSC, and NPFMC, by fishing year 1997-2003.

Year	Maximum permissible	Authors	Plan Teams	SSC	NPFMC
1997	23,200	17,200	19,600	17,200	17,200
1998	19,000	16,800	16,800	16,800	16,800
1999	15,900	15,900	15,900	15,900	15,900
2000	17,300	17,000	17,300	17,300	17,300
2001	16,900	16,900	16,900	16,900	16,900
2002	21,300	17,300	17,300	17,300	17,300
2003	25,400	18,400	18,400	20,900	20,900

Area allocation of harvests

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of inter-annual 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 differences in recruitment, growth, and survival by area (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 2004 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, but using the same exponential weights for the fishery and survey data does not.

Apportionments are based on survey and fishery information	**2003 ABC Percent**	**2003 Survey RPW**	**2002 Fishery RPW**	**2004 ABC Percent**	**2003 ABC**
Total					20,890
Bering Sea	14%	13%	10%	13%	2,900
Aleutians	15%	15%	15%	15%	3,100
Gulf of Alaska	71%	71%	75%	72%	14,890
Western	17%	21%	13%	18%	2,570
Central	43%	48%	37%	44%	6,440
W. Yakutat	16%	12%	18%	14%	2,320
E. Yakutat / Southeast	24%	20%	31%	24%	3,560

The survey percentages indicate more fish in the Western and Central Gulf of Alaska and fewer fish in the eastern Gulf of Alaska than the fishery percentages. This occurs because survey catch rates are higher than fishery catch rates in the Western and Central Gulf of Alaska and more or less similar in the eastern Gulf of Alaska (Figure 3.4).

The following table shows the regional apportionments for 2004 ABC values of maximum permissible, 0.9 of maximum permissible, and 0.8 of maximum permissible.

		Maximum permissible		0.9 of maximum permissible		0.8 of maximum permissible	
	2003 ABC	2004 ABC	Change	2004 ABC	Change	2004 ABC	Change
Total	20,890	25,400	**18%**	23,000	**9%**	20,700	**-1%**
Bering Sea	2,900	3,320	**13%**	3,006	**4%**	2,705	**-7%**
Aleutians	3,100	3,809	**19%**	3,449	**10%**	3,104	**0%**
Gulf of Alaska	14,890	18,272	**19%**	16,545	**10%**	14,891	**0%**
Western	2,570	3,233	**20%**	2,927	**12%**	2,634	**2%**
Central	6,440	8,061	**20%**	7,300	**12%**	6,570	**2%**
W. Yakutat	2,320	2,593	**11%**	2,348	**1%**	2,114	**-10%**
E. Yakutat / Southeast	3,560	4,385	**19%**	3,970	**10%**	3,573	**0%**

We computed 2004 ABC values based on methods applied last year by the Plan Teams (biomass change) and SSC (5-year average). The following table shows the regional apportionment of these values.

		Biomass change		5-year average	
	2003 ABC	2004 ABC	Change	2004 ABC	Change
Total	20,890	18,300	**-14%**	20,500	**-2%**
Bering Sea	2,900	2,392	**-21%**	2,679	**-8%**
Aleutians	3,100	2,744	**-13%**	3,074	**-1%**
Gulf of Alaska	14,890	13,164	**-13%**	14,747	**-1%**
Western	2,570	2,329	**-10%**	2,609	**1%**
Central	6,440	5,808	**-11%**	6,506	**1%**
W. Yakutat	2,320	1,868	**-24%**	2,093	**-11%**
E. Yakutat / Southeast	3,560	3,159	**-13%**	3,539	**-1%**

Regional estimates of age-4+ biomass are tabulated in Table 3.11.

Overfishing level

Applying an adjusted $F_{35\%}$ as prescribed for Over Fishing Level (OFL) in Tier 3b results in a value of 30,800 mt for the combined stock. The OFL is apportioned by region, Bering Sea (4,020 mt), Aleutian Islands (4,620 mt), and Gulf of Alaska (22,160 mt), by the same method as the ABC apportionment.

3.6 Ecosystem considerations

Ecosystem considerations for the Alaska sablefish fishery are summarized in Table 3.12.

3.6.1 Ecosystem effects on the stock

1) Prey population trends: Young-of-the-year sablefish prey mostly on euphausiids; juvenile and adult sablefish are opportunistic feeders (section 3.1). Larval sablefish abundance has been linked to copepod abundance (McFarlane and Beamish 1992). Young-of-the-year abundance may be similarly affected by euphausiid abundance because of their apparent dependence on a single species. Juvenile and adult sablefish unlikely are affected by availability and abundance of individual prey species because they are opportunistic feeders. The only likely way prey trends likely affect growth or survival of juvenile and adult sablefish is by overall changes in ecosystem productivity. The dependence of larval and young-of-

the-year sablefish on single prey species may be the cause of observed wide variation in annual sablefish recruitment. No time series of information is available on copepod and euphausiid abundance to predict sablefish abundance based on this predator-prey relationship.

2) Predator population trends: The main sablefish predators are adult coho and chinook salmon, which prey on young-of-the-year sablefish (section 3.1). Salmon abundance has decreased in recent years, likely reducing stock mortality rates over time.

3) Habitat quality: Water mass movements and temperature appear related to recruitment success (Sigler et al. 2001). Above-average recruitment was somewhat more likely with northerly winter currents and much less likely for years when the drift was southerly. Recruitment was above average in 61% of the years when temperature was above average, but was above average in only 25% of the years when temperature was below average. Growth rate of young-of-the-year sablefish is higher in years when they are more abundant.

3.6.2 Fishery effects on the ecosystem

1) Fishery-specific contribution to bycatch of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species such as sharks are tabulated on the next page. Sablefish fishery catches significant portions of the spiny dogfish and unidentified shark total catch. The trend is variable. Sablefish fishery catches the majority of grenadier total catch (average 71%). The trend is stable. Seabirds may be captured by longlines. Sablefish fishery catch of seabirds averages 10% of the total catch. The trend is variable but appears to be decreasing, presumably due to widespread use of measures to reduce seabird catch. Sablefish fishery catches of the remaining species is minor.

The fishing effects of the current fishery management regime are either minimal or temporary based on the criteria that sablefish currently are above MSST (Draft EFH SEIS). However caution is warranted. Sablefish are substantially dependent on benthic prey (18% of diet by weight) which may be adversely affected by fishing. Little is known about sablefish spawning habitat and effects of fishing on that habitat. Habitat requirements for growth to maturity are better known, but this knowledge is incomplete. Although sablefish do not appear substantially dependent on physical structure, living structure and coral are substantially reduced in much of the area where sablefish are concentrated. Living structure is reduced 6-15% and hard coral is reduced 29-55% in three areas comprising 87% of the habitat where sablefish are concentrated (Aleutian Islands deep [6% of sablefish habitat], Gulf of Deep Shelf [41%] and Gulf of Alaska slope [41%]). Other anthropogenic effects besides fishing, such as coastal development, may impact juvenile sablefish habitat. Other fishing effects not mediated by habitat (fishing on the continental shelf, catching juvenile sablefish as bycatch) may reduce juvenile survivorship and are a particular concern in areas of the Bering Sea and Gulf of Alaska where juvenile sablefish are concentrated and bottom trawl fishing intensity is high.

The shift from an open-access to an IFQ fishery has increased catching efficiency 1.8 times, thereby reducing the number of hooks deployed (Sigler and Lunsford 2001). Although the effects of longline gear on bottom habitat are poorly known, to whatever unknown extent the habitat is affected, the reduced number of hooks deployed during the IFQ fishery reduces these habitat effects. The IFQ fishery likely has also reduced discards of other species because of the slower pace of the fishery and the incentive to maximize value from the catch.

Table.—Catch (percent and for average, mt) of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species such as sharks in sablefish directed fisheries.

Species	1997	1998	1999	2000	2001	2002	Average catch (%)	Average catch (mt)
sculpin	0%	0%	0%	0%	0%	0%	0%	10
skates	2%	12%	2%	2%	2%	2%	4%	863
shark	26%	88%	4%	18%	43%	24%	66%	246
salmonshk	0%	0%	11%	1%	0%	1%	3%	3
dogfish	20%	7%	26%	34%	24%	59%	21%	102
sleepershk	12%	3%	3%	15%	3%	1%	6%	48
octopus	5%	0%	0%	0%	1%	1%	1%	6
squid	0%	0%	0%	0%	0%	0%	0%	1
smelts	0%	0%	0%	0%	0%	0%	0%	-
gunnel	0%	0%	0%	0%	0%	0%	0%	-
sticheidae	0%	0%	0%	0%	2%	0%	1%	0
sandfish	0%	0%	0%	0%	0%	0%	0%	-
lanternfish	0%	0%	0%	0%	0%	0%	0%	-
sandlance	0%	0%	0%	0%	0%	0%	0%	-
grenadier	73%	70%	66%	72%	80%	69%	71%	12,930
otherfish	1%	81%	3%	11%	5%	2%	38%	1,401
crabs	0%	0%	0%	0%	0%	0%	0%	0
starfish	0%	17%	0%	0%	0%	0%	2%	128
jellyfish	0%	0%	0%	0%	0%	0%	0%	0
invertunid	0%	0%	0%	0%	0%	0%	0%	0
seapen/whip	6%	0%	0%	2%	1%	0%	1%	0
sponge	0%	0%	0%	0%	0%	0%	0%	0
anemone	0%	0%	1%	0%	1%	1%	0%	1
tunicate	0%	0%	0%	0%	0%	0%	0%	0
benthinv	0%	0%	0%	0%	0%	1%	0%	1
snails					0%	0%	0%	-
echinoderm	0%	0%	0%	1%	1%	0%	1%	0
coral	0%	2%	1%	4%	0%	2%	1%	1
shrimp	0%	0%	0%	0%	1%	0%	0%	0
birds	7%	10%	21%	10%	13%	5%	11%	3

2) Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The sablefish fishery largely is dispersed in space and time. The longline fishery lasts 8-1/2 months. The quota is allocated among six regions of Alaska.

3) Fishery-specific effects on amount of large size target fish: The longline fishery catches mostly medium and large-size fish which are typically mature. The trawl fishery, which accounts for about 12% of the total catch, often catches small and medium fish. The trawl fishery typically occurs on the continental shelf which juvenile sablefish inhabit. Catching these fish as juveniles reduces the yield available from each recruit.

4) Fishery-specific contribution to discards and offal production: Discards of sablefish in the longline fishery are small, typically less than 5% of total catch (Table 3.3). The catch of sablefish in the longline fishery typically consists of a high proportion of sablefish, 90% and more. However at times grenadiers may be an significant catch and they are discarded.

5) Fishery-specific effects on age-at-maturity and fecundity of the target species: The shift from an open-

access to an IFQ fishery has decreased harvest of immature fish and improved the chance that individual fish will reproduce at least once. Spawning potential of sablefish, expressed as spawning biomass per recruit, increased 9% for the IFQ fishery (Sigler and Lunsford 2000).

The longline fishery catches mostly medium and large-size fish which are typically mature. The trawl fishery, which accounts for about 12% of the total catch, often catches small and medium fish. The trawl fishery typically occurs on the continental shelf which juvenile sablefish inhabit. Catching these fish as juveniles reduces the yield available from each recruit, though the shift likely is small because trawl fishery catches currently make up only a small part of the total sablefish caught.

6) Fishery-specific effects on EFH non-living substrate: See item 1.

3.6.3 Data gaps and research priorities

Data gaps which prevent assessing certain effects: No time series of information is available on copepod and euphausiid abundance to predict sablefish abundance based on this predator-prey relationship. Need better identification of shark species, which are easy to differentiate. Need improved coverage of trawl vessels catching sablefish, both to verify discard rates and to obtain the size of fish discarded. Not enough size information has been collected in recent years for the data to be usable.

3.7 Summary

The following table summarizes key results from the assessment of sablefish in Alaska:

Age at 50% selection for survey	4.3
Age at 50% selection for "derby" fishery	4.3
Age at 50% selection for IFQ fishery	5.2
Age at 50% selection for trawl fishery	2.9
Natural mortality (M)	0.107
Tier	3b
Equilibrium unfished spawning biomass	528
Reference point spawning biomass, $B_{40\%}$	211
Reference point spawning biomass, $B_{35\%}$	185
2004 exploitable biomass	221
2004 spawning biomass	210
2004 total (age-4+) biomass	250
Maximum permissible fishing level	
$F_{40\%}$	0.131
2004 $F_{40\%}$ adjusted	0.130
2004 $F_{40\%}$ adjusted Yield	25.4
Overfishing level	
$F_{35\%}$	0.161
2004 $F_{35\%}$ adjusted	0.160
2004 $F_{35\%}$ adjusted Yield	30.8
Authors' recommendation	
2004 F	0.117
2004 ABC	23.0
or	
2004 F	0.104
2004 ABC	20.7

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Tables

Table 3.1.--Sablefish fork length (cm), weight (kg), and proportion mature by age and sex.

	Fork length (cm)		Weight (kg)		Fraction mature	
Age	Male	Female	Male	Female	Male	Female
2	50	52	1.3	1.4	0.059	0.006
3	53	56	1.5	1.8	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	2.5	3.3	0.876	0.765
9	63	70	2.6	3.6	0.915	0.865
10	64	71	2.7	3.8	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	4.8	0.979	0.990
16	67	77	3.2	5.0	0.982	0.992
17	67	78	3.2	5.1	0.984	0.994
18	67	78	3.2	5.2	0.985	0.995
19	68	79	3.3	5.3	0.986	0.996
20	68	79	3.3	5.4	0.987	0.997
21	68	80	3.3	5.5	0.988	0.997
22	68	80	3.3	5.6	0.988	0.998
23	68	80	3.4	5.7	0.989	0.998
24	68	81	3.4	5.7	0.989	0.998
25	68	81	3.4	5.8	0.989	0.998
26	68	81	3.4	5.8	0.990	0.998
27	68	81	3.4	5.9	0.990	0.999
28	69	81	3.4	5.9	0.990	0.999
29	69	82	3.4	5.9	0.990	0.999
30	69	82	3.4	6.0	0.990	0.999

Table 3.2--Alaska sablefish catch (mt). The values include landed catch and discard estimates. Discards were estimated for U.S. fisheries before 1993 by multiplying reported catch by 2.9% for fixed gear and 26.9% for trawl gear (1994-1997 averages) because discard estimates were unavailable. Eastern includes both West Yakutat and East Yakutat / Southeast.

