Section 5 of Gulf of Alaska SAFE, Section 10 of Bering Sea/Aleutian Islands SAFE.

Alaska Sablefish Assessment for 2003

by
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5.1 Executive Summary

5.1.1 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 2002 longline survey, relative abundance and length data from the 2001 longline fishery, and age data from the 2001 longline survey and longline fishery were added to the assessment model. Recent length sample sizes from the trawl fishery are too small to be used in the assessment.

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

The survey abundance index increased 5% in number and 7% in weight from 2001 to 2002. These increases follow increases from 2000 to 2001 and decreases from 1999 to 2000, so that relative abundance in 2002 is about 10% higher than in 1999. Fishery abundance data for 2002 were not analyzed because the fishery remains open.

Exploitable and spawning biomass are projected to increase 6 and 3%, respectively, from 2002 to 2003. **Alaska sablefish abundance now appears moderate and increased from recent lows.** Projected 2003 spawning biomass is 39% of unfished spawning biomass, having been as low as 35% during 1998 to 2000. The increase confirms the projection from last year's assessment that abundance would increase due to the above average 1997 year class. The 1997 year class is an important part of the total biomass and is projected to account for 24% of 2003 spawning biomass. Another year class likely is above average, the 1998 year class. Whether sablefish abundance falls after the 2003 peak depends on the actual strength of the 1998 year class.

ABC recommendation and decision analysis: Our previous approach for recommending ABC considered the abundance trend. We chose a catch level that avoided further abundance decreases because abundance was low. Abundance now has increased, so we changed our ABC recommendation method to adapt to the changed circumstance. In our new approach, we completed a decision analysis to determine what catch levels likely will avoid the historic low abundance observed in 1979.

The decision analysis indicates that a yield of 18,400 mt has only 0.2 probability of reducing 2007 spawning biomass below the historic low. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is much higher, 25,400 mt, but with a higher probability (0.6) of decreasing 2007 spawning biomass below the historic low. **We recommend a 2003 ABC of 18,400 mt for the combined stock**, a yield with low probability of reducing spawning biomass below the historic low and a yield six percent higher than the 2002 ABC of 17,300 mt, consistent with recently increased sablefish abundance.

Regional ABC recommendation:

In December 1999, the Council approved an allocation of the 2000 ABC based on survey and fishery data. We used the same algorithm to allocate the 2003 ABC. A 5-year exponential weighting of the survey and fishery abundance indices in weight (relative population weight or RPW) by region and was used to apportion the combined ABC to regions, resulting in the following apportionments: Bering Sea 2,550 mt, Aleutian Islands 2,740 mt and Gulf of Alaska 13,110 mt, which is further apportioned Western 2,260 mt, Central 5,670 mt, West Yakutat 1,880 mt, and East Yakutat/Southeast 3,300 mt. The ABCs increase for all areas except East Yakutat/Southeast (section 5.8.7). The OFL of 30,900 mt is apportioned by region, Bering Sea (4,290 mt), Aleutian Islands (4,590 mt), and Gulf of Alaska (22,020 mt), by the same method as the ABC apportionment.

5.1.2 Response to Council, SSC, and Plan Team comments

At its December 2000 meeting, the SSC supported inclusion of the longline (fishery) CPUE in both the assessment and area apportionments. At its December 2001 meeting, the SSC requested carefully monitoring of the CPUE data when used in the assessment. Since 1999, we have examined the fishery catch rate data for biases (section 5.4.2) and since 2000, we have examined the effect of excluding fishery catch rates in the assessment model (section 5.7.1). *At its December 2001 meeting, the SSC also requested an examination of the qualification value for directed fishing, currently 50%.* We examined the proportion of sablefish in observed sets for Gulf of Alaska and found that sablefish were a large proportion of the catch for most sets (section 5.4.2).

At their December 2001 meeting, the SSC requested an initial attempt at examining the stock-recruitment relationship for sablefish, by simply fitting a Ricker, or alternate, curve through the model output estimates of stock and recruitment. A Beverton-Holt curve was fit to the estimates of spawning biomass and recruitment (section 5.8.2).

5.1.3 Sablefish longline survey - fishery interactions, 1995-2002

Sablefish longline survey - fishery interactions for 1995-2002 are described in appendix C.

5.2 Introduction

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

Stock structure and management units: Sablefish appear to form two populations, a northern 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 5.1). 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 euphasiids and jellyfish both also were found. Fish made up 76 percent of the diet in feeding studies conducted off Oregon and California (Laidig et al 1997). Euphausiids dominated the diet off the southwest coast of Vancouver Island; herring and other fish were increasingly important with sablefish size (Tanasichuk 1997).

Adult coho and chinook salmon 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 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).

5.3 Fishery

5.3.1 Description of the directed fishery

Early U.S. fishery, 1976 and earlier

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

Foreign fisheries, 1958 to 1987

Japanese longliners began operations in the eastern Bering Sea in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 mt in 1962 (Table 5.2, Figure 5.1). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the Aleutian Islands region and the Gulf of Alaska. In the Gulf of Alaska, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 mt overall in 1972. Catches in the Aleutian Islands region have historically remained at low levels with Japan harvesting the largest portion of the sablefish catch. Most sablefish harvests were taken from the eastern Being Sea until 1968, and then from the Gulf of Alaska until 1977. Heavy fishing by foreign vessels during the 1970's led to a substantial population decline and fishery regulations in Alaska which sharply reduced catches. Catch in the late 1970's was restricted to about one-fifth of the peak catch in 1972.

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

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

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

Recent U.S. fishery, 1977 to present

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

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

Season length continued to decrease until Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels in 1995 along with an 8-month season. Since 1985, the season has run from mid-March to mid-November, 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 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. 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
Vessels	871	1,078	613	578	504	450	446	436	438

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

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Hooks (millions)	96.9	78.0	84.9	86.7	81.5	50.1	45.1	34.4	35.0	33.2	43.4	43.1

Longline gear in Alaska is fished on-bottom. In 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.

5.3.2 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 5.2). 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.

5.3.3 Bycatch and discards

The percent of sablefish catch discarded during 1995 to 2000 averaged 2.8% in the Alaskan sablefish longline fishery, 31.0% in the Bering Sea/Aleutian Islands Greenland turbot longline fishery, and 41.4% in the Bering Sea/Aleutian Islands Pacific cod longline fishery, 20% in rockfish trawl fisheries and 42.1% in flatfish trawl fisheries (Table 5.3). The average discard from 1994 to 1997 was 3.7% for all longline fisheries and 30% for all trawl fisheries.

5.3.4 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: pollock 1%, Pacific cod 1%, deep flatfish 7%, rex sole 7%, flathead sole 7%, shallow flatfish 1%, arrowtooth flounder 0%, Pacific ocean perch 7%, shortraker and rougheye rockfish 7%, other rockfish 7%, northern rockfish 7%, pelagic rockfish 7%, demersal shelf rockfish in the Southeast Outside district 7%, thornyhead 7%, Atka mackerel 1%, other species 1%, and aggregated amount of non-groundfish species 1%.

Allowable gear:

Amendment 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 are allowed in the Aleutian Islands.

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

5.4 Data

Source	Data	Dates
Fisheries	Catch	1960-2001
Japanese longline fishery	Effort	1964-1981
	Length	1963-1980
Japanese trawl fishery	Length	1964-1971
U.S. longline fishery	Effort, length, discards	1990-2001
	Age	1999-2001
U.S. trawl fisheries	Length	1990,1991,1999
	Discards	1990-2001
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	1990-2002
	Age	1996-2001

5.4.1 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 5.4). 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 because a limited number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A.

The catches used in this assessment (Table 5.2) 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. Catches from these state waters 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 5.2 and 5.3, Table 5.5). 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 sample sizes for the trawl fishery length compositions. From 1992 to 1998, few lengths were collected each year and the resultant length frequencies were ragged and provide little or no information for 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.

5.4.2 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 incorrect interpretation of fishery catch rates: assessment scientists did not realize that the area occupied by the stock was diminishing while fishery catch rate remained level (Rose and Kulka 1999).

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). The 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 2001. Currently they are treated as a separate data set and are not included in the assessment model.

The Central Gulf region had the most sets observed and the Bering Sea the least (Table 5.6). 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 in required logbooks than by observers, 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 5.4). 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 and fishery catch rates increased since 1997 except for a drop in 2001.

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 5.4), the area with the highest sample size (Table 5.6). 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 5.5). 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 its 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 it's 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 are 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).

5.4.3 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 D.

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

Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 5.5). 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^{o} 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 5.7). 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 on discarded fish. The number of stations with sperm whale depredation was four in 1998, twelve in 1999, five in 2000, and five in 2001. An average of eight damaged sablefish per station were retrieved. Sablefish catches were significantly less at affected stations. The standard residual for the relative population number (RPN) for each station compared to the mean RPN for the area was computed. Standard residuals 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.

5.4.4 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 D.

5.4.5 Recruitment data

Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1 juveniles likely indicates 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.

5.4.6 Relative abundance trends

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 5.5, Figures 5.2 and 5.3). 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 5.6). 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 1984 year class first became an important year class in western areas at age 5 (1998 plot), but not until age 9 (1993 plot) in the central and eastern areas (Figure 5.7). This pattern holds true for the above average year classes 1980-81, 1984, 1990, and 1995 which became abundant in the central area at ages 7-9 and in the eastern area at ages 7-10 (Table 5.8a). This pattern fails only for the 1977 year class, which became an important year class in the central and eastern areas at age 4 (1981 plot).

Last year, we predicted when the above 1995 and 1997 year classes will become abundant in the central and eastern Gulf of Alaska based on these patterns. The 1995 year class was predicted to become abundant in the central Gulf of Alaska in 2002 to 2004 and in the eastern Gulf of Alaska in 2002 to 2005 (Table 5.8b). The 1997 year class was predicted to become abundant in the western Gulf of Alaska in 2001 to 2003, in the central Gulf of Alaska in 2004 to 2006 and in the eastern Gulf of Alaska in 2004 to 2007. Decreasing abundance may reverse in the central and eastern Gulf of Alaska once the 1995 and 1997 above average year classes become abundant in these areas.

As predicted, the 1997 year class became abundant in the western Gulf of Alaska in 2001 (Figure 5.7). Further, decreasing abundance appears to have reversed in the central and eastern Gulf of Alaska. Abundance increased in these two areas from 2001 to 2002 and in the eastern Gulf of Alaska, is the first annual increase after ten years of steady decline (Figure 5.6). The reverse may be due to the 1995 above average year class becoming abundant in these areas. The increase in the central Gulf of Alaska also may be due to the 1997 year class, which was abundant in this area in 2001 (Figure 5.6).

5.5 Analytic approach

5.5.1 Model

Model structure

The analysis generally follows the approach described by Kimura (1990) for age-structured population analysis. This approach also was tested for sablefish by Sigler (1999). The analysis was completed using AD The sablefish population in Alaska is represented with an age-structured model. The age range for the model is 2 to 31, where 31 represents all ages 31 and greater. Abundance for years 1960 to 2001 are estimated.

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.

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 is estimated in the assessment model.

Some information used in the assessment model was estimated independently of the assessment model. For example, growth and maturity parameters were estimated separately and then incorporated into the assessment model as fixed values.

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 2002 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002. 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 2003, 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 2003 recommended in the assessment to the *max* F_{ABC} for 2002. (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 1998-2002 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 2003 and above its MSY level in 2013 under this scenario, then the stock is not overfished.)

Scenario 7: In 2003 and 2004, 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 2015 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 equally 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 computed by normalizing the likelihoods (i.e. sum to 1.0). We examined the 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

Our previous approach for recommending ABC considered the abundance trend. We chose a catch level that avoided further abundance decreases because abundance was low. Abundance now has increased, so we changed our ABC recommendation method to adapt to the changed circumstance. We describe the previous method for ABC recommendation in this paragraph and the new method in the next paragraph. We constructed a set of projection runs based on fixed catch levels, running 21 different scenarios with catches of 5, 6, ... 25 thousand metric tons. Each scenario was repeated 250 times, resampling from the estimated year classes from 1982-98. The probability of decreasing abundance (2007 abundance < 2003 abundance) was computed for 21 scenarios from the posterior probability of the Bayesian analysis. Five years was chosen for the projection time frame because projected abundance is only slightly influenced by the assumed value of future stock productivity compared to longer-term projections. Year classes earlier than 1982 were not included in the projections because the 1977-1981 year classes were stronger and may not recur in the next five years. These strong year classes were associated with a singular event, the regime shift of the North Pacific, and we don't know when this event may recur.