Year	Grand total	BY AREA								BY GEAR	
		Bering Sea	Aleu-tians	Western	Central	Eastern	West Yakutat	East Yakutat/ Soeast.	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
2000	15,919	828	1,314	1,587	6,172	6,018	2,066	3,952	0	13,906	2,013
2001	14,097	878	1,092	1,589	5,518	5,020	1,737	3,283	0	10,863	1,783
2002	14,789	1,166	1,139	1,863	6,180	4,441	1,550	2,891	0	10,852	2,261

Table 3.3--Discarded catches of sablefish (amount [mt] and percent of total catch) by target fishery, gear (H&L=hook & line, TWL=trawl), and management area.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ Southeast	
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
	2000	2	1	7	1	49	4	168	4	46	2	159	3
	2001	9	5	16	2	34	2	133	3	33	2	1153	2
	2002	5	2	5	2	32	2	109	3	33	2	79	3
Greenland turbot (H&L)	1994	1	1	2	3	0	-	0	-	0	-	0	-
	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	-
	2000	27	15	15	14	0	-	0	-	0	-	0	-
	2001	36	25	0	1	0	-	0	-	0	-	0	-
	2002	84	67	0	2	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	-
	2000	54	79	3	15	0	23	34	81	0	-	1	100
	2001	34	57	9	23	1	9	7	27	0	-	0	5
	2002	36	61	2	3	20	81	12	44	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
	2000	1	100	0	2	0	-	0	5	0	-	0	-
	2001	0	42	0	10	0	100	2	28	1	49	90	38
	2002	0	29	0	2	0	27	2	18	10	98	11	49
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
	2000	83	20	26	3	49	4	213	4	52	2	240	4
	2001	80	20	25	3	35	2	142	3	34	2	1243	2
	2002	125	27	27	3	52	3	123	3	43	3	91	3

Table 3.3 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	-
	2000	0	-	0	-	0	2	0	-	0	-	0	-
	2001	0	-	0	-	0	-	0	-	0	-	0	-
	2002	0	-	0	-	0	-	0	-	17	23	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	-
	2000	0	-	0	-	1	2	155	18	1	1	0	-
	2001	0	-	1	3	0	-	191	25	30	0	0	-
	2002	0	4	0	1	24	25	433	36	2	3	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	-
	2000	4	5	0	-	60	48	115	64	0	-	0	-
	2001	10	13	0	-	7	93	7	93	0	-	0	-
	2002	18	19	0	-	69	63	55	57	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	-
	2000	0	-	0	-	0	-	3	13	0	4	0	-
	2001	0	-	0	-	17	41	17	41	4	32	0	-
	2002	0	-	0	-	0	-	18	57	0	-	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	-
	2000	0	-	0	-	0	-	34	67	2	100	0	-
	2001	0	-	0	-	34	86	34	86	0	-	0	-
	2002	0	-	0	-	0	-	8	54	0	-	0	-

Table 3.3 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.
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	-
	2000	0	-	0	-	40	58	82	62	0	-	0	-
	2001	0	-	0	-	119	73	119	73	0	-	0	-
	2002	0	-	0	-	58	32	58	32	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	-
	2000	0	-	0	-	0	-	0	-	0	-	0	-
	2001	0	-	0	-	0	-	0	-	0	-	0	-
	2002	2	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	-
	2000	48	37	0	23	11	98	108	75	0	-	0	-
	2001	16	10	1	100	37	53	37	53	0	-	0	-
	2002	30	21	1	9	1	4	1	4	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	-
	2000	54	19	0	-	112	45	496	36	3	4	0	-
	2001	26	7	2	4	405	37	405	37	4	2	0	-
	2002	51	17	1	2	575	37	575	37	19	15	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
	2000	138	19	26	3	161	10	709	11	55	3	240	4
	2001	106	14	27	3	116	7	547	10	38	2	66	2
	2002	176	23	27	3	149	8	697	11	62	4	91	3

Table 3.4.--Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from the observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data.

	LENGTH						AGE		
	Japanese fishery		U.S. fishery		Cooperative longline survey	Domestic longline survey	Cooperative longline survey	Domestic longline survey	U.S. longline fishery
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			19,349				
1980		1,944							
1981							1,146		
1982									
1983							889		
1984									
1985							1,294		
1986									
1987							1,057		
1988									
1989							655		
1990			1,229	33,822		101,530			
1991			721	29,615		95,364	902		
1992			0	21,000		104,786			
1993			468	23,884		94,699	1,178		
1994			89	13,614		70,431			
1995			87	18,174		80,826			
1996			239	15,213		72,247		1,175	
1997			0	20,311		82,783		1,211	
1998			35	8,900		57,773		1,183	
1999			1,268	26,662		79,451		1,188	1,145
2000			472	29,240		62,513		1,236	1,152
2001			473	30,362		83,726		1,214	1,023
2002			526	35,380		75,937		1,136	1,061
2003						77,678			

Table 3.5.--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. Relative population number equals catch per effort in numbers weighted by respective strata areas. Relative population weight equals catch per effort measured in weight multiplied by strata areas. Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands 1979, 1995, 1997, 1999, 2001, and 2003 and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, and 2002.

	RELATIVE POPULATION NUMBER		RELATIVE POPULATION WEIGHT			
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			1,595		
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	1,152
2001		533			1,798	1,209
2002		559			1,916	1,226
2003		532			1,759	

Table 3.6.--Average CPUE (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. The standard error is not available when vessel sample size equals one.

Observer Fishery Data

Bering Sea

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.37	0.07	0.10	715	39
1991	0.26	0.11	0.21	55	15
1992	0.15	0.06	0.20	13	6
1993	0.13	0.08	0.30	29	4
1994	0.32	0.36	0.57	8	4
1995	0.38	0.11	0.15	60	16
1996	0.44	0.16	0.19	51	17
1997	0.30	0.11	0.19	30	10
1998	0.24	0.10	0.21	38	10
1999	0.17	0.05	0.16	49	17
2000	0.22	0.06	0.14	36	12
2001	0.46	0.14	0.16	91	26
2002	0.21	0.09	0.21	20	8

Aleutian Islands

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.51	0.20	0.20	182	7
1991	0.45	0.06	0.07	547	17
1992	0.39	0.07	0.09	369	11
1993	0.28	0.07	0.13	705	10
1994	0.29	0.08	0.14	405	22
1995	0.29	0.06	0.10	345	15
1996	0.23	0.04	0.08	251	18
1997	0.37	0.10	0.14	157	11
1998	0.23	0.06	0.13	94	10
1999	0.31	0.08	0.14	369	16
2000	0.28	0.07	0.12	377	16
2001	0.28	0.09	0.16	238	9
2002	0.32	0.07	0.10	280	12

Western Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.54	0.23	0.21	214	10
1991	0.43	0.11	0.12	284	9
1992	0.32	0.04	0.07	522	25
1993	0.29	0.05	0.09	214	6
1994	0.29	0.07	0.12	78	5
1995	0.56	0.18	0.17	508	22
1996	0.53	0.09	0.09	302	22
1997	0.47	0.08	0.09	375	21
1998	0.46	0.05	0.05	337	15
1999	0.60	0.07	0.06	377	23
2000	0.50	0.10	0.10	233	16
2001	0.55	0.13	0.11	404	19
2002	0.57	0.10	0.09	485	18

Central Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.59	0.10	0.08	816	51
1991	0.54	0.13	0.12	666	11
1992	0.56	0.09	0.08	764	41
1993	0.76	0.51	0.34	1191	7
1994	0.53	0.13	0.12	474	25
1995	0.80	0.09	0.06	749	37
1996	0.85	0.10	0.06	599	59
1997	0.92	0.10	0.06	567	51
1998	0.85	0.09	0.05	508	39
1999	0.89	0.13	0.07	338	38
2000	0.84	0.11	0.06	419	50
2001	0.73	0.11	0.08	300	34
2002	0.83	0.13	0.08	320	32

West Yakutat

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.65	0.16	0.13	135	19
1991	0.63	0.16	0.13	300	9
1992	0.54	0.21	0.20	314	20
1993	0.57	0.12	0.11	515	5
1994	0.55	0.29	0.27	124	8
1995	0.98	0.18	0.09	267	23
1996	0.90	0.13	0.07	284	33
1997	1.21	0.18	0.08	177	29
1998	1.11	0.16	0.07	226	32
1999	1.32	0.28	0.11	117	21
2000	1.39	0.22	0.08	207	33
2001	1.05	0.14	0.07	229	32
2002	1.26	0.23	0.93	210	27

East Yakutat / Southeast

Year	CPUE	SE	CV	# Sets	Vessels
1990	0.60	0.60	0.51	39	3
1991	0.69	0.27	0.20	57	5
1992	0.62	0.27	0.22	47	4
1993	0.80	0.03	0.02	40	2
1994	0.32			5	1
1995	1.21	0.32	0.14	164	18
1996	1.10	0.19	0.09	185	30
1997	1.26	0.24	0.10	157	38
1998	1.21	0.18	0.08	260	34
1999	1.09	0.17	0.08	135	18
2000	0.99	0.27	0.14	91	17
2001	0.92	0.14	0.07	179	17
2002	1.17	0.36	0.15	147	19

Table 3.6 cont.

Required Logbook Fishery Data

Bering Sea

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.52	0.14	0.14	523	52
2000	0.19	0.09	0.23	530	28
2001	0.39	0.16	0.21	241	17

Aleutian Islands

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.36	0.17	0.24	475	17
2000	0.19	0.06	0.16	1008	28
2001	0.32	0.13	0.21	358	18

Western Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.56	0.13	0.12	394	23
2000	0.60	0.10	0.09	667	44
2001	0.61	0.12	0.10	463	37

Central Gulf

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.84	0.15	0.09	807	83
2000	0.79	0.08	0.05	1253	127
2001	0.70	0.09	0.07	1179	135

West Yakutat

Year	CPUE	SE	CV	# Sets	Vessels
1999	1.11	0.23	0.10	210	36
2000	1.07	0.10	0.05	463	59
2001	1.01	0.14	0.07	451	72

East Yakutat / Southeast

Year	CPUE	SE	CV	# Sets	Vessels
1999	0.93	0.15	0.08	169	16
2000	0.98	0.17	0.09	325	40
2001	1.02	0.23	0.11	277	36

Table 3.7.–Sablefish abundance (relative population weight, RPW) from annual sablefish longline surveys (domestic longline survey only) and number of stations where sperm whale (SW) and killer whale (KW) depredation of sablefish catches occurred. Some stations were not sampled all years, indicated by "na". Recording of sperm whale depredation began with the 1998 survey.

Year	Bering			Aleutians			Western		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	na	na	na	Na	na	na	244,164	na	0
1991	na	na	na	Na	na	na	203,357	na	1
1992	na	na	na	Na	na	na	94,874	na	1
1993	na	na	na	Na	na	na	234,169	na	2
1994	na	na	na	Na	na	na	176,820	na	0
1995	na	na	na	Na	na	na	198,247	na	0
1996	na	na	na	186,270	na	1	213,126	na	0
1997	160,300	na	3	Na	na	na	182,189	na	0
1998	na	na	na	271,323	0	1	203,590	0	0
1999	136,313	0	7	na	na	na	192,191	0	0
2000	na	na	na	260,665	0	1	242,707	0	1
2001	248,019	0	4	na	na	na	294,277	0	0
2002	na	na	na	292,425	0	1	256,548	0	4
2003	232,996	0	7	na	na	na	258,996	0	3

Year	Central			West Yakutat			East Yakutat / Southeast		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	684,738	na	0	268,334	na	0	393,964	na	0
1991	641,693	na	0	287,103	na	0	532,242	na	0
1992	568,474	na	0	316,770	na	0	475,528	na	0
1993	639,161	na	0	304,701	na	0	447,362	na	0
1994	603,940	na	0	275,281	na	0	434,840	na	0
1995	595,903	na	0	245,075	na	0	388,858	na	0
1996	783,763	na	0	248,847	na	0	390,696	na	0
1997	683,294	na	0	216,415	na	0	358,229	na	0
1998	519,781	0	0	178,783	4	0	349,350	0	0
1999	608,225	3	0	183,129	5	0	334,516	4	0
2000	506,368	0	0	158,411	2	0	303,716	2	0
2001	561,168	3	0	129,620	0	0	290,747	2	0
2002	643,363	4	0	171,985	3	0	287,133	2	0
2003	605,417	1	0	146,631	1	0	245,367	2	0

Table 3.8a.– Ages that above average year classes became abundant by region (Figure 3.7, relative population number greater than 10,000). "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska. Age data was not available for the Western areas until 1985. The 1984 year class never was abundant in the Eastern area. The 1995 year class was only moderately abundant in the Central and Eastern areas.

Year class	Western	Central	Eastern
1977	na	4	4
1980-81	5	6	6
1984	5	9	na
1990	6	7	7
1995	4	7	7
1997	4	4	5
1998	4	na	na

Table 3.8b– Years that the above average 1995, 1997, and 1998 year classes became abundant by region. "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska. The 1998 year class is predicted to appear in the Central and Eastern areas in 2003 or 2004. The relative population number at age-4 for the 1998 year class (20,000) is less than the value for the 1997 year class (53,000), indicating that the 1998 year class is substantially weaker than the 1997 year class.

Year class	Western	Central	Eastern
1995	1999	2002	2002
1997	2001	2001	2002
1998	2002	2003-04 (pred.)	2003-04 (pred.)

Table 3.9.--Sablefish age 4+ biomass, exploitable biomass, spawning biomass, and catch (thousands mt), and number (millions) at age 2 by year.