We term the previous approach for recommending ABC the "abundance trend" approach and the new approach the "abundance status" approach. In the abundance status approach, we consider whether projected abundance will reach the historic low observed in 1979. We constructed a set of projection runs based on fixed catch levels, running 21 different scenarios with catches of 5, 6, ... 25 thousand metric tons. We ran a 22nd scenario applying an $F_{40\%}$ strategy. Each scenario was repeated 1,000 times, resampling from the estimated year classes from 1982-98. The probability that projected abundance was less than the historic low (projected spawning biomass < 1979 biomass) was computed for the 22 scenarios from the posterior probability of the Bayesian analysis. Note that historic low is computed for each *q-M* pair of the likelihood mapping grid.

Some of the largest year classes of sablefish occurred when abundance was near the historic low. The 1977-1981 year classes were very large and were associated with the regime shift of the North Pacific. The large year classes indicate that the population, though low, still was able to take advantage of favorable environmental conditions and produce large year classes. However we don't know whether a population below the historic low could do the same, which is why we chose the historic low as a boundary to avoid.

5.6 Model evaluation

5.6.1 Data fits

The model fit the observed abundance indices, survey and fishery length data, and survey age data (Figures 5.2, 5.3, and 5.8 [the length fits are not shown for brevity]).

5.7 Results

5.7.1 Model

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 5.9). 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 5.4.5 for evidence, but appears relatively weak in the model estimates. Estimates of the strength of recent year classes strength are uncertain because these year classes have been observed only a few times and are only partially recruited. More reliable estimates of the strength of the 1998 year class will be available with 1-2 more years of survey data.

Sablefish abundance increased during the mid-1960's (Table 5.9, Figure 5.10) 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.

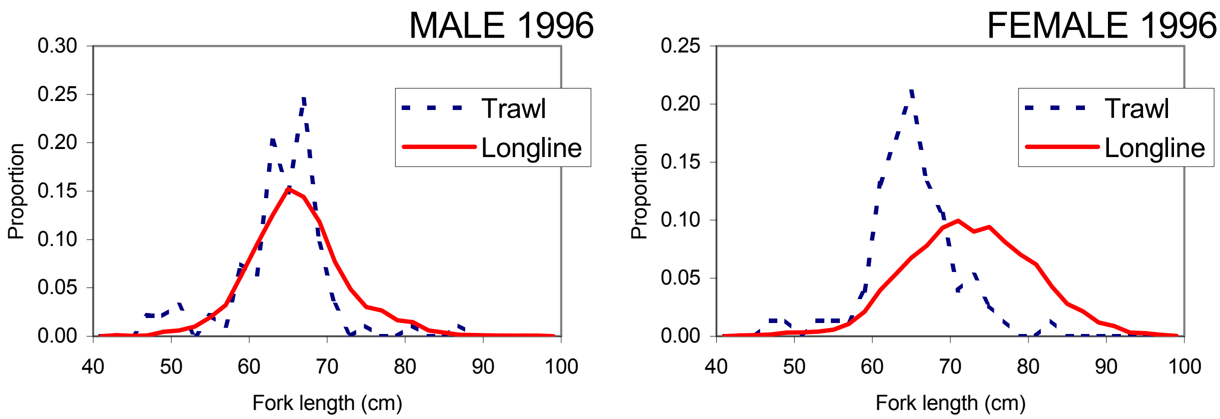
Combined exploitable biomass for the Aleutian Islands, eastern Bering Sea, Gulf of Alaska increased 4.6% and spawning biomass increased 3.2% from 2001 to 2002. Projected 2003 exploitable biomass is about 221,000 mt, spawning biomass 210,000 mt, increases of 5.5% and 2.5% from the estimated values for 2002. **Alaska sablefish abundance now appears moderate and increased from recent lows.** Spawning biomass is projected to increase to 39% of unfished spawning biomass in 2003, having been as low as 35% during 1998 to 2000 and 30% in 1979. The increase confirms the projection from last year's assessment that abundance will increase due to the above average 1997 year class. This year class is an important part of the total biomass and is projected to account for 24% of 2003 spawning biomass. Another year class likely is above average, the 1998 year class. Whether sablefish abundance falls after the 2003 peak depends on the actual strength of the 1998 year class.

The 1977, 1980 and 1981 strong year classes appear to be exceptional year classes associated with the regime shift of 1976-1977. Subsequent year classes are weaker, but may be "normal" for the changed oceanographic state following the regime shift. A major change in the productivity of the stock appears to have occurred following these exceptional year classes. Average recruitment for the 1957-1998 and 1977-1998 year classes is similar, about 22 million 2-year old sablefish per year, compared to 15 million for the 1982-1998 year classes.

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

Estimated natural mortality was 0.106. Some variation in estimates of natural mortality is not unusual. The value of 0.106 for this year's assessment is similar to 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), 5.3 years for the IFQ longline fishery, and 2.9 years for the trawl fishery (Figure 5.11). 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 1990-2001. 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 5.4.2. The assessment results shown in this section used both survey and fishery catch rates as measures of sablefish relative abundance. Because of the potential bias of sablefish fishery catch rates, we tested the effect of the sablefish fishery catch rates. Both Japan and US fishery catch rate data are used in the assessment, but we only tested the effect of US fishery catch rate data because there was no alternative abundance index during most years of the Japanese longline fishery, unlike the US fishery, which overlaps the longline surveys. We found that US fishery catch rates have little effect on spawning biomass estimates. Their inclusion in the assessment model resulted in minor (0.4% to 1.3%) changes in spawning biomass estimates for 1990-2001, the years of US fishery catch rate data.

5.7.2 Comparison to last year's model

The scale and trend of estimated spawning biomass and recruitment are similar between recent assessments, except estimates of abundance have increased somewhat (Figure 5.12). For example, estimated 2000 spawning biomass was 171,000 mt in the 2000 assessment, 184,000 mt in the 2001 assessment, and 190,000 mt in the 2002 assessment, increases of 7.6% and 3.3% from one assessment to the next. The estimated population status also has improved. For example, low abundance during 1998-2000 was 32% of unfished spawning biomass in the 2000 assessment and 35% in the 2002 assessment.

5.8 Projections and harvest alternatives

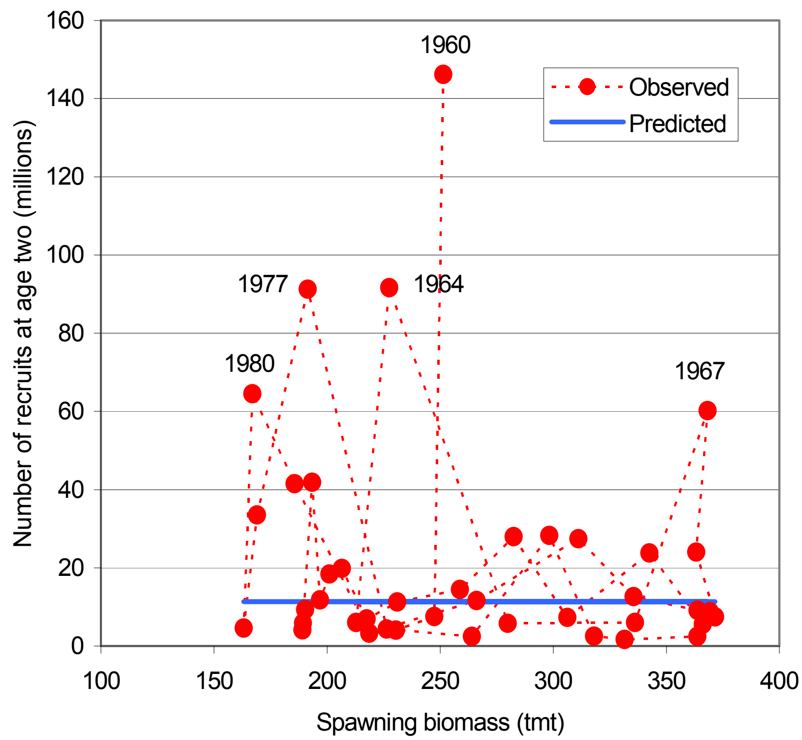
5.8.1 Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2003 spawning biomass, are shown in Table 5.10. Reference biomass values were computed for recruitment equal to average recruitment from the 1977-1998 year classes. Projected 2003 spawning biomass is 39% of unfished spawning biomass and 97% 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 the same as last year's assessment. For example, $F_{40\%}$ = 0.133 for both 2001 and 2002 assessments. Increased natural mortality, from 0.104 to 0.106, was balanced by increased age of 50% selection by the longline fishery, from 5.1 to 5.3 years, and the reference fishing mortality values remained the same.

5.8.2 Maximum sustainable yield

At their December 2001 meeting, the SSC requested an initial attempt at examining the stock-recruitment relationship for sablefish, by simply fitting a Ricker, or alternate, curve through the model output estimates of stock and recruitment. 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.



5.8.3 Population projections

Projected 2003 exploitable biomass is 221,000 mt for Aleutian Islands, eastern Bering Sea, Gulf of Alaska combined, and spawning (male and female) biomass is 210,000 mt. Spawning biomass currently equals 39% of the unfished value. Future stock conditions depend on future average recruitment and fishing mortality (Figure 5.13). If catch is 18,400 mt, then abundance is projected to decrease if future average recruitment equals 1982-1998 average recruitment. With the same catch and future average recruitment equal to 1977-1998 average recruitment, then abundance is projected to decrease until 2006, then increase. The latter recruitment scenario is more optimistic because it includes the exceptional 1977-1981 year classes. Spawning biomass is projected to remain above 35% of the unfished value only if future recruitment equals the more optimistic recruitment level or if fishing mortality is substantially reduced. Projected abundance for maximum permissible fishing mortality is substantially lower; spawning biomass is projected to fall below 35% of the unfished value even for the more optimistic recruitment level.

Spawning biomass, fishing mortality, and yield also are tabulated for the seven standard projection scenarios (Table 5.11).

Status determination

Alaska sablefish are not overfished nor are they approaching an overfished condition (Table 5.11).

5.8.4 Bayesian analysis

The data provides information about the values of *M* and *q*. Their estimates are 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 5.14). The probability changes smoothly and is well-mapped by the chosen values for the *q*-*M* grid. It is probably best to use the estimates, because they are well-defined by the data, and not develop priors for *M* and *q*.

We tested adding informative priors. Adding more informative priors narrowed the posterior, with the amount of narrowing dependent on the variance assumed for the prior. Using biologists' opinion of the value of natural mortality is one method for developing an informative prior distribution. However these opinions would be based on experience interpreting results from age-structured models. Therefore adding an opinion-based prior to the age-structured model is not independent from the data. Therefore we chose to use only non-informative prior distributions.

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

5.8.5 Decision analysis

The "abundance trend" decision analysis conducted in previous years addressed the question: Given future catch levels, what is the probability that spawning biomass will decrease? We conducted the abundance trend analysis again this year to compare to the new approach of the "abundance status" decision analysis. The abundance trend analysis shows that 2003 and 2007 spawning biomass most likely will be equal for annual catch of 7,400 mt, i.e. 7,400 mt is the catch where probability equals 0.5 that 2007 spawning biomass is less than 2003 spawning biomass (Figure 5.15). A low catch is required to keep 2003 and 2007 abundance the same because abundance is projected to decrease, but appears unreasonable given that abundance now is at a moderate level.

The abundance trend analysis considers the direction of the abundance trend, whereas the abundance status analysis considers whether abundance again will fall below the historic low. The abundance status analysis shows that annual catch of 18,400 mt has only a 0.2 probability of driving 2007 spawning biomass below the historic low (Figure 5.13). If a $F_{40\%}$ harvest strategy is followed, then this probability is higher, 0.6. The 2003-2006 cumulative catch for the $F_{40\%}$ harvest strategy is 89,400 mt compared to 73,600 mt for annual catch of 18,400 mt.

A lower ABC recommendation when abundance is projected to decrease is the intended behavior of the abundance trend decision analysis and is a desirable action when abundance is low. However abundance now is moderate, which the abundance trend decision analysis doesn't consider. Keeping abundance stable, the goal of the abundance trend analysis, is less critical when abundance is moderate. In contrast, the abundance status decision analysis accounts for the level of abundance by using a different criteria, to keep abundance above the historic low. For example, 2007 spawning biomass may be less than 2003 spawning biomass, but remain greater than the historic low if 2003 spawning biomass is large enough. We recommend choosing the 2003 ABC based on the probability of avoiding the historic low. Avoiding the historic low is a more appropriate rule for recommending ABC than the direction of the abundance trend now that abundance is higher.

The $F_{40\%}$ strategy and annual catch of 20,500 mt have equal probability (0.6) of decreasing 2007 spawning biomass below the historic low. However the $F_{40\%}$ strategy results in higher 2003-2006 cumulative catch, 89,400 mt vs. 82,000 mt. The same risk with higher yields probably results because early catches are higher for the $F_{40\%}$ strategy. More fish are caught before dying by natural mortality.

The probability that spawning biomass is below the historic low increases first for the $F_{40\%}$ strategy. For example, this probability is 0.2 in 2005 for the $F_{40\%}$ strategy and near-zero for all other catch scenarios considered. Subsequently this probability is less for the $F_{40\%}$ strategy than some catch scenarios. A possible reason the probability is initially higher for the $F_{40\%}$ strategy is the uncertainty in estimating $F_{40\%}$, which translates into a higher probability of falling below the historic low. Later, annual catch is higher for some catch scenarios than the $F_{40\%}$ strategy, which increases the probability abundance will fall below the historic low for these catch strategies.

5.8.6 Acceptable biological catch

The abundance status decision analysis indicates that a yield of 18,400 mt has only 0.2 probability of reducing 2007 spawning biomass below the historic low. The maximum permissible yield from an adjusted $F_{40\%}$ strategy is much higher, 25,400 mt, but with a higher probability (0.6) of decreasing 2007 spawning biomass below the historic low. The 2003-2006 cumulative catch for the $F_{40\%}$ harvest strategy is 89,400 mt compared to 73,600 mt for annual catch of 18,400 mt. The fishing mortality for a 2003 ABC of 18,400 mt is 0.092, 18% higher than the 5-year average fishing mortality of 0.078. The maximum permissible fishing mortality corresponding to a 2003 ABC of 25,400 mt is 0.129, 65% greater than the 5-year average.

We recommend a 2003 ABC of 18,400 mt for the combined stock. This yield has low probability of reducing spawning biomass below the historic low. This yield is six percent higher than the 2002 ABC of 17,300 mt. A six percent ABC increase is consistent with recently increased sablefish abundance. Exploitable and spawning biomass are projected to increase 6% and 3%, respectively, from 2002 to 2003. The survey abundance index increased 5% and 7% from 2001 to 2002. These increases follow increases from 2000 to 2001 and decreases from 1999 to 2000, so that so that relative abundance in 2002 is about 10% higher than in 1999 (Table 5.5).

The criteria we chose to recommend an ABC were a 5-year time horizon and a 0.2 probability of falling below the historic low. We view the 5-year horizon as short-term and the 0.2 probability as low. The choice of criteria is subjective. Other defensible criteria exist and may lead to different ABC recommendations. For example another short-term horizon is 3 years. A 3-year horizon leads to a different recommendation. The $F_{40\%}$ harvest strategy has only 0.2 probability of reducing 2005 spawning biomass below the historic low.

5.8.7 Regional and area apportionment

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

Previously, the Council approved allocations of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an allocation based on survey and fishery data. We also used survey and fishery data to allocate the 2003 ABC.

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

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

Apportionments are based on survey and fishery information	2002 ABC Apportion ment	2002 Survey RPW	2001 Fishery RPW	2003 ABC Apportion ment	2002 ABC	2003 ABC	change
Total					17,300	**18,400**	6%
Bering Sea	11%	14%	23%	14%	1,930	**2,550**	32%
Aleutians	15%	15%	13%	15%	2,550	**2,740**	7%
Gulf of Alaska	74%	71%	64%	71%	12,820	**13,110**	2%
Western	17%	19%	15%	17%	2,240	**2,260**	1%
Central	42%	47%	38%	43%	5,430	**5,670**	4%
W. Yakutat	14%	13%	18%	14%	1,770	**1,880**	6%
E. Yakutat / Southeast	26%	21%	29%	25%	3,380	**3,300**	-2%

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 (section 5.4.2, Figure 5.4).

The ABC recommendation for East Yakutat/Southeast is lower even though survey abundance increased in 2002. (Figure 5.6). The ABC decreased because the recommendation depends on both survey and fishery data. Fishery CPUE has steadily decreased in East Yakutat/Southeast from 1997 to 2001, the last year fishery data is available. Abundance has steadily decreased in the eastern Gulf of Alaska during the 1990s, until 2002, when abundance increased. Regional abundance trends are discussed further in section 5.4.5.

Regional estimates of age-4+ biomass are tabulated in Table 5.12.

5.8.8 Overfishing level

Applying an adjusted $F_{35\%}$ as prescribed for Over Fishing Level (OFL) in Tier 3b results in a value of 30,900 mt for the combined stock. The OFL is apportioned by region, Bering Sea (4,290 mt), Aleutian Islands (4,590 mt), and Gulf of Alaska (22,020 mt), by the same method as the ABC apportionment.

5.8.9 Ecosystem considerations

Ecosystem effects on the stock

1) Prey population trends: Larval sablefish abundance has been linked to copepod abundance (McFarlane and Beamish 1992) and young-of-the-year sablefish prey mostly on euphausiids; juvenile and adult sablefish are opportunistic feeders (section 5.2). Young-of-the-year abundance may be linked to euphausiid abundance because of their dependence on a single prey 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 only predation of sablefish that appears significant has been by adult coho and chinook salmon, which prey on young-of-the-year sablefish (section 5.2). The occurrence of this predation has not been documented consistently over the years, however, and no studies have been done to relate salmon predation to sablefish abundance.

Biota	In sablefish fisheries	In all fisheries	Percent sablefish fisheries
Coral	513	44,069	1.2%
Anemone	645	172,225	0.4%
Seawhip	68	5,399	1.3%
Sponge	73	457,374	0.0%

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.

Fishery effects on the ecosystem

1) Fishery-specific contribution to bycatch of prohibited species, forage (including herring and juvenile pollock), HAPC biota, marine mammals and birds, and other sensitive non-target species (including top predators such as sharks), expressed as a percentage of the total bycatch of that category of bycatch: No tables currently are available to show percentages of total bycatch by fishery. Seabirds may be captured by longlines. Catch of seabirds in the Gulf of Alaska, where most sablefish are caught, has generally decreased in recent years (Ecosystem chapter, table 9), presumably due to widespread use of measures to reduce seabird catch. Longlines may hook HAPC biota. Their bycatch attributable to the sablefish fishery is no more than 1.3% of the total for all fisheries. No data is currently available to determine the fraction of HAPC biota affected.

Average bycatch (kg) of HAPC Biota, 1997-1999, Gulf of Alaska, Bering Sea, and Aleutian Islands. Source is the Draft Programmatic SEIS, January 2001, Table 4.7-5.

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 opportunity to maximize value from the fishing operation.

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 last 8 months and the ABC is allocated among

6 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 5.3). The catch of sablefish in the longline fishery typically consists of a high proportion of sablefish, 90% and more. However at times the catch of grenadiers may be significant 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 (using gear specific fishing effort as a proxy for amount of possible substrate disturbance): 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.

Data gaps and research priorities

Data gaps which prevent assessing certain effects: Seabird bycatch is tabulated by region and gear type, but not by target species. This lack is generally true of prohibited species, forage (including herring and juvenile pollock), HAPC biota, marine mammals and birds, and other sensitive non-target species (including top predators such as sharks).

Ecosystem considerations for the Alaska sablefish fishery are summarized in Table 5.13.

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

Table 5.2--Alaska sablefish catch (mt), 1956-2001. 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.

		BY AREA								**BY GEAR**	
Year	**GRAND TOTAL**	**Bering Sea**	**Aleutians**	**Western**	**Central**	**Eastern**	**West Yakutat**	**E. Yakutat/ Southeast**	**Un-known**	**Fixed**	**Trawl**
1956	773	0	0	0	0	773			0	773	0
1957	2,059	0	0	0	0	2,059			0	2,059	0
1958	477	6	0	0	0	471			0	477	0
1959	910	289	0	0	0	621			0	910	0
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,433	668	2,080	739	11,971	9,975	4,619	5,356	0	22,912	2,521
1994	23,760	694	1,726	555	9,495	11,290	4,497	6,793	0	20,797	2,963
1995	20,954	990	1,333	1,747	7,673	9,211	3,866	5,345	0	18,342	2,612
1996	17,577	697	905	1,648	6,772	7,555	2,899	4,656	0	15,390	2,187
1997	14,922	728	929	1,374	6,237	5,653	1,928	3,725	0	13,287	1,635
1998	14,108	614	734	1,435	5,877	5,448	1,969	3,479	0	12,644	1,464
1999	13,575	677	671	1,487	5,873	4,867	1,709	3,158	0	11,590	1,985
2000	15,601	753	1,071	1,587	6,172	6,018	2,066	3,952	0	13,581	2,020
2001	14,097	878	1,092	1,589	5,518	5,020	1,737	3,283	0	12,314	1,783

Table 5.3--Discarded catches of sablefish (amount [mt] and percent of total catch) by target fishery, gear (H&L=hook & line, TWL=trawl), and management area for 1994 to 2000.

		Eastern Bering Sea		**Aleutian Islands**		**Western**		**Central**		**West Yakutat**		**East Yakutat/ SEO**	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (H&L)	1994	7	4	16	1	11	2	75	1	39	1	66	1
	1995	5	1	8	1	40	2	111	2	71	2	132	2
	1996	7	2	9	1	33	2	137	3	56	2	79	2
	1997	8	4	19	3	41	3	116	2	88	5	123	3
	1998	6	4	5	1	91	6	210	5	46	2	184	5
	1999	2	1	34	6	38	3	124	3	27	2	68	2
	2000	2	1	7	1	49	4	168	4	46	2	159	3
Greenland	1994	1	1	2	3	0	-	0	-	0	-	0	-
turbot (H&L)	1995	82	48	40	53	0	-	0	-	0	-	0	-
	1996	75	41	5	17	0	-	0	-	0	-	0	-
	1997	92	40	1	11	0	-	0	-	0	-	0	-
	1998	85	31	7	5	0	-	0	-	0	-	0	-
	1999	45	24	13	19	0	-	0	-	0	-	0	-
	2000	27	15	15	14	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
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	-
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

Table 5.3 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	-
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	-
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	-
Deepwater	1994	0	-	0	-	0	-	180	40	12	26	47	73
flatfish (TWL)	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	-
Shallow water	1994	0	-	0	-	0	-	9	8	0	-	0	-
flatfish (TWL)	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	-
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	-
Greenland	1994	35	12	10	18	0	-	0	-	0	-	0	-
turbot (TWL)	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	-

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ SEO	
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	-
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	-
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

Table 5.4.--Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data.

	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									

Table 5.5.--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. RPN (relative population number) equals catch per effort in numbers weighted by respective strata areas. RPW (relative population weight) equals catch per effort measured in weight multiplied by strata areas. Indices were extrapolated for unsampled survey areas: Aleutian Islands 1979, 1995, 1997, 1999, 2001; Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002.

Year	RPN Cooperative longline survey	RPN Domestic longline survey	RPW Japanese longline fishery	RPW Cooperative longline survey	RPW Domestic longline survey	RPW 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	

Table 5.6.--Average CPUE (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. Note: standard error not available when vessel 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

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

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

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

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

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

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

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

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

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

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

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

Table 5.7.–Number of stations where sperm or killer whale depredation of sablefish catches occurred during annual sablefish longline surveys (domestic longline survey only). Some longline survey stations were not sampled all years, indicated by "na". Recording of sperm whale depredation began with the 1998 survey. Killer whale depredation only occurred in the Aleutians, Bering Sea, and Western areas. Sperm whale depredation only occurred in the Central, E. Yakutat/Southeast, and W. Yakutat areas.

Killer whale depredation

Year	Aleutians	Bering Sea	Western
1991	na	na	1
1992	na	na	1
1993	na	na	2
1996	1	na	0
1997	na	3	0
1998	1	na	0
1999	na	8	0
2000	1	na	1
2001	na	4	0
2002	1	na	4

Sperm whale depredation

Year	Central	E. Yakutat/Southeast	W. Yakutat
1998	1	0	3
1999	4	4	4
2000	0	3	2
2001	3	2	2
2002	4	2	3

Table 5.8a.–Ages that above average year classes became abundant by region (see Figure 5.7). "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska.

Year class	Western	Central	Eastern
1977	na	4	4
1980-81	4-5	7-8	9-10
1984	4-5	8-9	8-9
1990	4-6	7	7
1995	4	>6	>6
1997	4	4	>4

Table 5.8b–Predicted years that the above average 1995 and 1997 year classes will become abundant by region. "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska.