Year	Age 4+ biomass	Exploitable biomass	Spawning biomass	Number at age 2	Catch	Catch / Age 4+ biomass
1960	294	262	252	3.9	3.1	0.011
1961	281	258	248	4.9	16.1	0.057
1962	254	240	231	145.9	26.4	0.104
1963	219	213	212	11.1	16.9	0.077
1964	423	216	227	4.3	7.3	0.017
1965	437	278	279	5.6	8.7	0.020
1966	434	362	336	93.0	15.6	0.036
1967	415	389	369	6.4	19.2	0.046
1968	516	380	365	6.1	31.0	0.060
1969	485	389	374	57.1	36.8	0.076
1970	437	394	372	28.7	37.8	0.086
1971	470	379	366	7.4	43.5	0.093
1972	443	349	333	8.8	53.0	0.120
1973	393	339	320	2.6	36.9	0.094
1974	351	319	301	1.7	34.6	0.099
1975	300	283	268	2.4	29.9	0.100
1976	252	243	229	27.8	31.7	0.126
1977	208	202	194	2.6	21.4	0.103
1978	216	175	172	4.6	10.4	0.048
1979	200	170	165	92.6	11.9	0.059
1980	186	172	168	34.2	10.4	0.056
1981	316	182	187	4.7	12.6	0.040
1982	359	220	221	65.4	12.0	0.033
1983	356	283	269	42.5	11.8	0.033
1984	442	326	315	3.3	14.1	0.032
1985	483	353	339	11.6	14.5	0.030
1986	465	393	368	28.0	28.9	0.062
1987	434	395	370	12.7	35.2	0.081
1988	419	365	346	9.2	38.4	0.092
1989	376	328	310	5.5	34.8	0.093
1990	337	302	286	24.3	32.1	0.095
1991	296	274	262	7.0	27.0	0.091
1992	286	244	234	28.7	24.9	0.087
1993	261	228	220	14.6	25.4	0.097
1994	269	216	209	11.6	23.8	0.088
1995	259	209	203	6.8	20.9	0.081
1996	249	209	199	19.5	17.6	0.071
1997	232	205	196	18.5	14.9	0.064
1998	237	199	191	8.8	14.1	0.059
1999	245	197	191	46.8	13.6	0.056
2000	233	197	191	4.2	15.9	0.068
2001	285	203	198	6.4	14.1	0.050
2002	269	213	205	12.4	14.8	0.055
2003	256	225	211	9.1	14.8	0.058
2004	250	221	210			

Table 3.10--Sablefish spawning biomass, fishing mortality, and yield for seven harvest scenarios. Abundance projected using 1977-1999 year classes. Sablefish are not classified as overfished because abundance currently exceeds $B_{35\%}$.

Year	Maximum permissible F	0.9 maximum F	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass							
2003	211	211	211	211	211	211	211
2004	210	210	210	210	210	210	211
2005	189	191	200	198	212	184	193
2006	180	184	198	194	220	173	189
2007	177	181	200	194	231	168	186
2008	181	186	209	201	249	171	189
2009	187	192	219	209	266	176	189
2010	195	201	232	221	290	183	193
2011	201	208	242	229	309	187	195
2012	206	213	252	238	328	191	197
2013	210	218	260	245	346	194	197
2014	211	220	265	250	360	195	198
2015	213	222	271	254	374	196	198
2016	215	224	276	259	389	197	198
Fishing mortality							
2003	0.072	0.072	0.072	0.072	0.072	0.072	0.072
2004	0.130	0.117	0.065	0.077	0.000	0.160	0.130
2005	0.117	0.106	0.062	0.077	0.000	0.139	0.119
2006	0.111	0.102	0.061	0.077	0.000	0.130	0.142
2007	0.108	0.099	0.061	0.077	0.000	0.126	0.137
2008	0.109	0.100	0.061	0.077	0.000	0.127	0.137
2009	0.110	0.101	0.061	0.077	0.000	0.128	0.135
2010	0.113	0.104	0.062	0.077	0.000	0.132	0.137
2011	0.114	0.105	0.063	0.077	0.000	0.134	0.138
2012	0.116	0.106	0.063	0.077	0.000	0.135	0.138
2013	0.117	0.107	0.064	0.077	0.000	0.137	0.139
2014	0.117	0.108	0.064	0.077	0.000	0.137	0.139
2015	0.118	0.108	0.064	0.077	0.000	0.138	0.139
2016	0.118	0.109	0.064	0.077	0.000	0.138	0.139
Yield							
2003	14.8	14.8	14.8	14.8	14.8	14.8	14.8
2004	25.4	23.0	13.1	15.4	0.0	30.8	25.7
2005	20.7	19.1	11.9	14.5	0.0	23.9	21.7
2006	18.8	17.6	11.6	14.2	0.0	21.1	25.3
2007	18.2	17.2	11.7	14.3	0.0	20.1	24.6
2008	19.2	18.2	12.5	14.9	0.0	21.2	25.1
2009	20.3	19.2	13.2	15.6	0.0	22.3	25.2
2010	21.8	20.7	14.2	16.5	0.0	23.9	26.2
2011	22.8	21.6	15.0	17.1	0.0	24.9	26.5
2012	23.5	22.4	15.6	17.7	0.0	25.7	26.9
2013	24.2	23.0	16.2	18.2	0.0	26.3	27.0
2014	24.5	23.4	16.6	18.6	0.0	26.5	27.1
2015	24.8	23.7	16.9	18.9	0.0	26.7	27.1
2016	25.0	24.0	17.3	19.2	0.0	26.9	27.1

Table 3.11.--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	36	39	126	200
1980	33	36	117	186
1981	53	75	188	316
1982	62	81	217	359
1983	61	72	223	356
1984	79	90	273	442
1985	88	105	289	483
1986	89	99	277	465
1987	86	86	262	434
1988	61	89	269	419
1989	46	70	259	376
1990	46	66	225	337
1991	40	49	207	296
1992	27	44	216	286
1993	22	36	203	261
1994	15	36	218	269
1995	18	35	206	259
1996	19	34	196	249
1997	20	27	186	232
1998	21	25	192	237
1999	21	33	191	245
2000	19	35	179	233
2001	23	44	218	285
2002	29	41	198	269
2003	32	40	185	256
2004	32	39	179	250

Table 3.12.--Analysis of ecosystem considerations for sablefish fishery.

Indicator	***Observation***	***Interpretation***	***Evaluation***
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends			
Zooplankton	None	None	Unknown
Predator population trends			
Salmon	Decreasing	Increases the stock	No concern
Changes in habitat quality			
Temperature regime	Warm increases recruitment	Variable recruitment	No concern (can't affect)
Prevailing currents	Northerly increases recruitment	Variable recruitment	No concern (can't affect)
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch			
Prohibited species	Small catches	Minor contribution to mortality	No concern
Forage species	Small catches	Minor contribution to mortality	No concern
HAPC biota (seapens/whips, corals, sponges, anemones)	Small catches, except long-term reductions predicted	Long-term reductions predicted in hard corals and living structure	Definite concern
Marine mammals and birds	Bird catch about 10% total	Appears to be decreasing	Possible concern
Sensitive non-target species	Grenadier, spiny dogfish, and unidentified shark catch notable	Grenadier catch high but stable, shark catch is variable	Possible concern for sharks
Fishery concentration in space and time	IFQ less concentrated	IFQ improves	No concern
Fishery effects on amount of large size target fish	IFQ reduces catch of immature	IFQ improves	No concern
Fishery contribution to discards and offal production	sablefish <5% in longline fishery, but 30% in trawl fishery	IFQ improves, but notable discards in trawl fishery	Trawl fishery discards definite concern
Fishery effects on age-at-maturity and fecundity	trawl fishery catches smaller fish, but only small part of total catch	slightly decreases	No concern

Figures

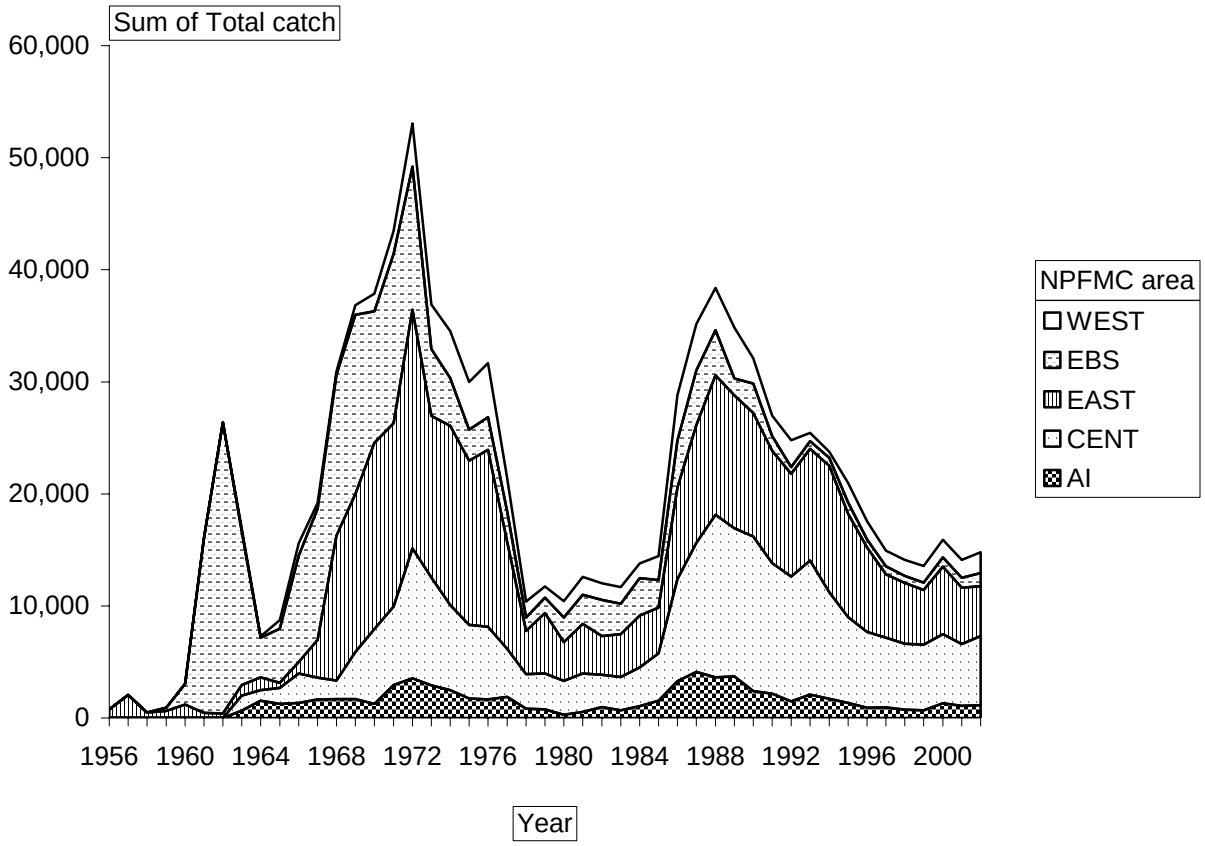


Figure 3.1–Sablefish fishery total reported catch (mt) by North Pacific Fishery Management Council area (WEST is Western Gulf of Alaska, EBS is eastern Bering Sea, EAST is Eastern Gulf of Alaska, CENT is Central Gulf of Alaska, and AI is Aleutian Islands) and year.

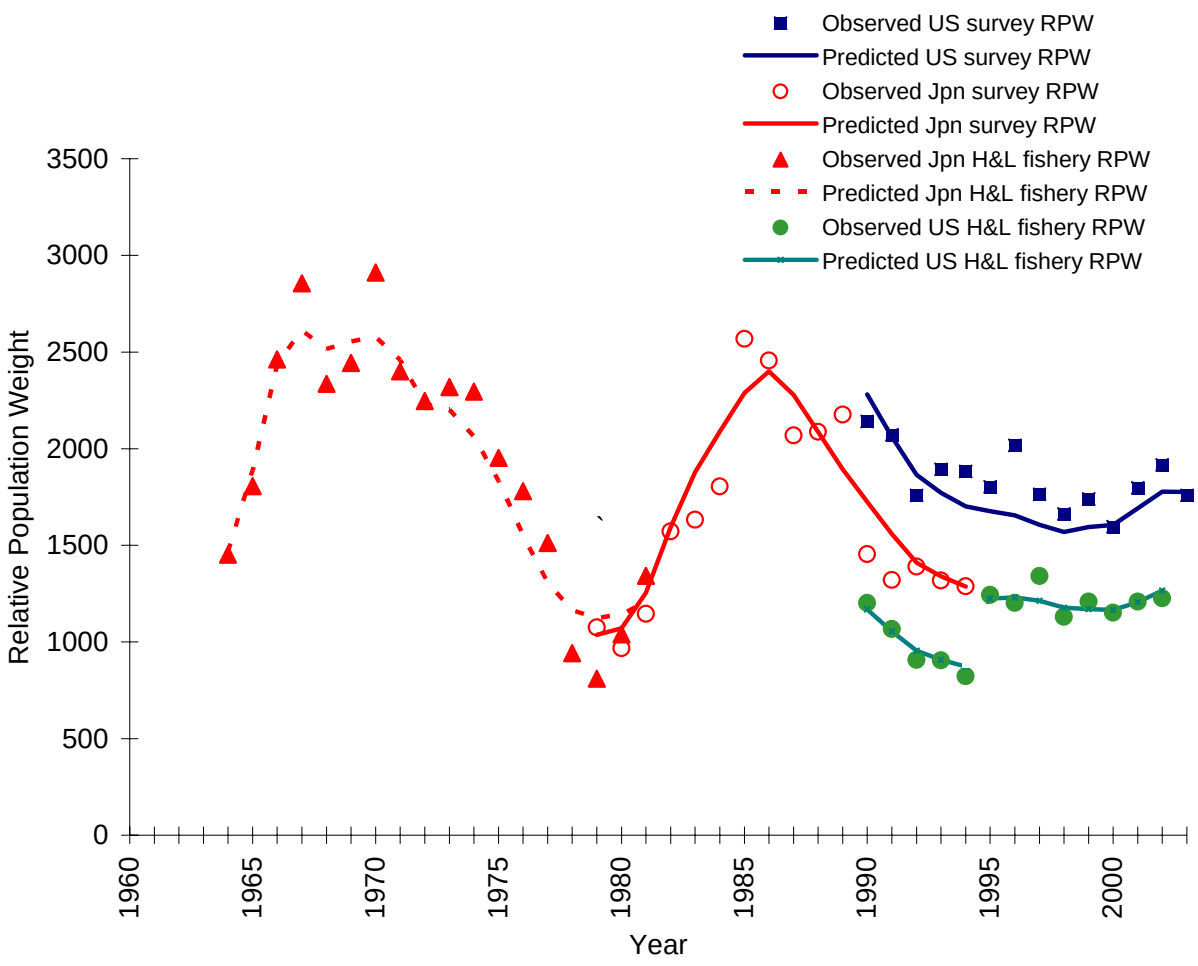


Figure 3.2.--Observed and predicted sablefish relative population weight versus year.