Year class	Western	Central	Eastern
1995	appeared 1999	2002 to 2004	2002 to 2005
1997	appeared 2001	appeared 2001	2004 to 2007

Table 5.9.--Sablefish age 4+ biomass, exploitable biomass, spawning biomass, and catch (thousands mt), and number (millions) at age 2 by year. Projected values assume catch of 18,400 mt and recruitment based on average for 1982-1998 year classes.

Year	Age 4+ biomass	Exploitable biomass	Spawning biomass	Number (millions) at age 2	Catch	Catch / Age 4+ biomass
1960	293	259	251	4.2	3.1	0.011
1961	281	256	247	5.7	16.1	0.057
1962	254	238	230	146.2	26.4	0.104
1963	221	211	213	7.5	16.9	0.076
1964	425	213	228	4.0	7.3	0.017
1965	435	270	280	6.0	8.7	0.020
1966	431	354	336	91.6	15.6	0.036
1967	413	384	368	5.8	19.2	0.047
1968	513	374	363	6.0	31.0	0.060
1969	481	380	372	60.2	36.8	0.076
1970	433	385	369	24.0	37.8	0.087
1971	471	372	364	7.4	43.5	0.092
1972	438	343	332	8.7	53.0	0.121
1973	388	333	318	2.4	36.9	0.095
1974	346	313	298	1.6	34.6	0.100
1975	296	278	264	2.5	29.9	0.101
1976	248	239	226	28.2	31.7	0.128
1977	204	199	191	2.4	21.4	0.105
1978	214	171	169	4.4	10.4	0.049
1979	198	165	163	91.2	11.9	0.060
1980	185	168	167	33.5	10.4	0.056
1981	313	177	186	4.6	12.6	0.040
1982	355	211	219	64.5	12.0	0.034
1983	352	272	266	41.5	11.8	0.034
1984	437	317	311	3.2	14.1	0.032
1985	477	406	336	11.6	14.5	0.030
1986	460	433	364	27.4	28.9	0.063
1987	430	415	366	12.6	35.2	0.082
1988	414	384	343	9.1	38.4	0.093
1989	371	348	306	5.5	34.8	0.094
1990	333	317	282	23.8	32.1	0.097
1991	292	285	259	7.3	27.0	0.092
1992	283	258	231	28.0	24.9	0.088
1993	259	246	218	14.4	25.4	0.098
1994	266	236	207	11.3	23.8	0.089
1995	256	204	201	6.9	20.9	0.082
1996	246	203	197	19.8	17.6	0.072
1997	229	200	193	18.4	14.9	0.065
1998	235	194	189	11.8	14.1	0.060
1999	243	193	189	41.9	13.6	0.056
2000	237	194	190	4.1	15.6	0.066
2001	282	200	198	5.9	14.1	0.050
2002	265	209	204	9.3	14.1	0.053
2003	253	221	210		18.4	0.073
2004	238	213	204		18.4	0.077
2005	230	196	189		18.4	0.080
2006	226	185	180		18.4	0.082
2007	221	177	173		18.4	0.083

Table 5.10--Alaska sablefish harvest information.

M	0.106
Age (years) at 50% selection for survey	4.3
Age (years) at 50% selection for "derby" fishery	4.3
Age (years) at 50% selection for IFQ fishery	5.3
Age (years) at 50% selection for trawl fishery	2.9
Equilibrium unfished spawning biomass (thousands mt)	541
Reference point spawning biomass, $B_{40\%}$ (thousands mt)	216
Reference point spawning biomass, $B_{35\%}$ (thousands mt)	189
2003 exploitable biomass (thousands mt)	221
2003 spawning biomass (thousands mt)	210
Ratio 2003 : unfished spawning biomass	0.39
HARVEST ALTERNATIVES	
Maximum permissible fishing level	
$F_{40\%}$	0.133
2003 $F_{40\% \text{ adj}}$	0.129
2003 $F_{40\% \text{ adj}}$ Yield (thousands mt)	25.4
Overfishing level	
$F_{35\%}$	0.164
2003 $F_{35\% \text{ adj}}$	0.159
2003 $F_{35\% \text{ adj}}$ Yield (thousands mt)	30.9
Authors' recommendation	
2003 F	0.081
2003 ABC (thousands mt)	18.4

Table 5.11--Alaska sablefish spawning biomass, fishing mortality, and yield for seven harvest scenarios. Sablefish abundance currently exceeds the reference spawning biomass used to determine if the population is overfished, $B_{35\%}$ = 189 thousand mt, so Alaska sablefish are not classified as overfished. Projections are based on the 1977 to 1998 year classes.

Year	Maximum permissible F	Fraction maximum F	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass							
2002	204	204	204	204	204	204	205
2003	210	210	210	210	210	210	211
2004	198	204	209	207	221	193	203
2005	182	193	201	197	224	175	192
2006	180	193	204	197	236	170	189
2007	183	198	211	203	252	173	191
2008	191	208	224	214	273	180	193
2009	196	215	233	221	291	184	195
2010	205	226	246	233	315	191	199
2011	209	233	256	241	333	194	200
2012	214	239	264	249	352	198	201
2013	216	243	270	254	366	199	202
2014	218	246	275	259	381	200	202
2015	219	249	280	263	394	201	202
Fishing mortality							
2002	0.073	0.073	0.073	0.073	0.073	0.073	0.073
2003	0.129	0.092	0.064	0.078	0.000	0.159	0.130
2004	0.122	0.090	0.064	0.078	0.000	0.146	0.124
2005	0.111	0.084	0.062	0.078	0.000	0.131	0.143
2006	0.109	0.083	0.061	0.078	0.000	0.127	0.139
2007	0.109	0.084	0.062	0.078	0.000	0.127	0.138
2008	0.112	0.085	0.063	0.078	0.000	0.131	0.139
2009	0.113	0.086	0.063	0.078	0.000	0.133	0.138
2010	0.116	0.088	0.064	0.078	0.000	0.136	0.140
2011	0.117	0.089	0.064	0.078	0.000	0.138	0.141
2012	0.119	0.090	0.065	0.078	0.000	0.140	0.141
2013	0.119	0.090	0.065	0.078	0.000	0.140	0.142
2014	0.120	0.091	0.065	0.078	0.000	0.141	0.141
2015	0.120	0.091	0.065	0.078	0.000	0.141	0.141
Yield							
2002	14.1	14.1	14.1	14.1	14.1	14.1	14.1
2003	25.4	18.4	13.1	15.7	0.0	30.9	25.8
2004	22.5	17.4	12.9	15.4	0.0	26.0	23.4
2005	19.0	15.4	11.9	14.6	0.0	21.3	25.6
2006	18.4	15.2	12.0	14.6	0.0	20.3	24.9
2007	19.1	15.9	12.5	15.0	0.0	21.0	25.1
2008	20.7	17.2	13.5	15.9	0.0	22.7	25.7
2009	21.7	18.1	14.3	16.6	0.0	23.8	26.1
2010	23.1	19.3	15.3	17.4	0.0	25.3	27.0
2011	23.9	20.0	15.9	18.0	0.0	26.1	27.3
2012	24.6	20.7	16.5	18.6	0.0	26.7	27.5
2013	25.0	21.2	17.0	19.0	0.0	27.0	27.6
2014	25.3	21.6	17.3	19.3	0.0	27.3	27.6
2015	25.5	21.8	17.6	19.6	0.0	27.4	27.6

Table 5.12.--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	35	38	125	198
1980	33	36	116	185
1981	53	74	186	313
1982	61	80	214	355
1983	60	71	221	352
1984	78	89	270	437
1985	87	104	286	477
1986	88	97	274	460
1987	85	85	259	430
1988	61	88	266	414
1989	46	69	256	371
1990	45	65	222	333
1991	39	49	205	292
1992	27	43	213	283
1993	22	36	201	259
1994	15	36	215	266
1995	18	35	203	256
1996	19	34	193	246
1997	20	26	184	229
1998	20	24	191	235
1999	21	33	189	243
2000	20	35	182	237
2001	23	44	215	282
2002	29	41	195	265
2003	31	39	182	253

Table 5.13.--Analysis of ecosystem considerations for Alaska sablefish fishery.

Indicator	*Observation*	*Interpretation*	*Evaluation*
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends	variable	variable recruitment	no concern (can't do anything to affect)
Predator population trends	variable	variable recruitment	no concern (can't do anything to affect)
Changes in habitat quality	variable	variable recruitment	no concern (can't do anything to affect)
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch	summarize the past, present and foreseeable future trends	provide interpretation of how the trend affects the ecosystem	indicate whether the trend is of : no concern possible concern definite concern
Prohibited species	need data		
Forage (including herring, Atka mackerel, cod, and pollock)	need data		
HAPC biota (seapens/whips, corals, sponges, anemones)	little bycatch attributable to sablefish fisheries (<1.3%)	small additional effect attributable to sablefish fisheries	no concern
Marine mammals and birds	need data		
Sensitive non-target species	need data		
Fishery concentration in space and time	IFQ less concentrated	improves	no concern
Fishery effects on amount of large size target fish	IFQ reduces catch of immature	improves	no concern
Fishery contribution to discards and offal production	sablefish <5%, need data for other species, but likely less for IFQ fishery	improves	no 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

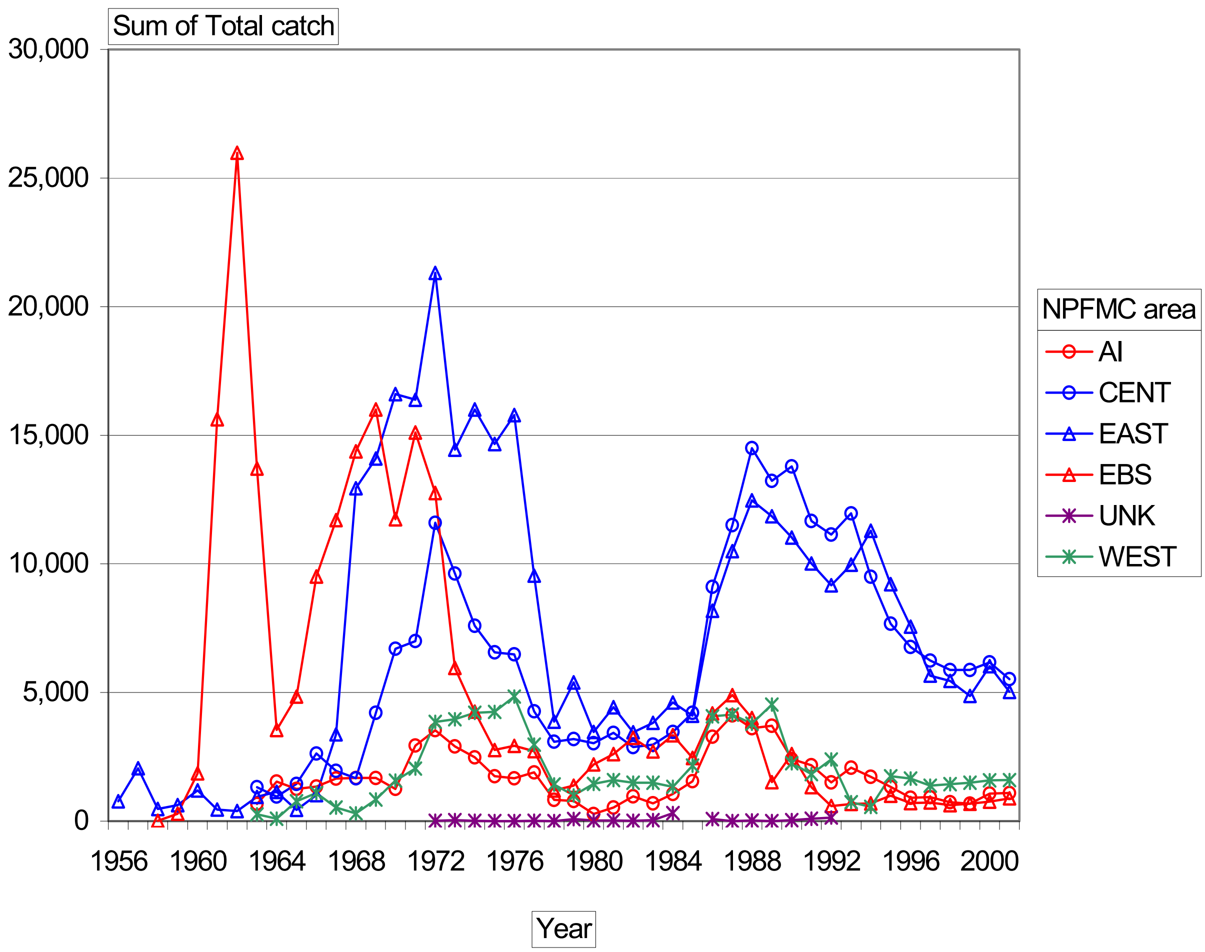

Figure 5.1–Sablefish fishery total reported catch (mt) by area and year.

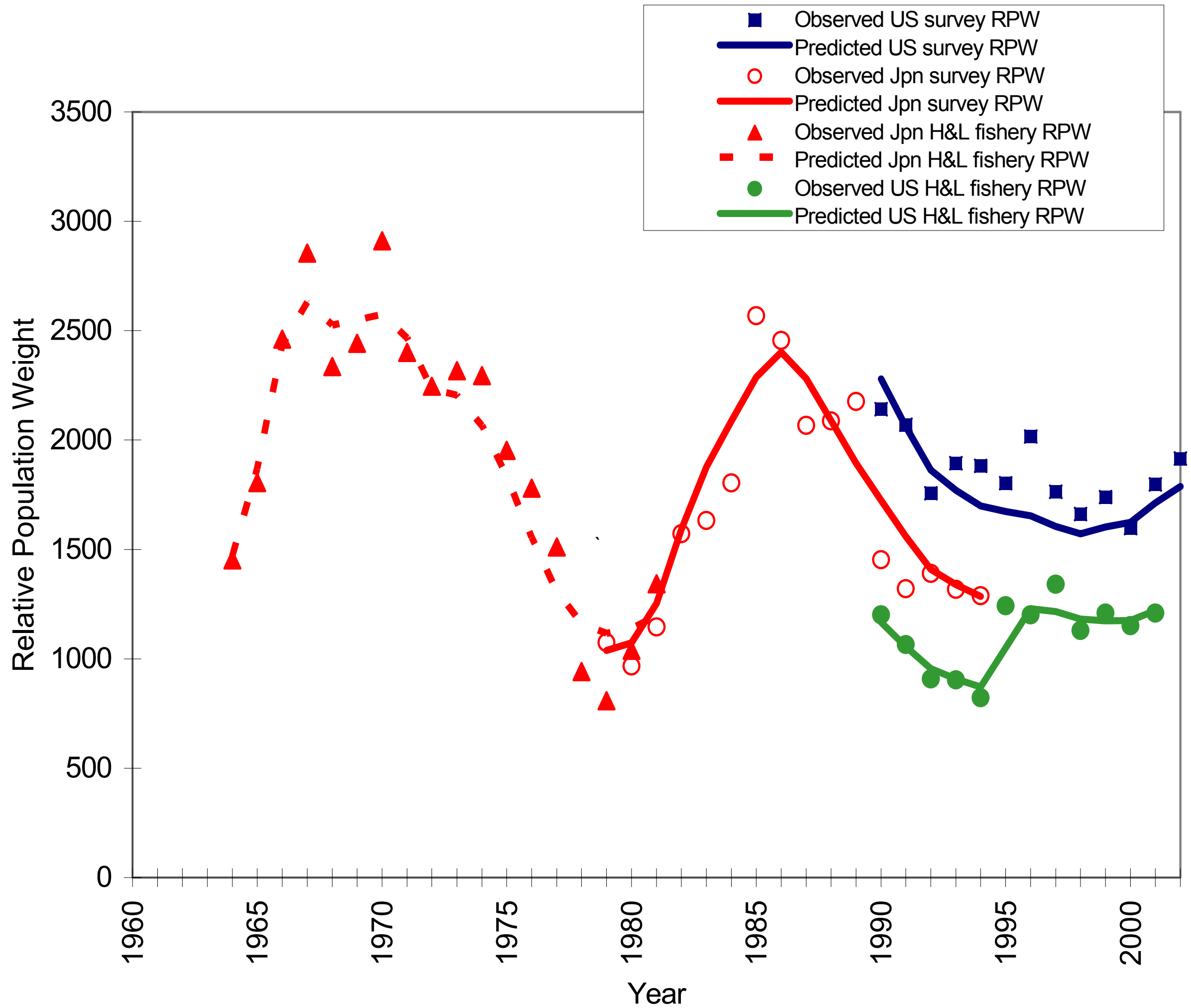

Figure 5.2.--Observed and predicted sablefish relative population weight versus year.

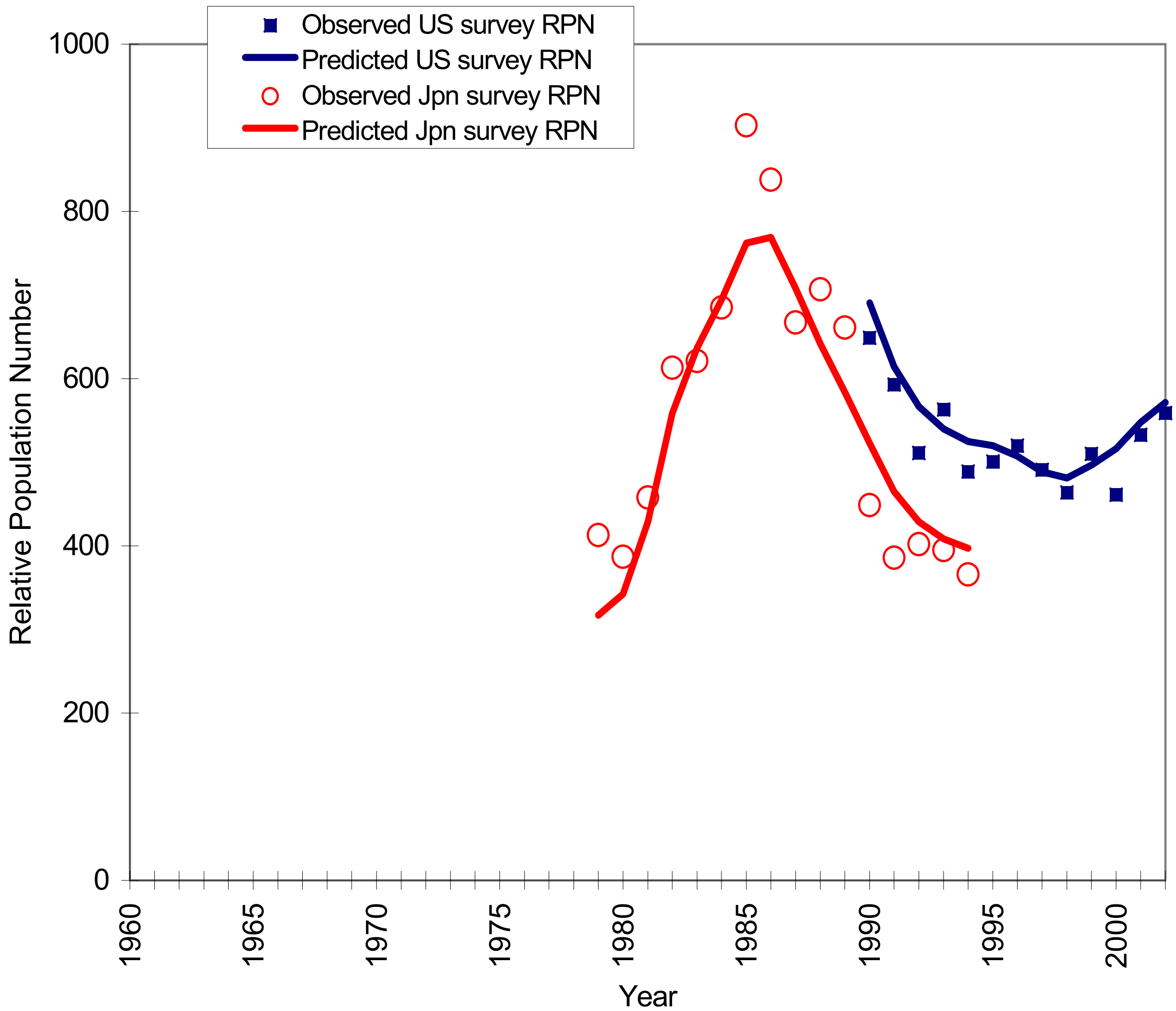

Figure 5.3.--Observed and predicted sablefish relative population number versus year.

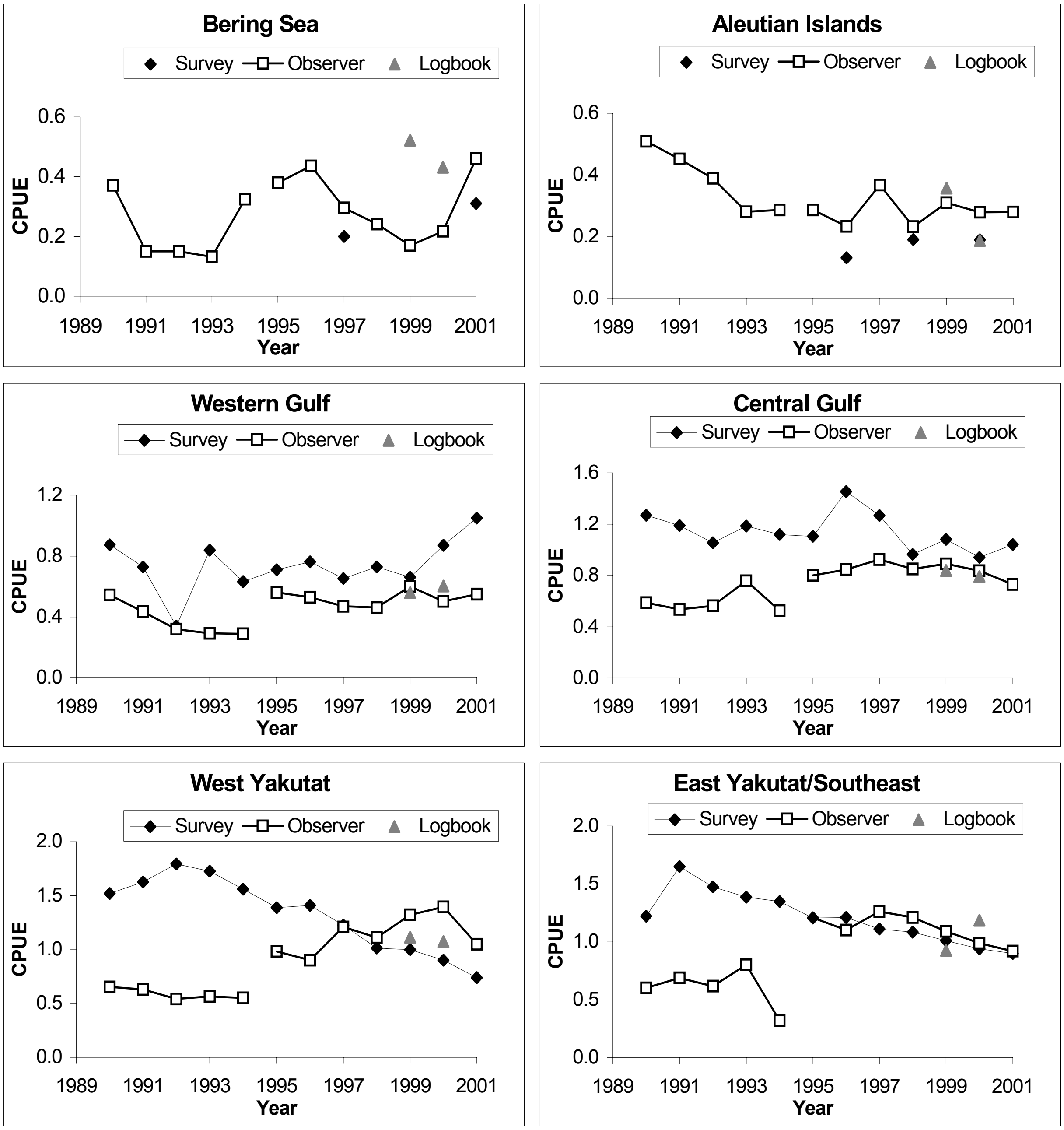

Figure 5.4.–Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data, 1990-2000. Open-access "derby" fishery from 1990-1994 and IFQ fishery from 1995-present.