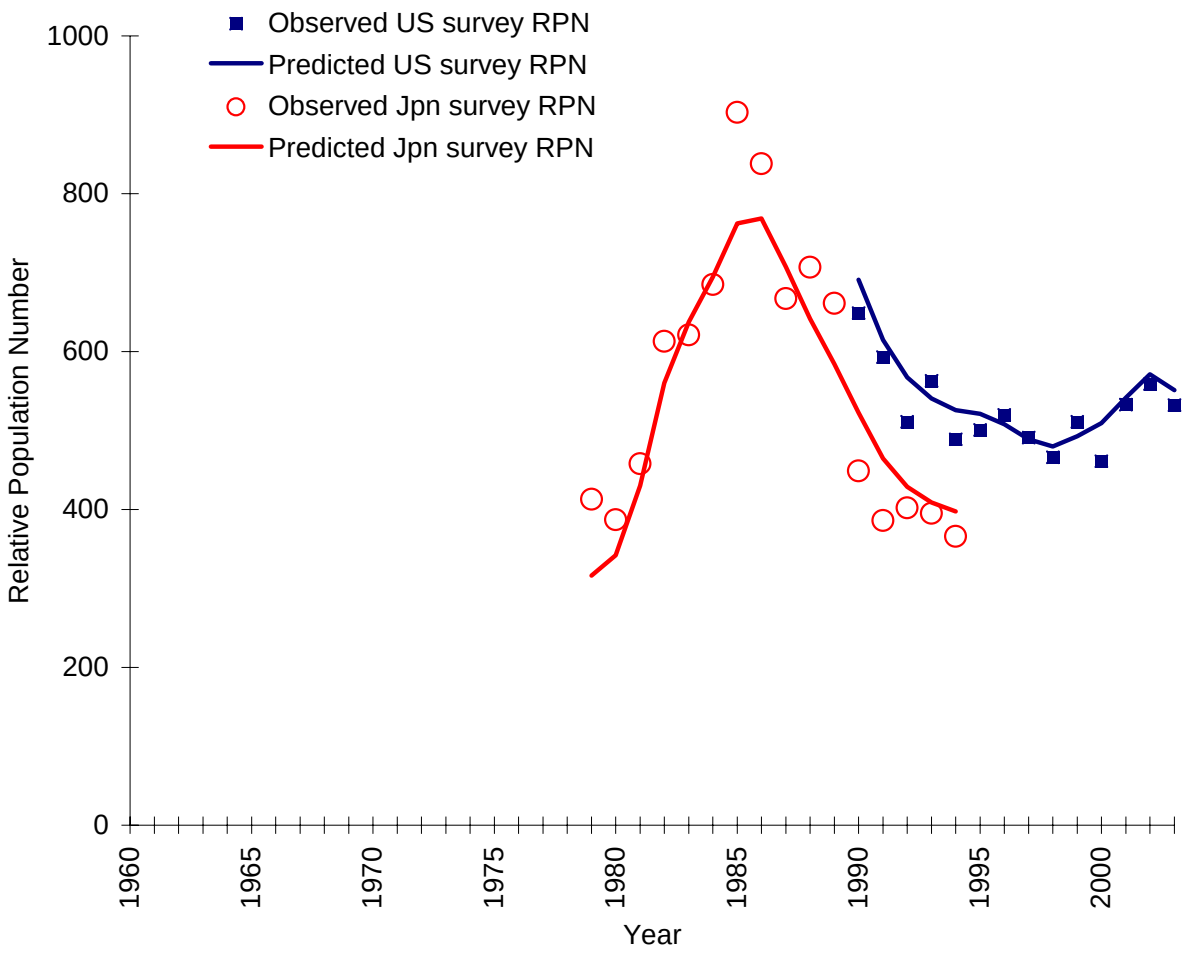


Figure 3.3.--Observed and predicted sablefish relative population number versus year.

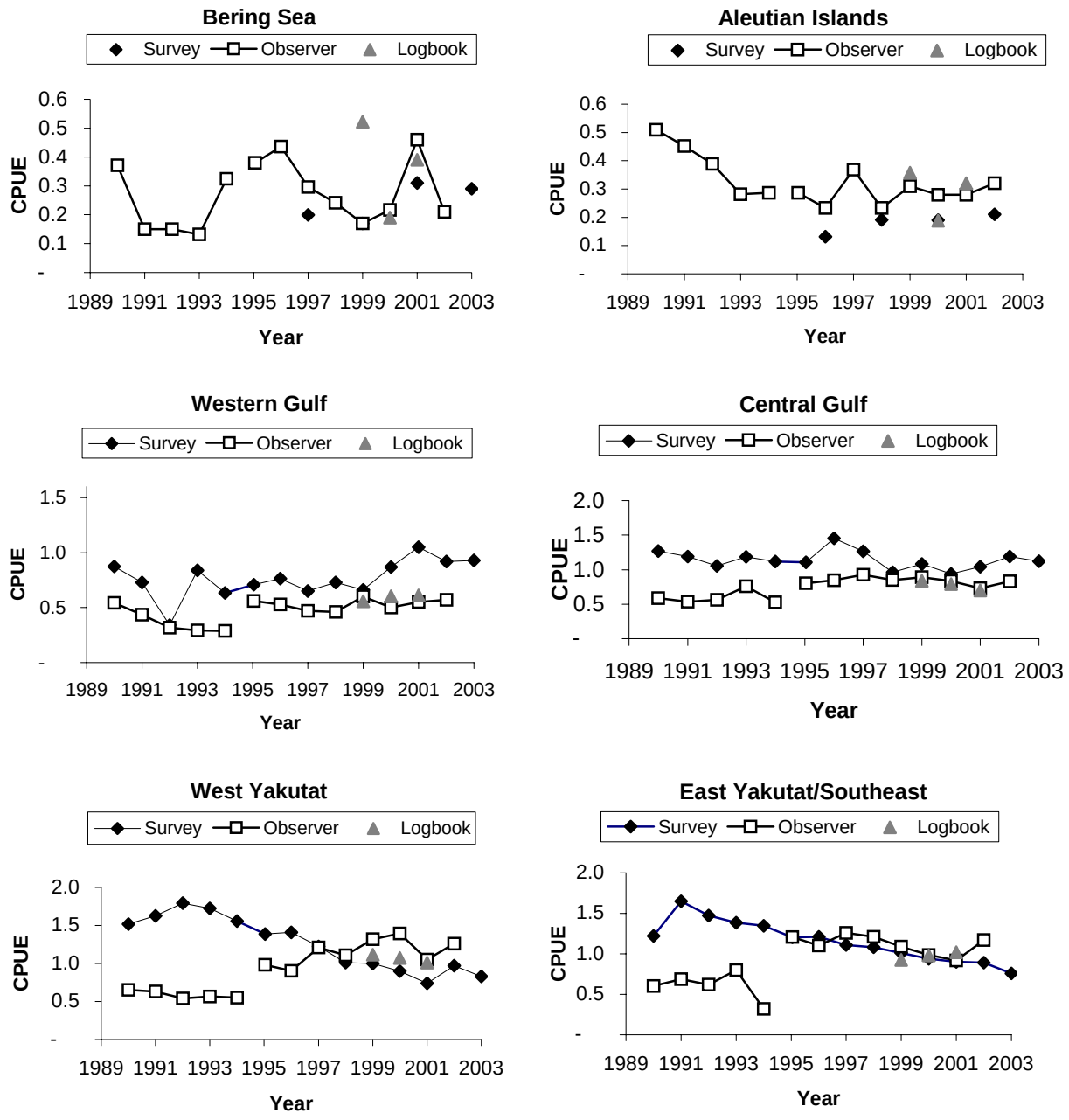


Figure 3.4.–Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

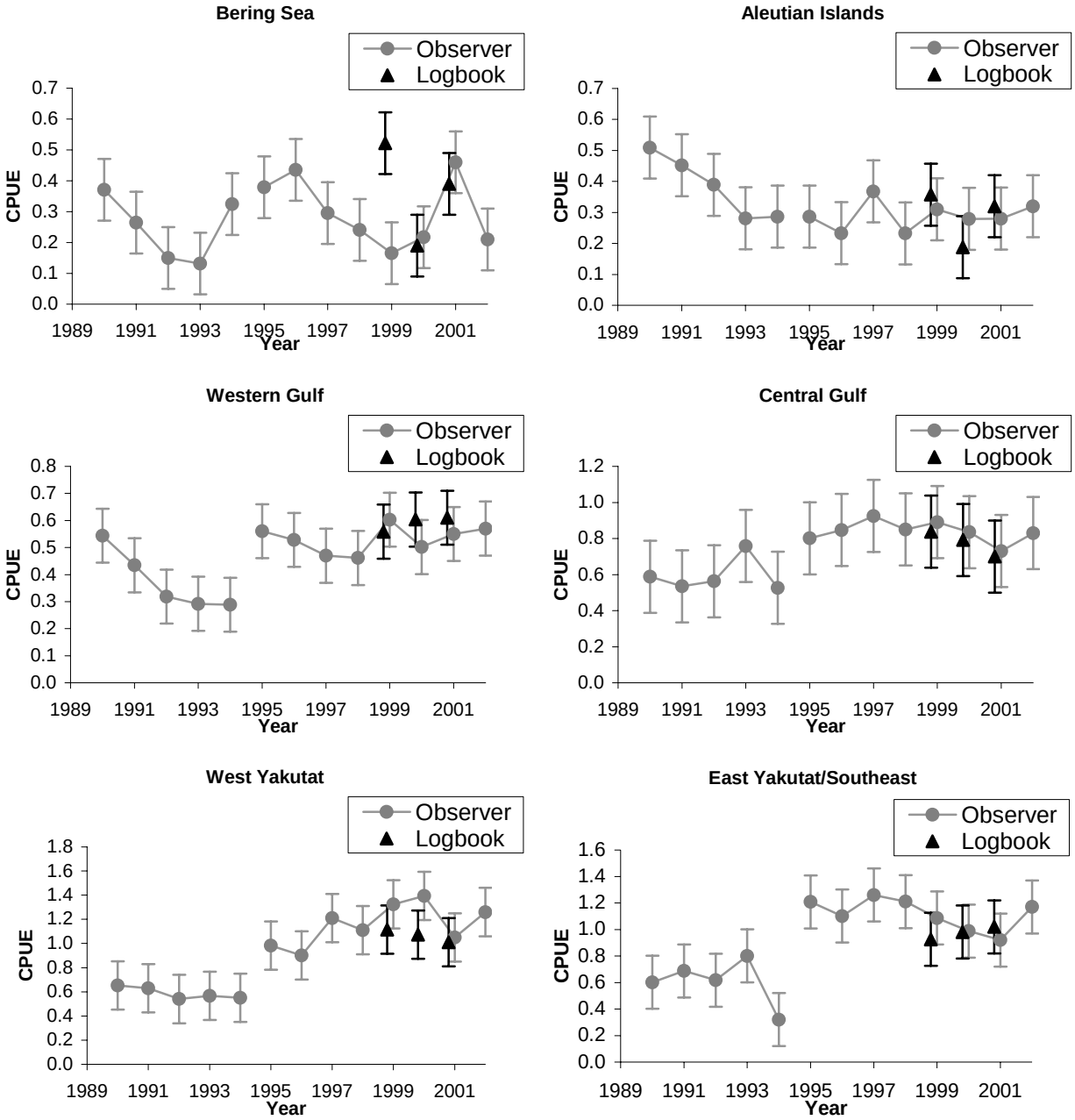


Figure 3.5.–Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

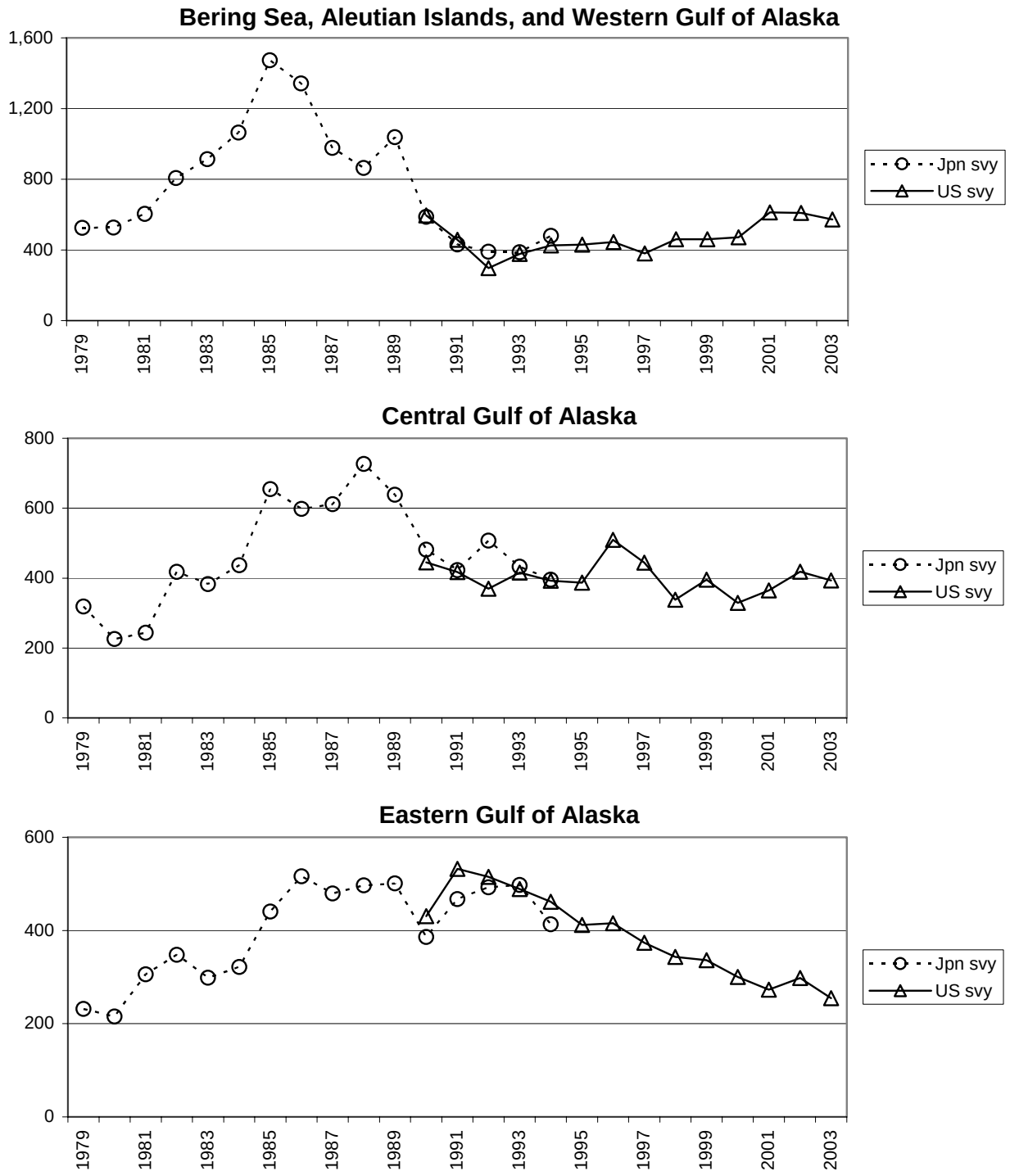


Figure 3.6.—Relative abundance (weight) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear.

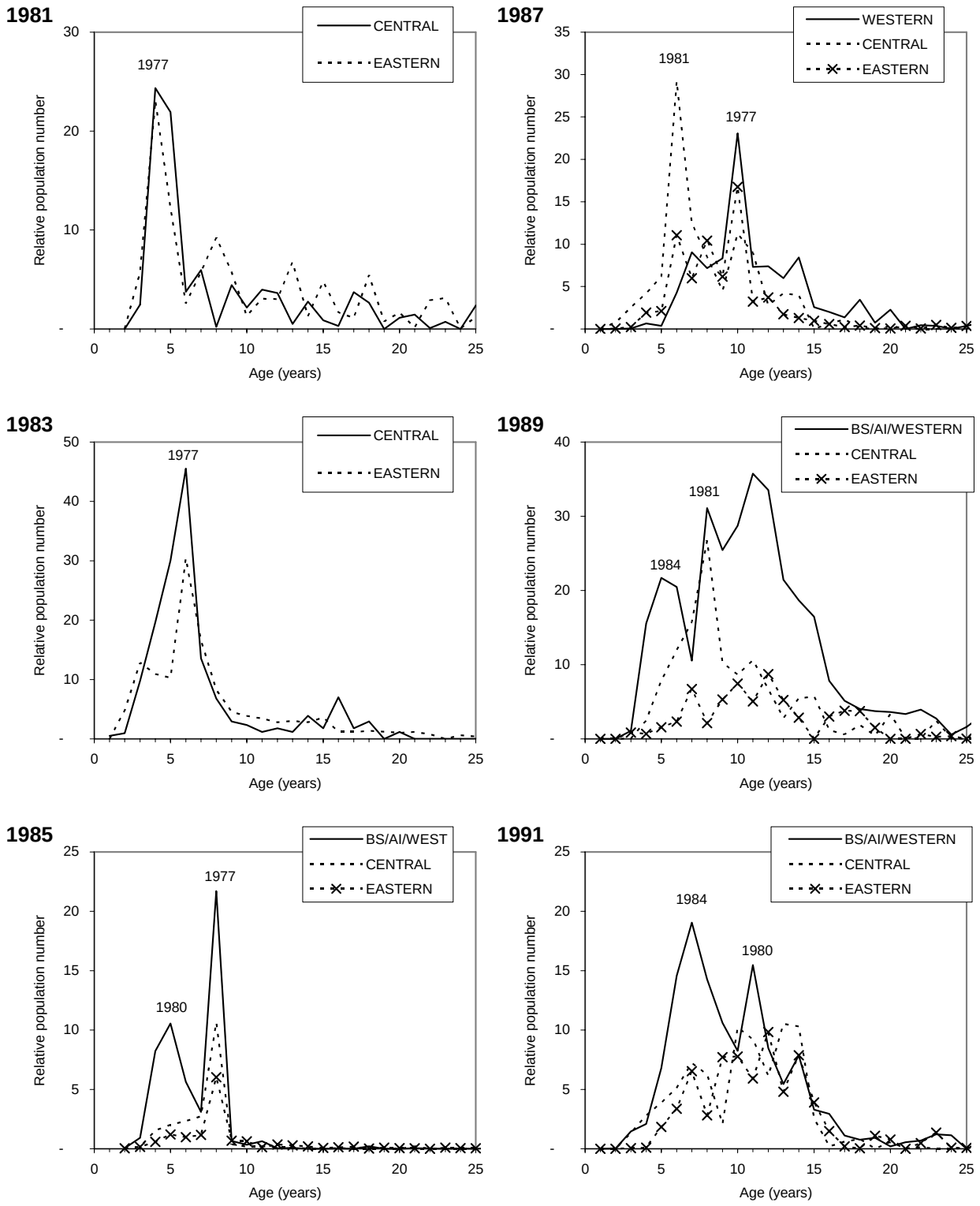


Figure 3.7.—Relative abundance (number, thousands) by age and region. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

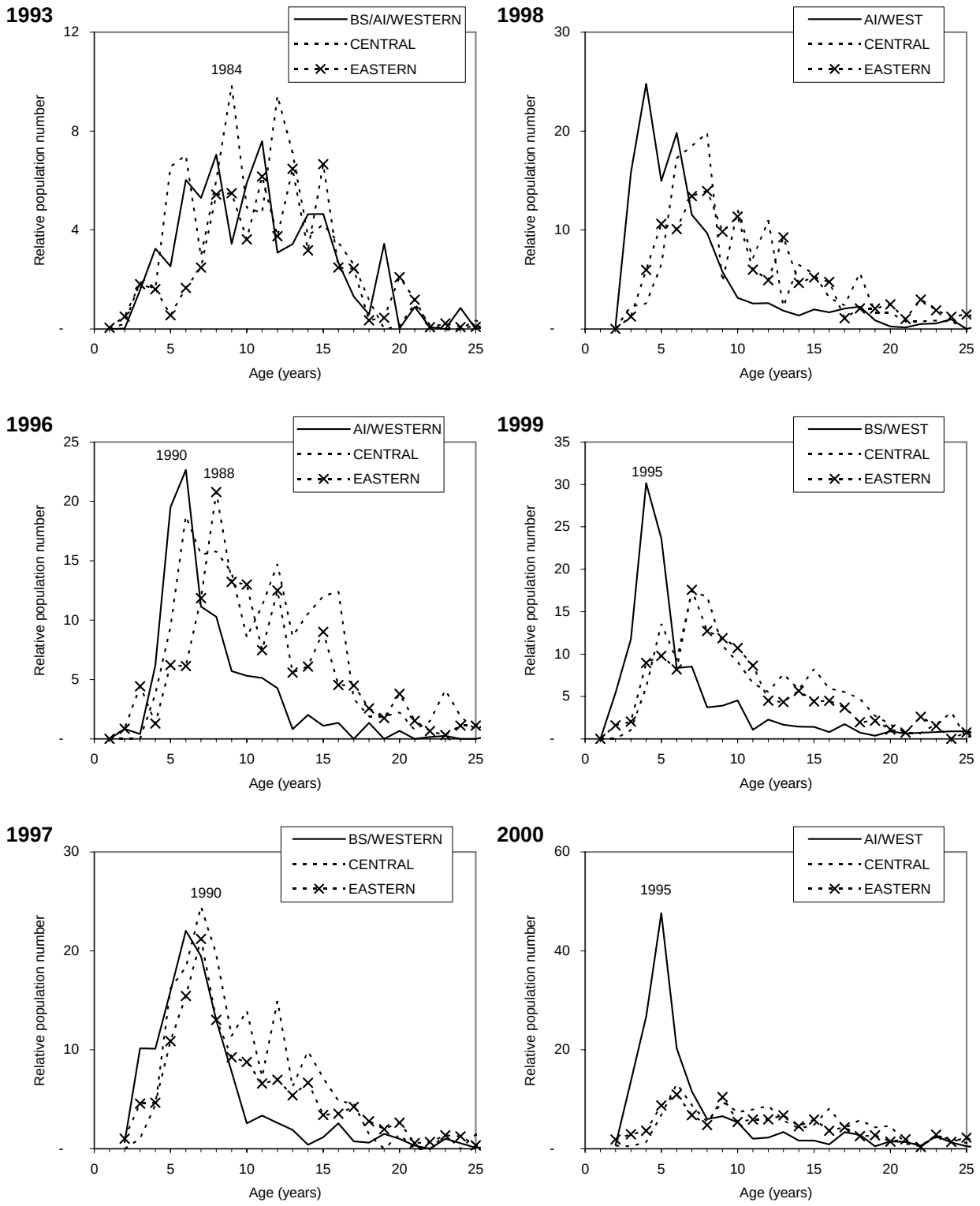


Figure 3.7 cont.

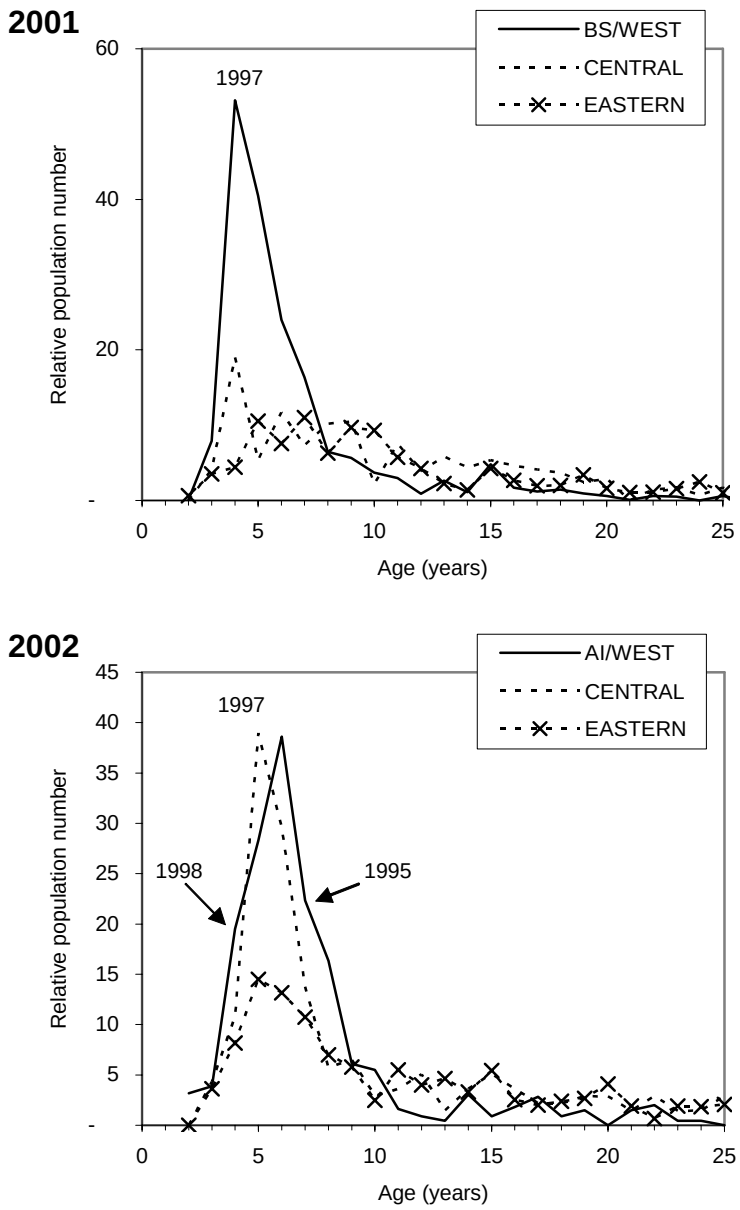


Figure 3.7 cont.