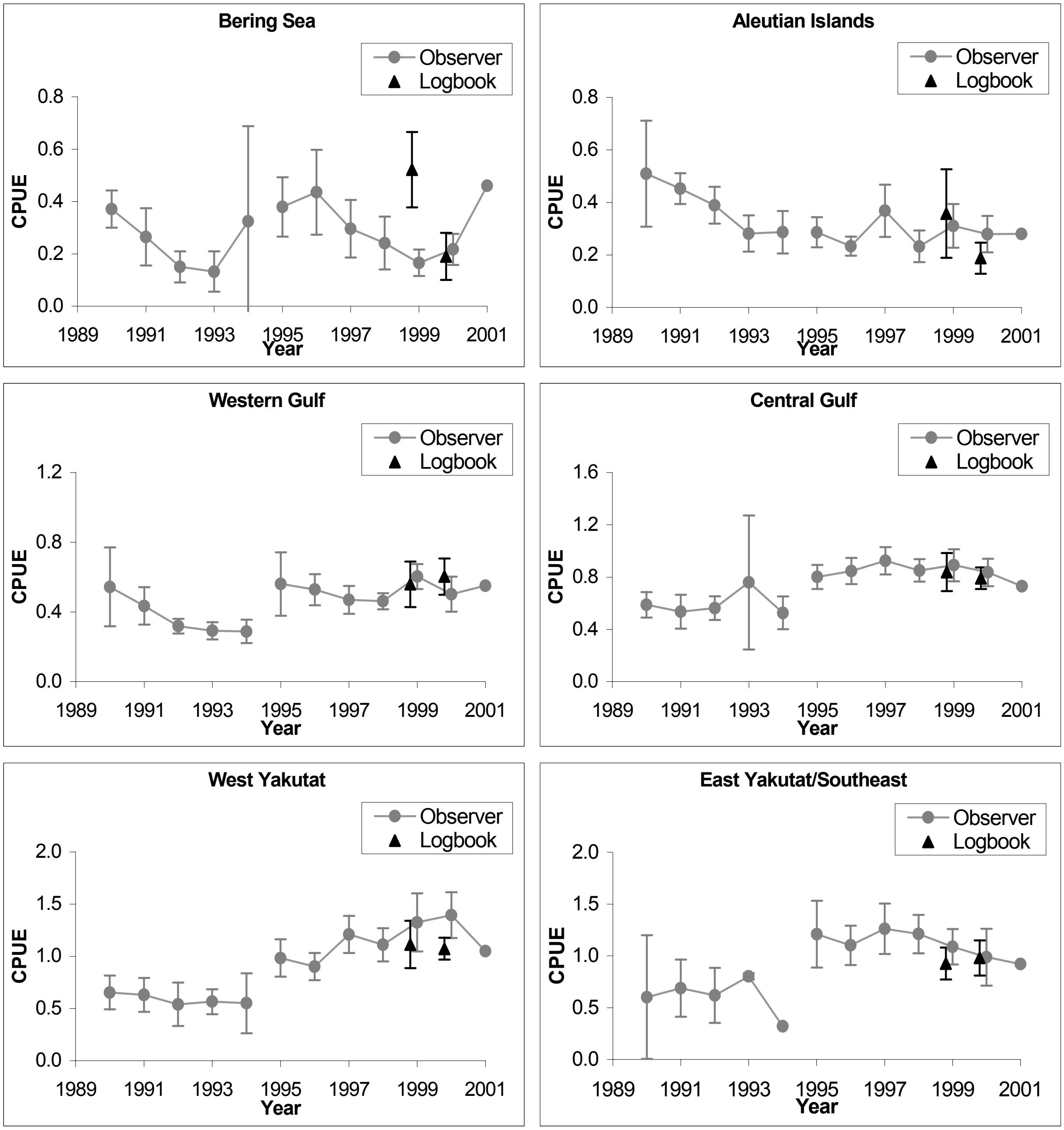

Figure 5.5.–Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source, 1990-2000. Open-access "derby" fishery from 1990-1994 and IFQ fishery from 1995-present.

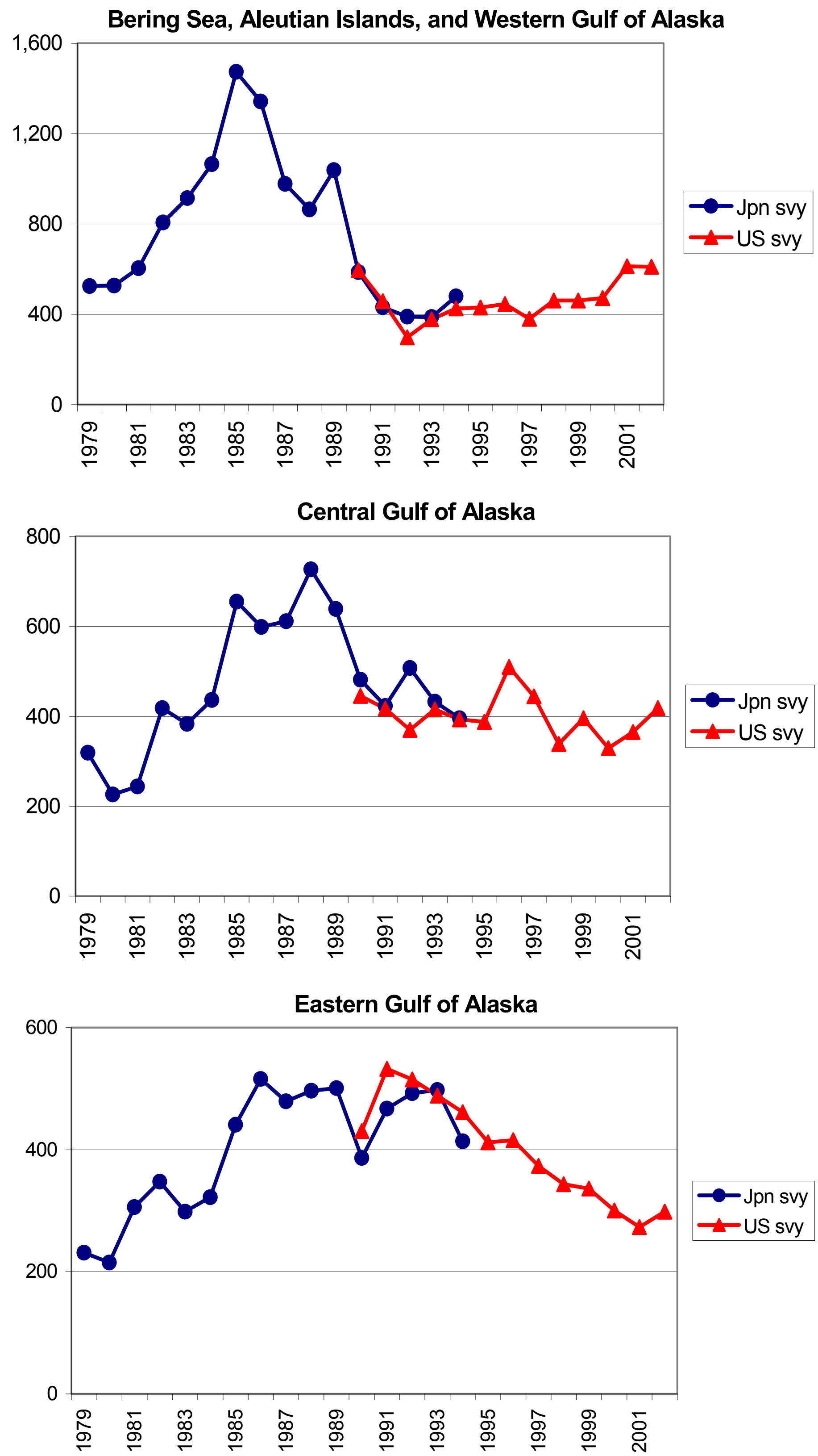

Figure 5.6.--Plot of relative abundance in weight by region and survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear.

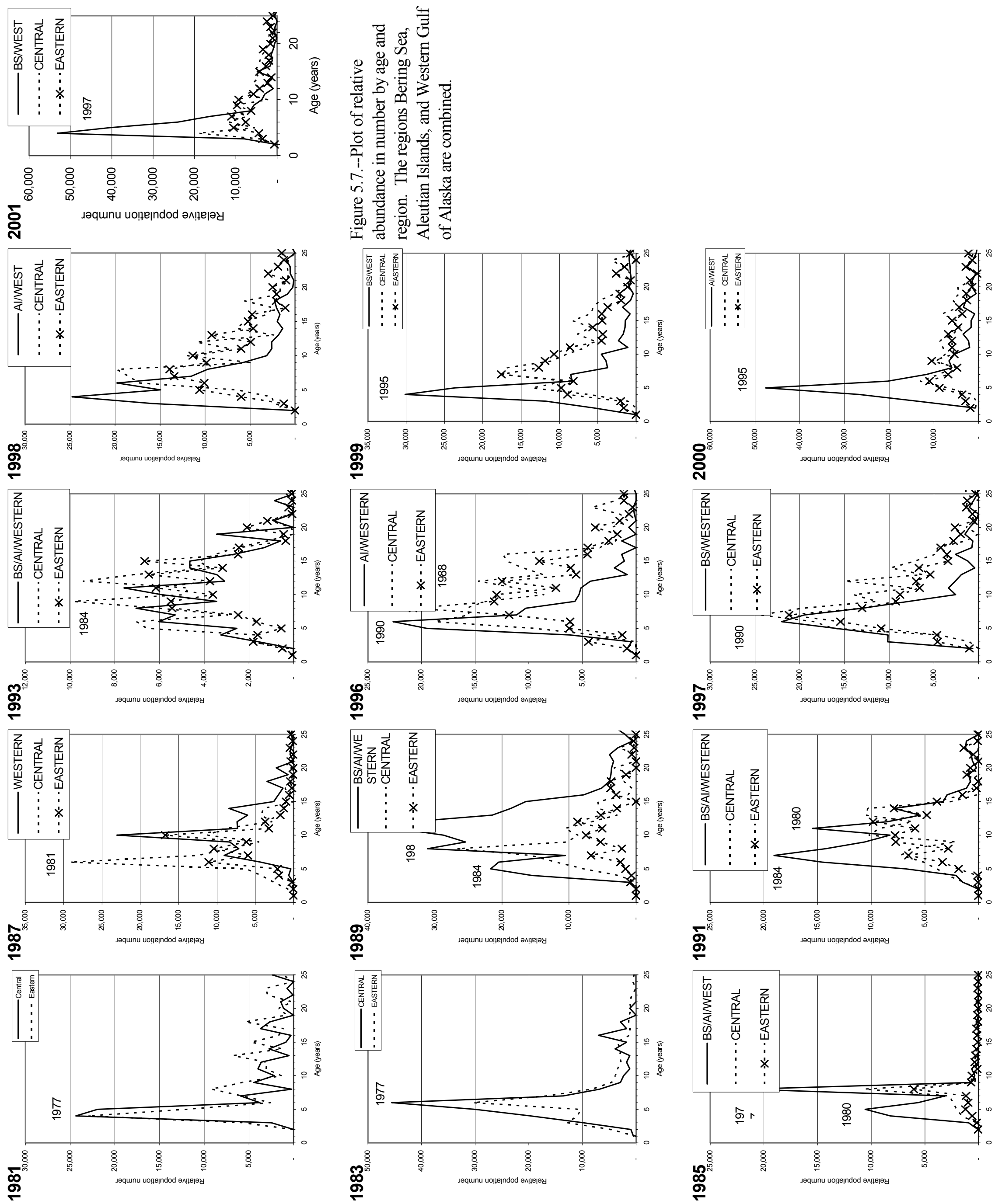

Figure 5.7.--Plot of relative abundance in number by age and region. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