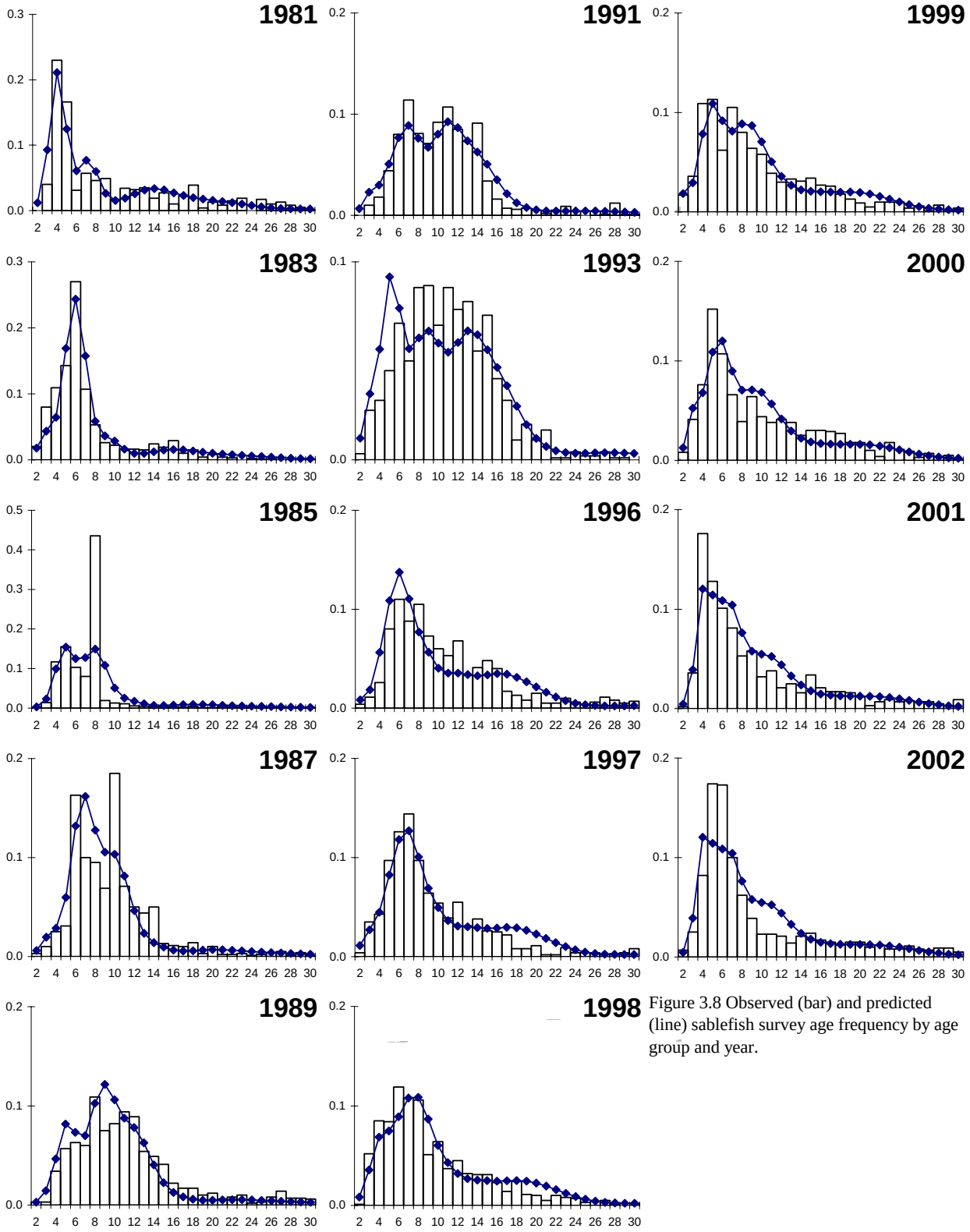


Figure 3.8 Observed (bar) and predicted (line) sablefish survey age frequency by age group and year.

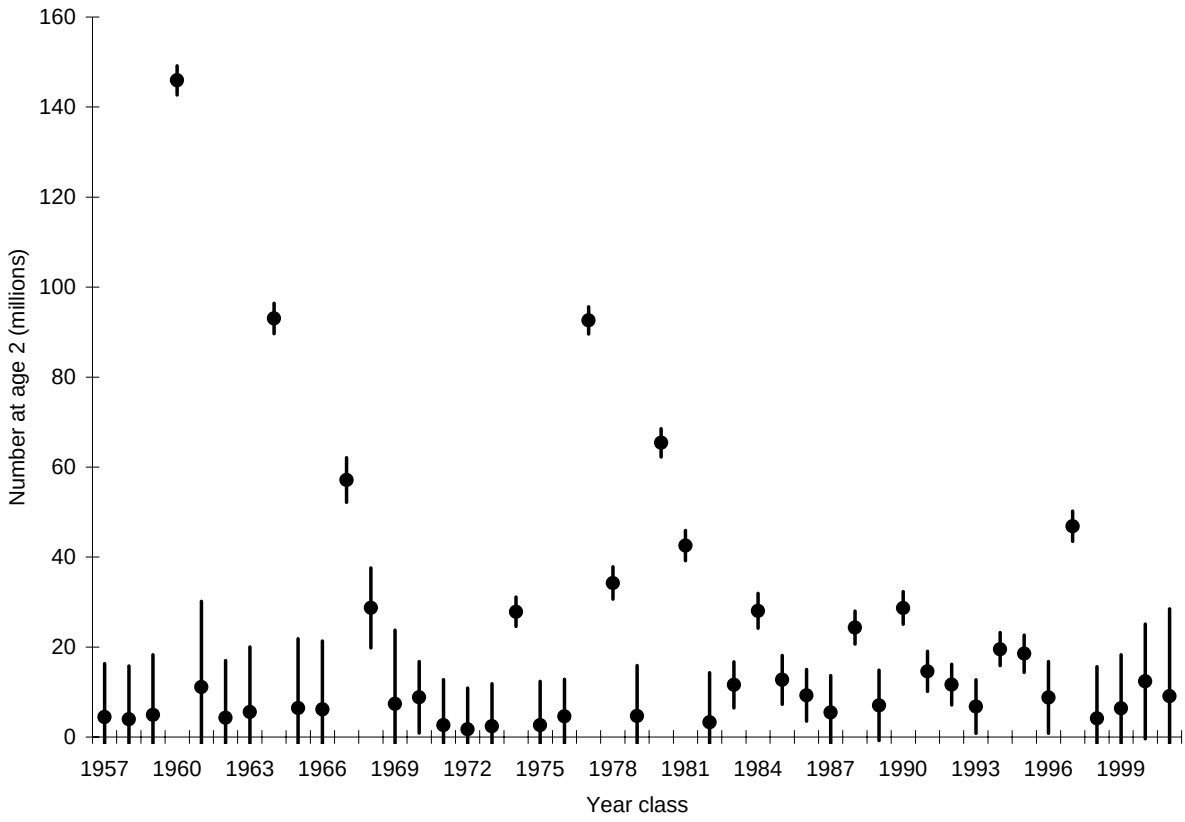


Figure 3.9.--Model estimates of the number of age-2 sablefish (millions) +/- 2 standard errors by year class. Standard error estimates based on covariance matrix from age-structured model output.

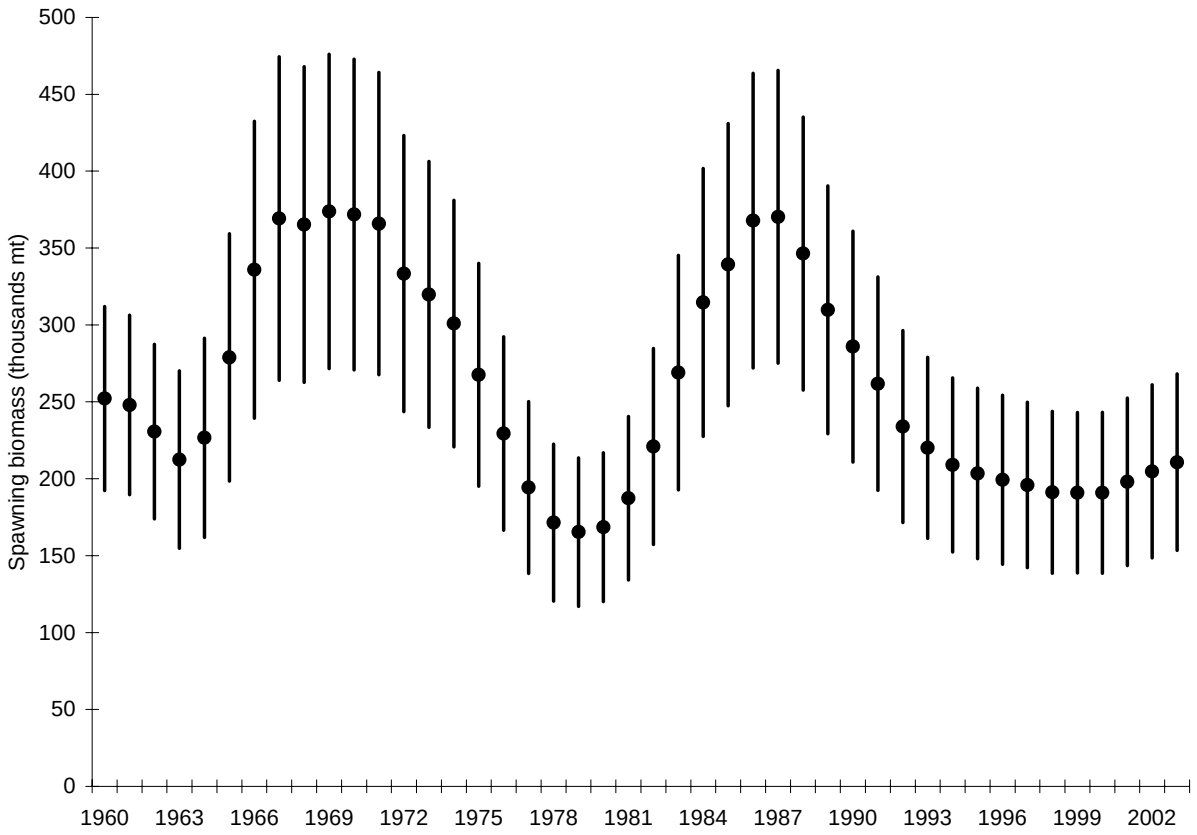


Figure 3.10.--Model estimates of male and female spawning biomass (thousands mt) +/- 2 standard errors by year. Standard error estimates based on covariance matrix from age-structured model output.

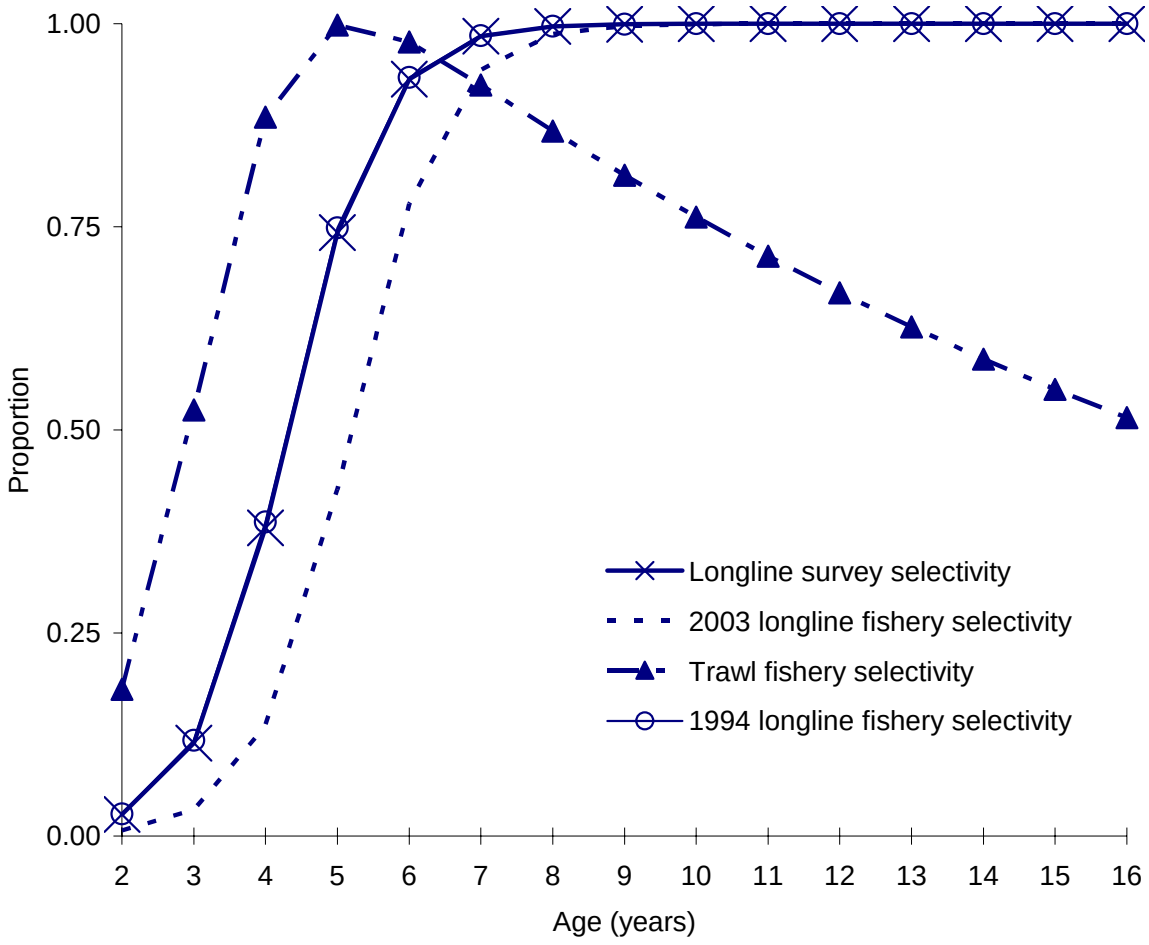


Figure 3.11 Sablefish survey, longline fishery, and trawl fishery selectivity functions. The displayed 1994 and 2003 longline selectivity functions are representative of the selectivity functions for the short open-access "derby" and IFQ seasons respectively.