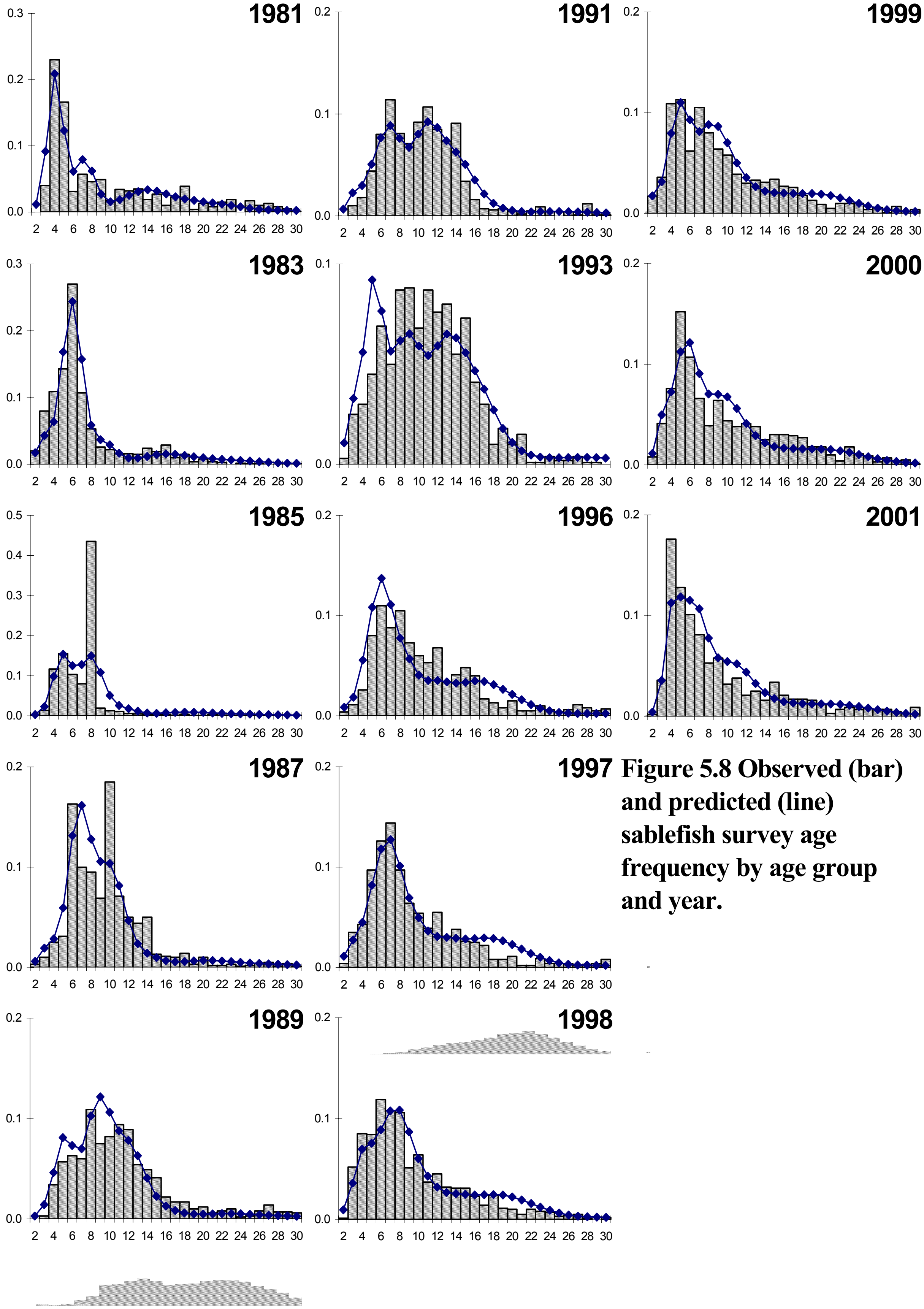

Figure 5.8 Observed (bar) and predicted (line) sablefish survey age frequency by age group and year.

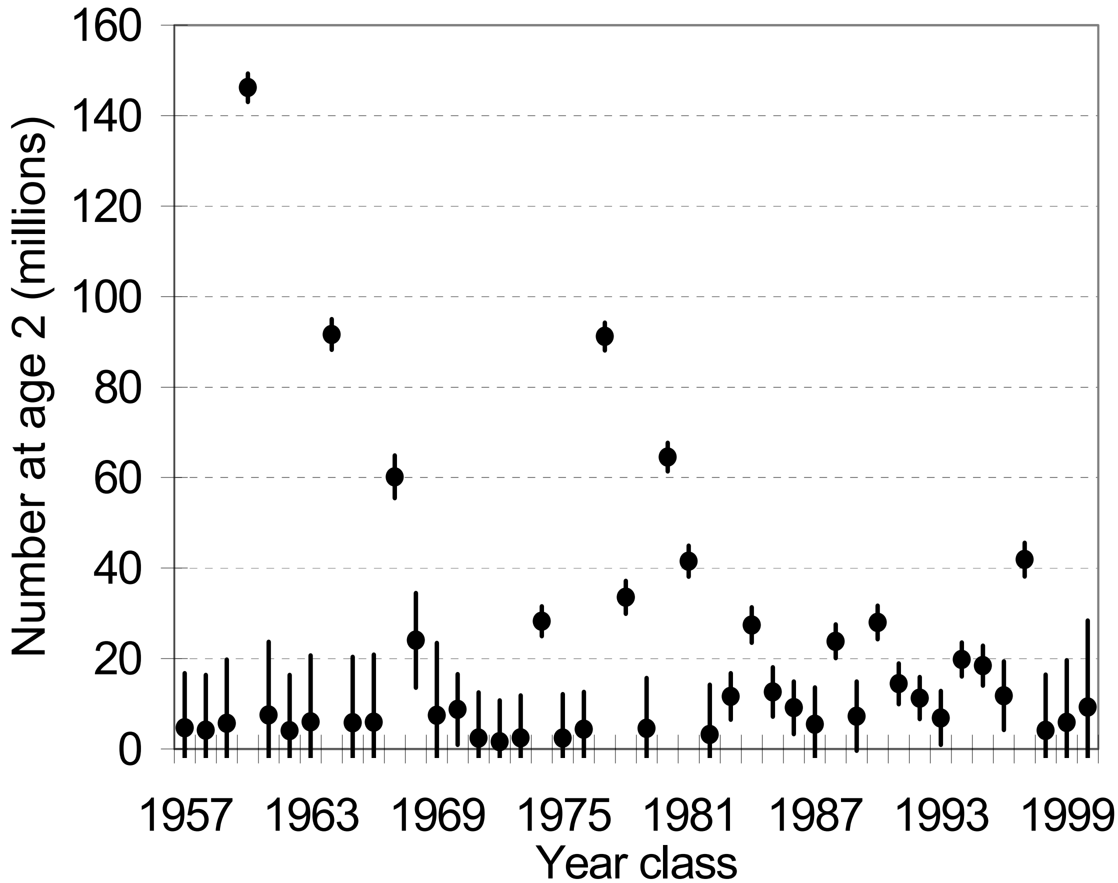

Figure 5.9.--Model estimates of the number of age-2 sablefish (millions) +/- 2 standard errors by year class. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated.

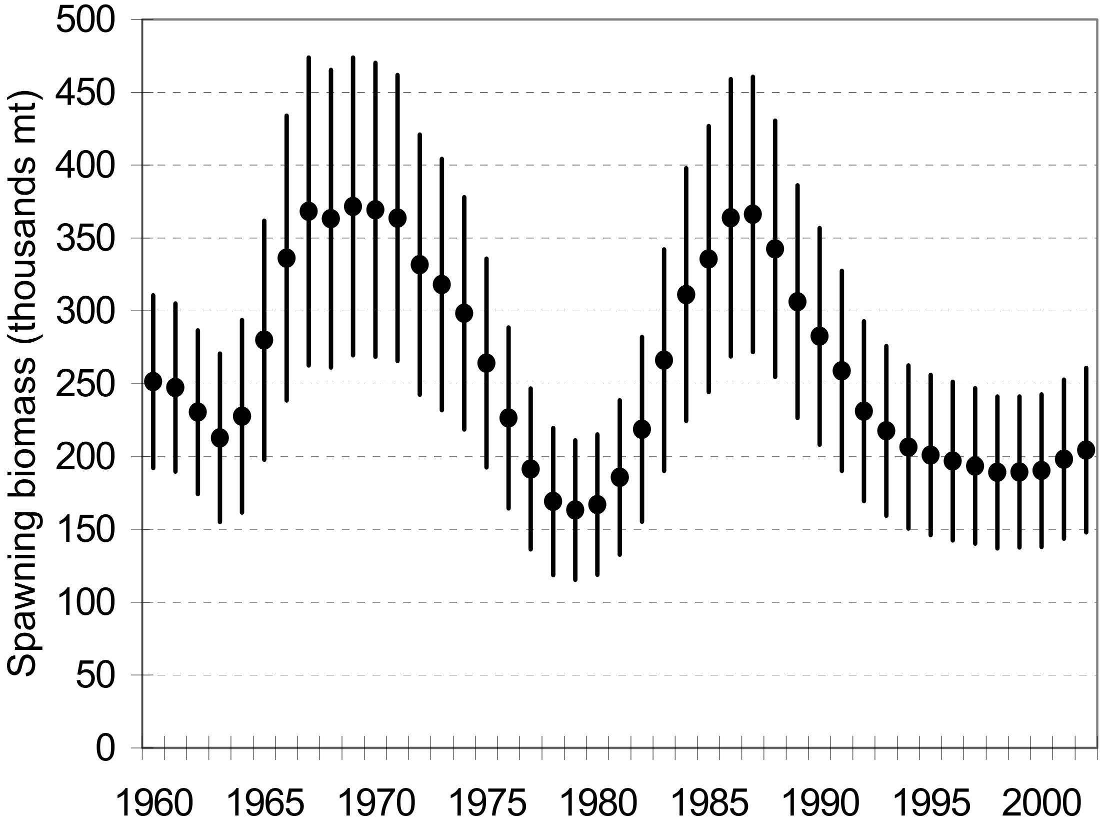

Figure 5.10.--Model estimates of male and female spawning biomass (thousands mt) +/- 2 standard errors by year. Standard error estimates based on covariance matrix from age-structured model output. The variability estimates do not include variability of the independently estimated parameters, so the variability is underestimated..

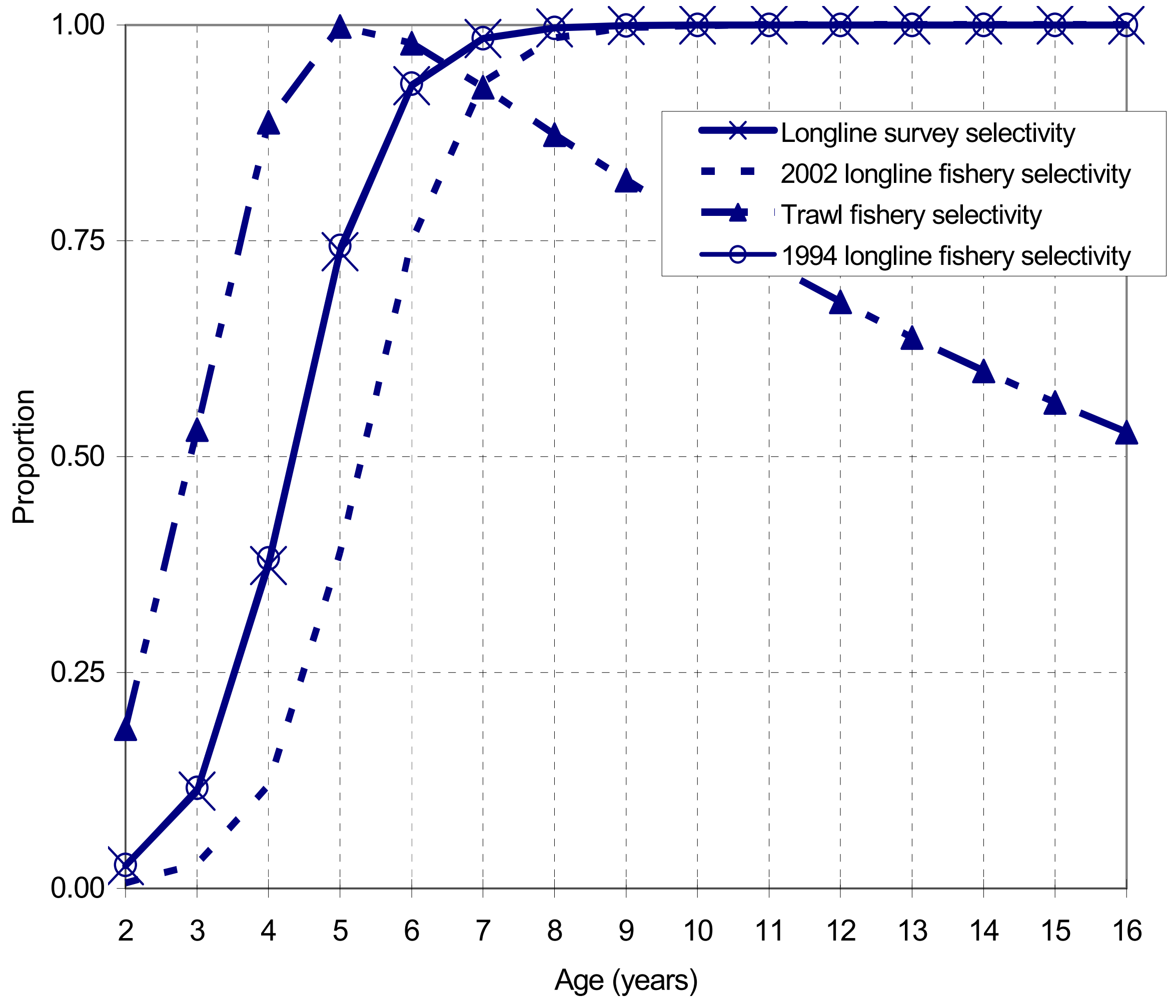

Figure 5.11 Sablefish survey, longline fishery, and trawl fishery selectivity functions. The displayed 1994 and 2002 longline selectivity functions are representative of the selectivity functions for the short open-access "derby" and IFQ seasons respectively.