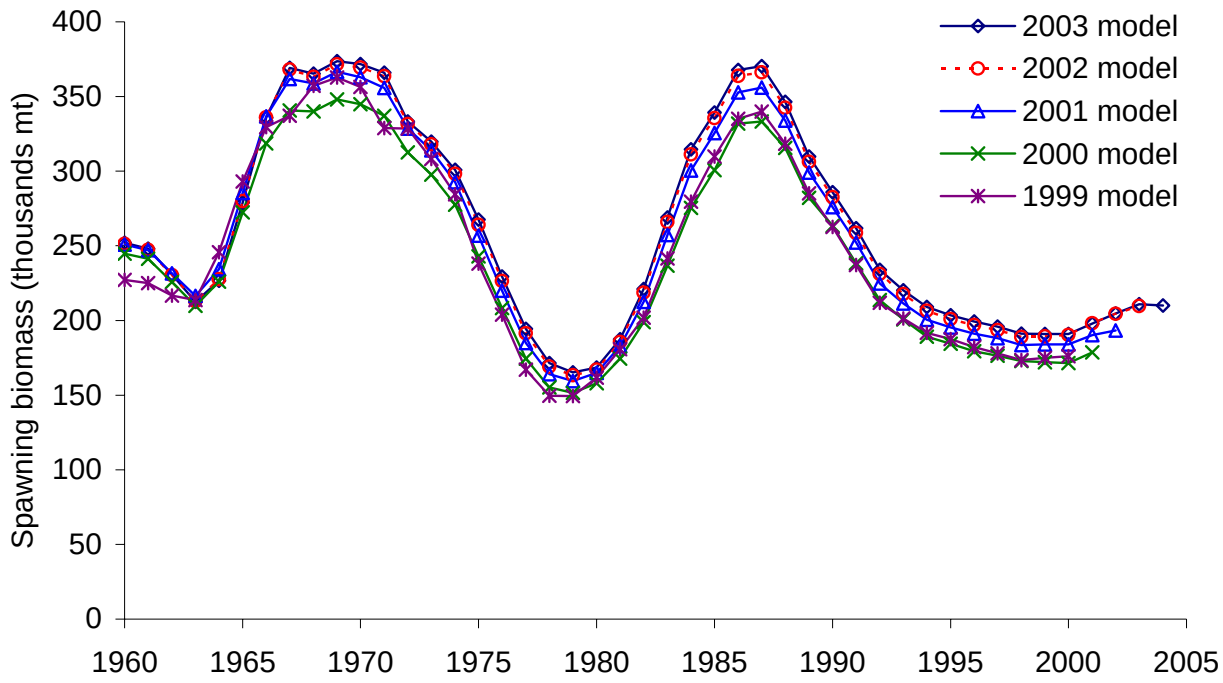


Figure 3.12a.--Estimated and one-year ahead projected sablefish spawning biomass (thousands mt) versus year by assessment model year. The current model is the 2003 assessment model.

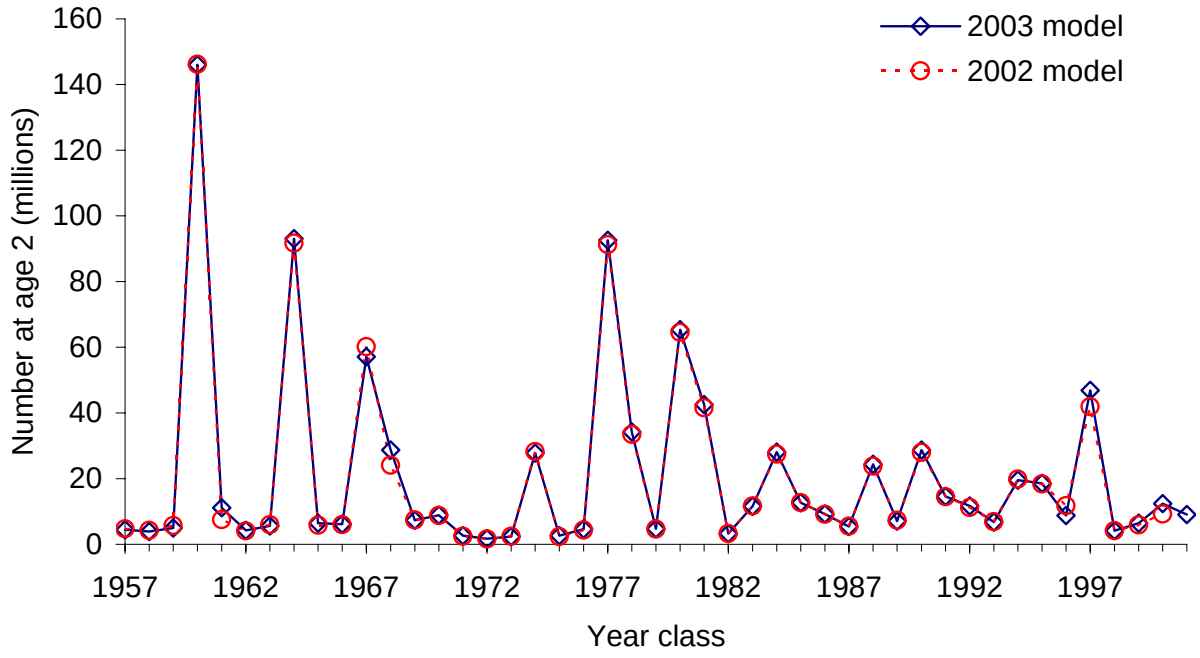


Figure 3.12b.--Estimated recruitment (number at age 2, millions) versus year for the 2002 and 2003 assessment models. Only two years are displayed for display clarity.

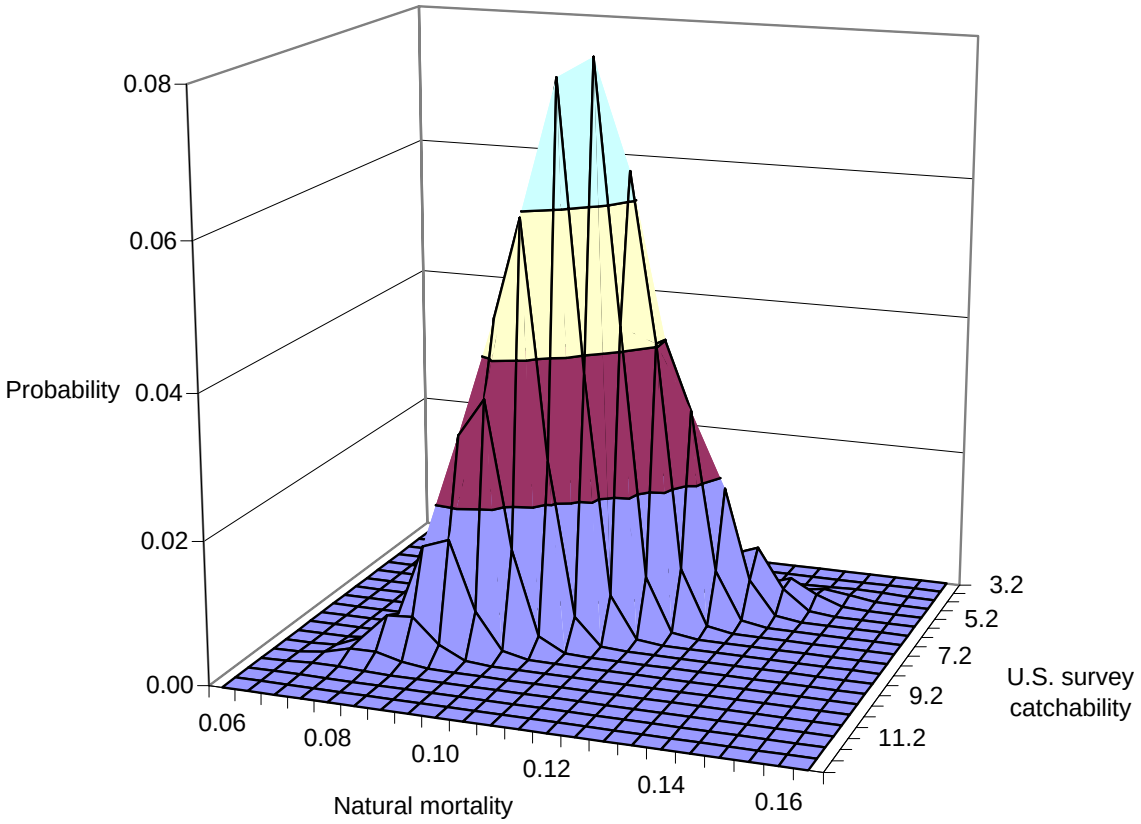


Figure 3.13.--Posterior probability versus catchability and natural mortality.

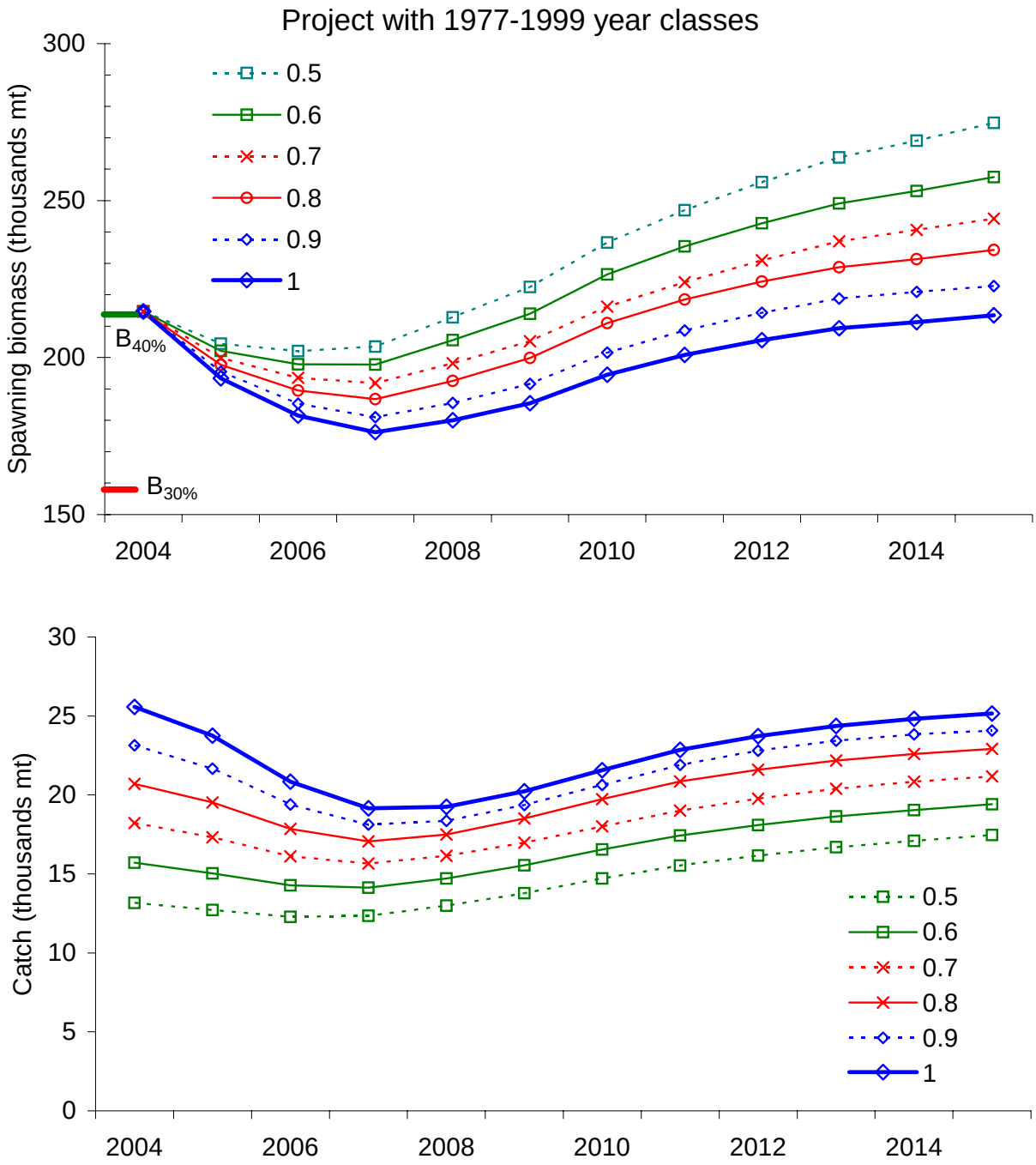
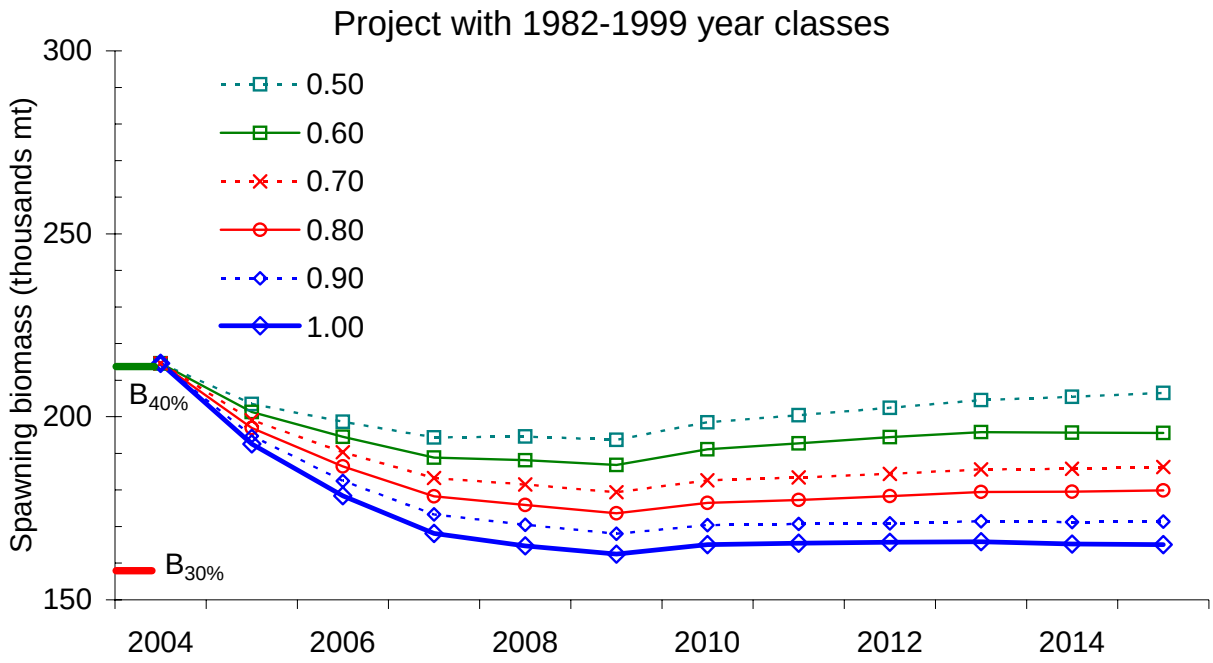


Figure 3.14--Sablefish spawning biomass and catch (thousands mt) for several harvest alternatives that vary the proportion of maximum allowable fishing mortality. Recruitment is projected using the 1977-1999 year classes and 1982-1999 year classes. The harvest alternatives are described in section 3.5.1, *Standard set of population projections* and *Decision Analysis*.



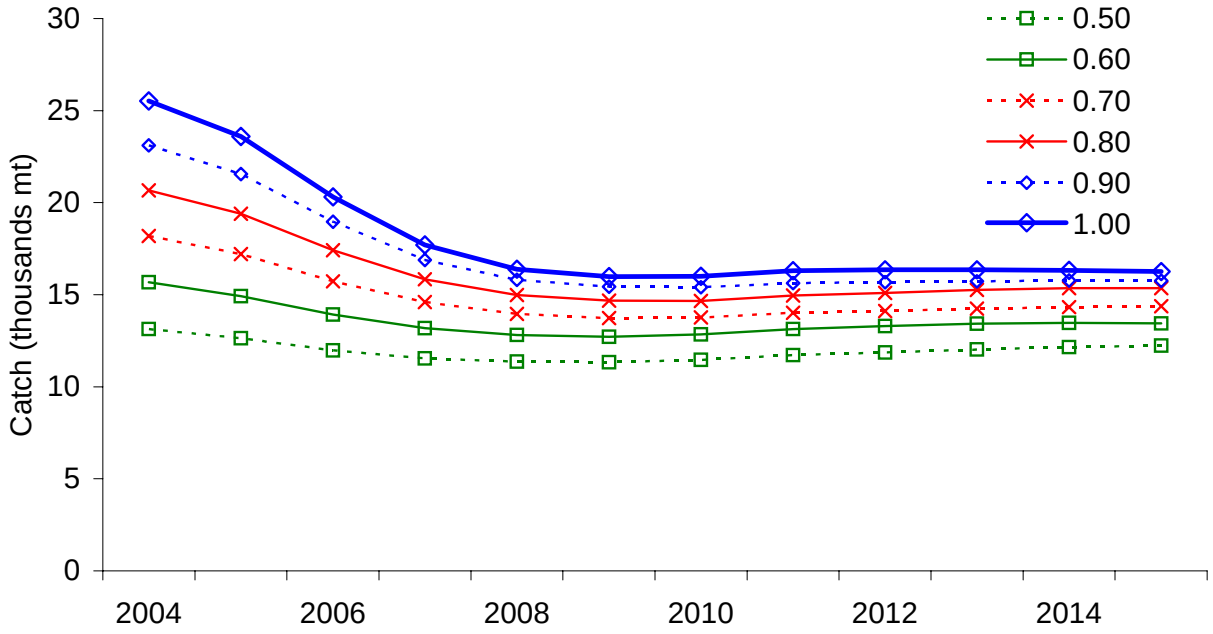


Figure 3.14 cont.

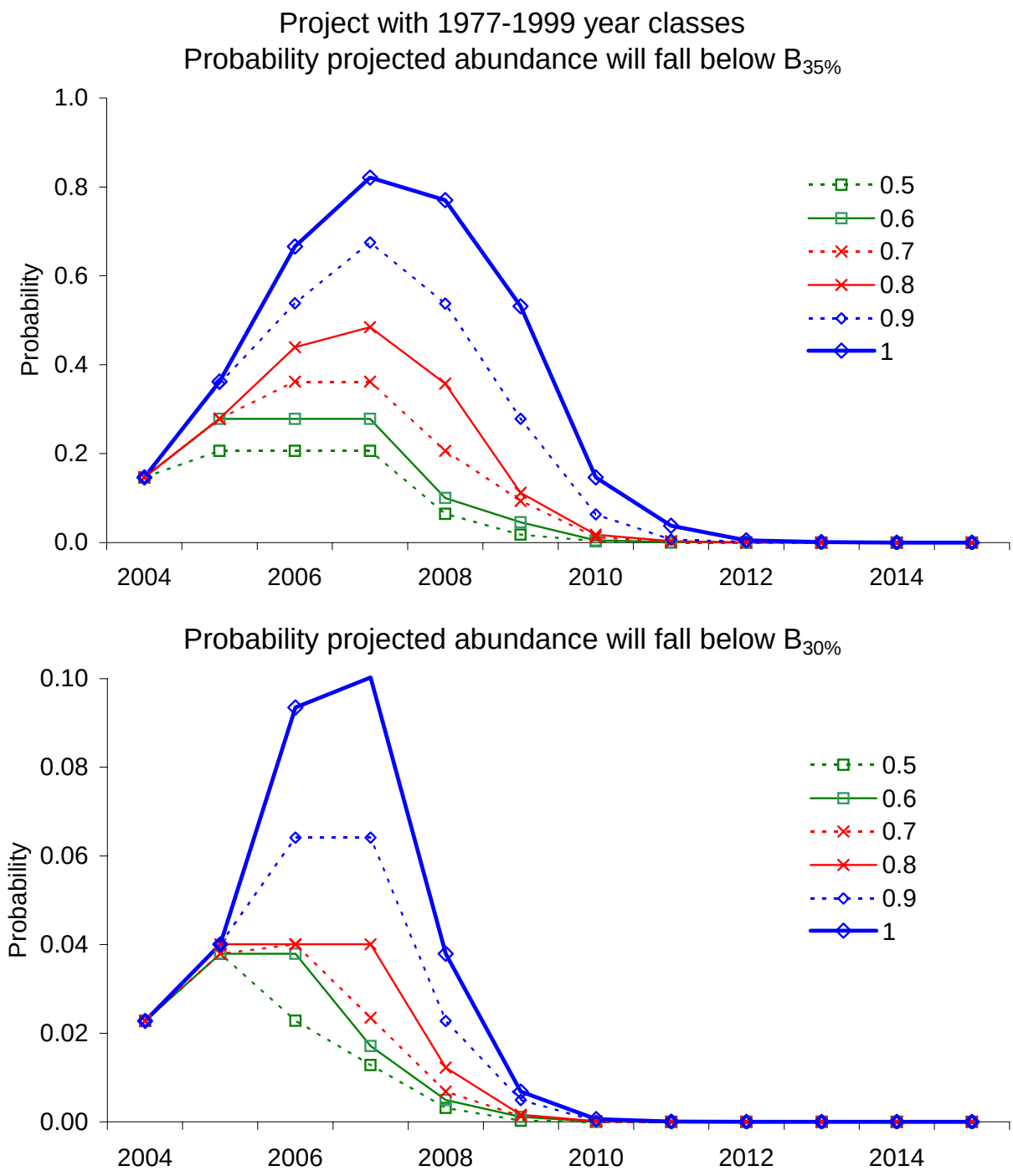
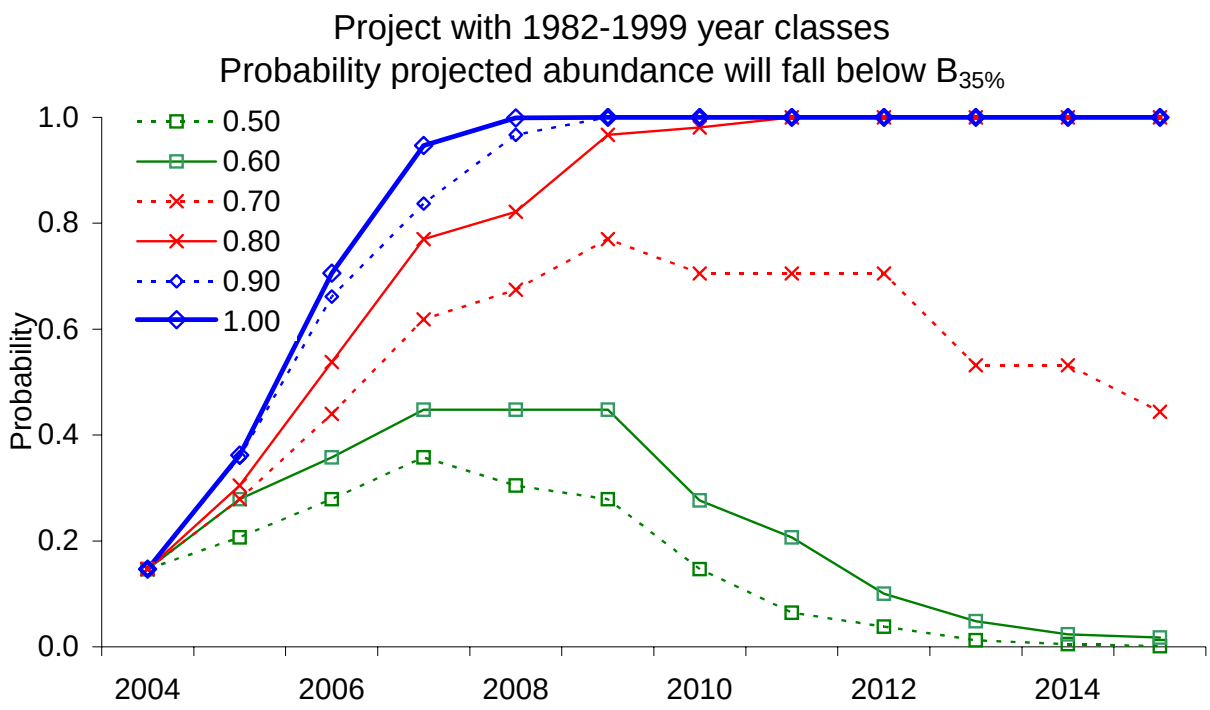


Figure 3.15.–Probability that projected abundance will fall below $B_{35\%}$ and $B_{30\%}$ for several harvest alternatives. The harvest scenarios vary the proportion of maximum allowable fishing mortality from 0.5-1.0, where 1.0 represents maximum allowable fishing mortality and 0.5 represents half of maximum allowable fishing mortality. Recruitment is projected using the 1977-1999 year classes and 1982-1999 year classes. The probability that projected abundance falls below $B_{25\%}$ during any projection year is less than 0.002 for 1977-1999 projections and is less than 0.003 for 1982-1999 projections. The harvest alternatives are described in section 3.5.1, *Standard set of population projections* and *Decision Analysis*.



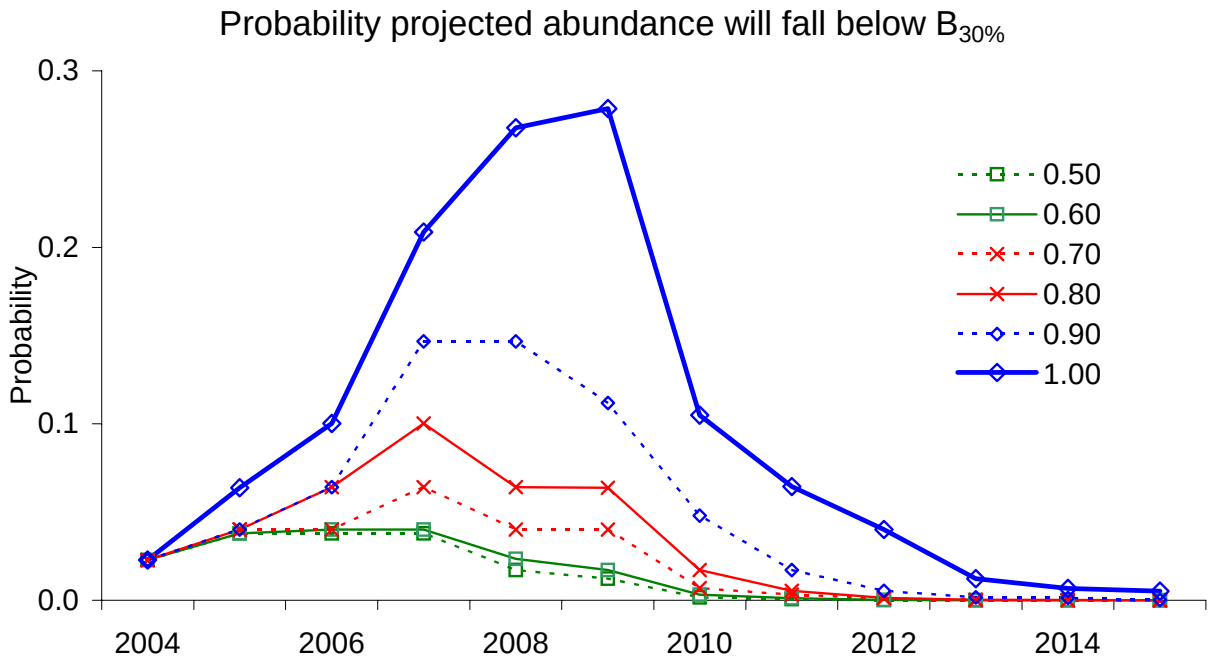


Figure 3.15.—cont.

Appendix A.--Sablefish longline survey - fishery interactions

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 allow for survey delays). Beginning in 1998, 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 and 2002 and only one in 2001.

Distribution of the survey schedule to all IFQ permit holders, radio announcements from the survey vessel, and the threat of a regulatory rolling closure have had intermittent success at reducing the annual number of longline fishery interactions. The number of fishing vessels has been about 10, except 1999, 2001, and 2002, when the numbers were 3, 1, and 3. In 2003, four longline vessels were contacted by the survey vessel and made sets that interacted with a survey station. Fifty-five different longline vessels have interacted with the survey vessel since 1995, about 10% of the fleet.

LONGLINE SURVEY - FISHERY INTERACTIONS

	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	4	4	2	6	6	10
2000	10	10	0	0	10	10
2001	1	1	1	1	2	2
2002	3	3	0	0	3	3
2003	4	4	2	2	6	6

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions decreased in 1999, and 2001-2003. 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.

Appendix B.--Research survey catches (kg) by survey.

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		430,447	439,165
1997	0	1,080		395,579	397,347
1998	5	25,528		324,957	336,096
1999	0	43,224		311,358	293,149
2000	0	2,316		289,966	271,654
2001	2	11,411		326,274	315,538
2002	154	2,607		309,098	295,617
2003	141	15,737		279,687	295,565

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