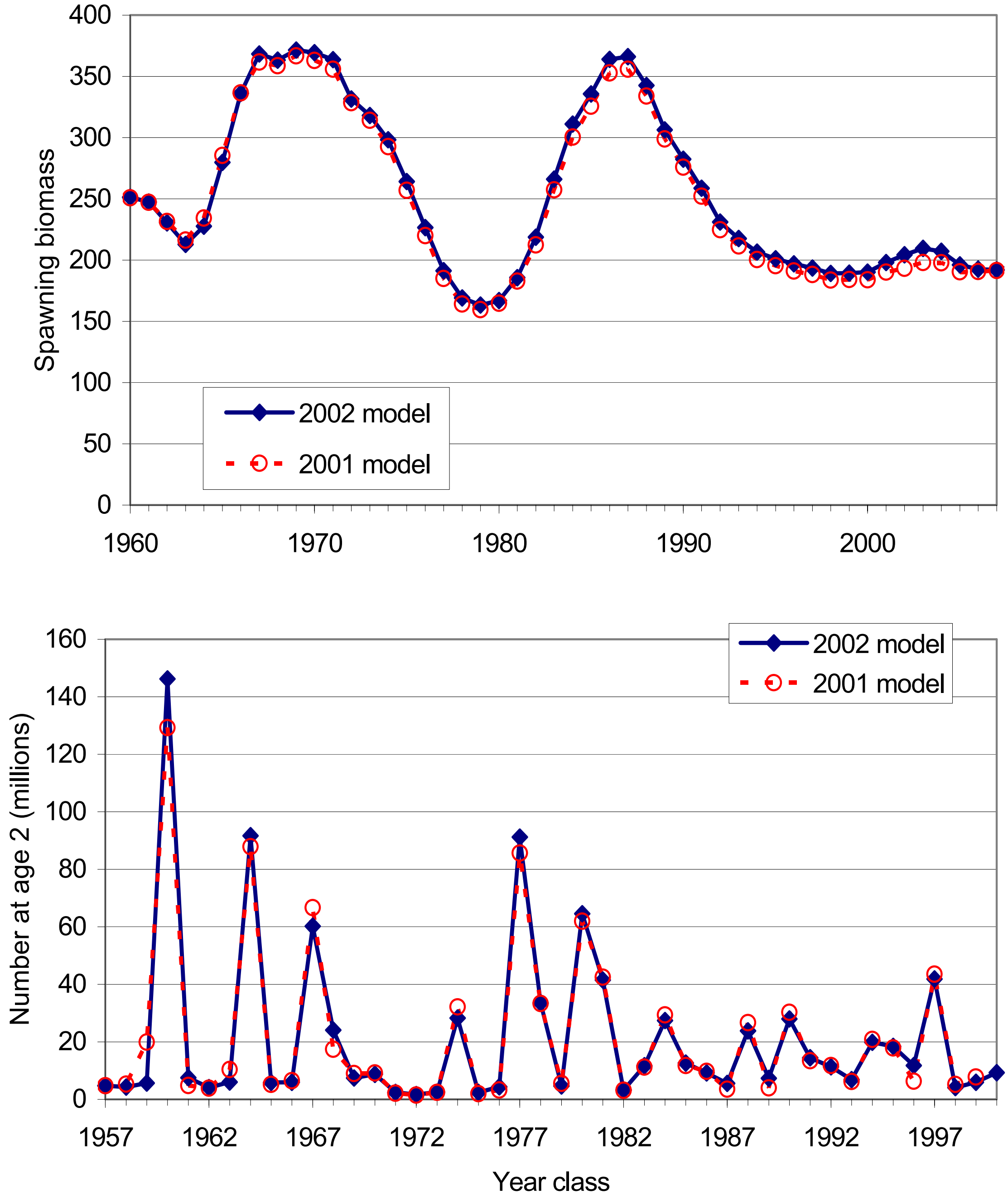

Figure 5.12 Estimated and projected sablefish spawning biomass (thousands mt) versus year and estimated recruitment (number at age 2, millions) for the 2001 and 2002 assessments.

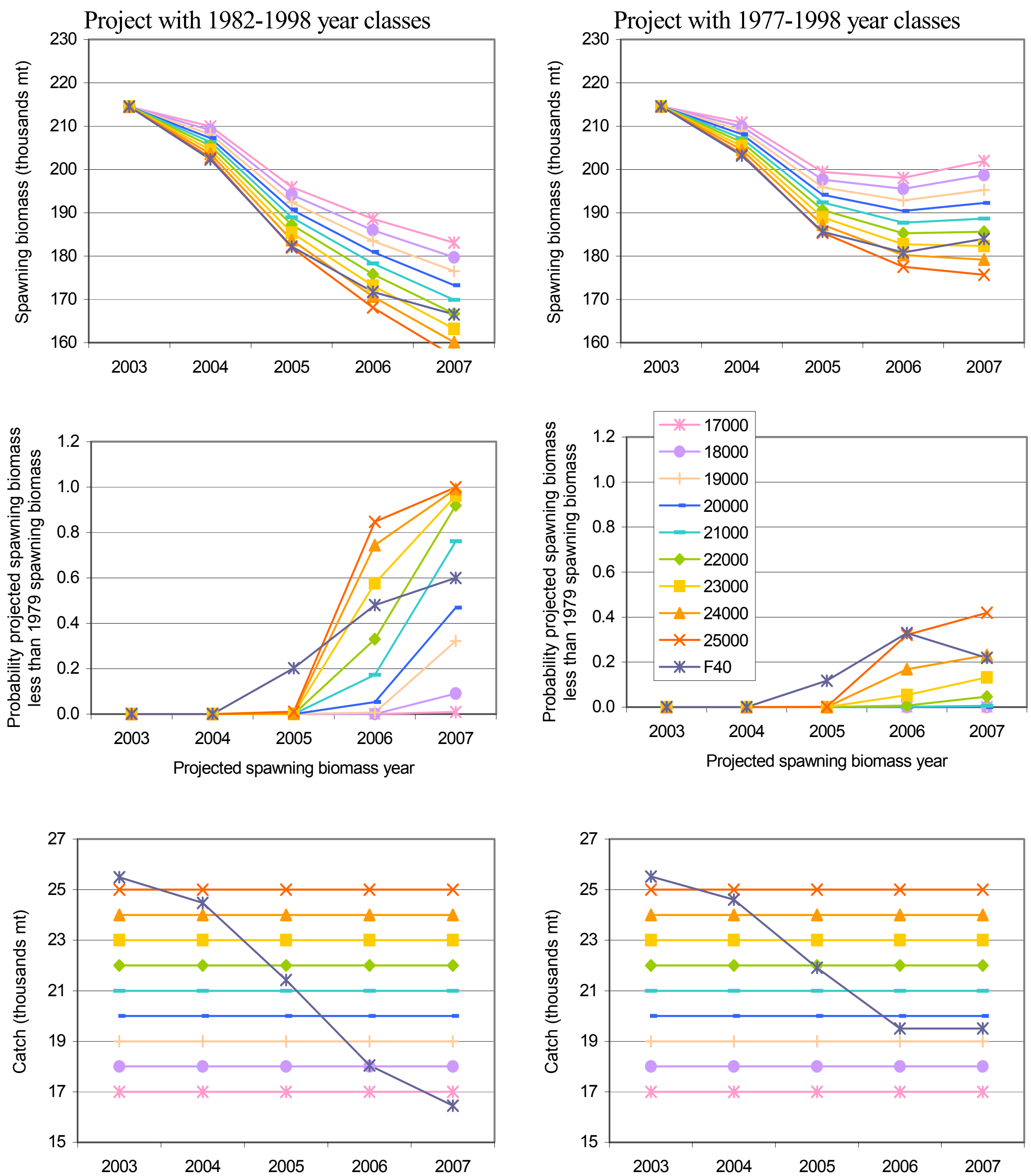

Figure 5.13--Sablefish spawning biomass and catch (thousands mt) for two recruitment scenarios and several harvest alternatives. Recruitment is projected using average recruitment for the 1982-1997 year classes or for the 1977-1997 year classes, which includes the exceptional 1977-1981 year classes. The harvest alternatives are described in section 5.5.1, *Standard set of population projections* and *Decision Analysis*. The authors' recommended ABC is 18,400 mt.

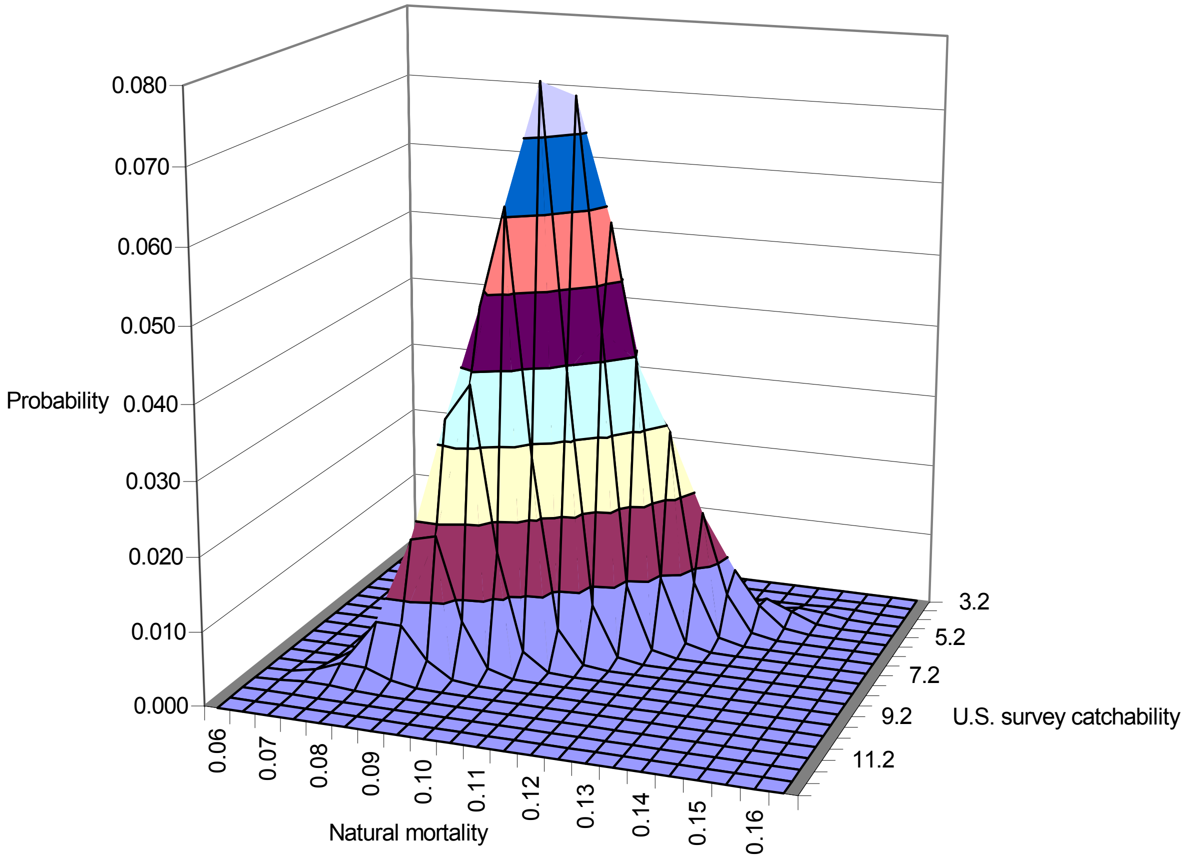

Figure 5.14.--Posterior probability versus catchability and natural mortality.

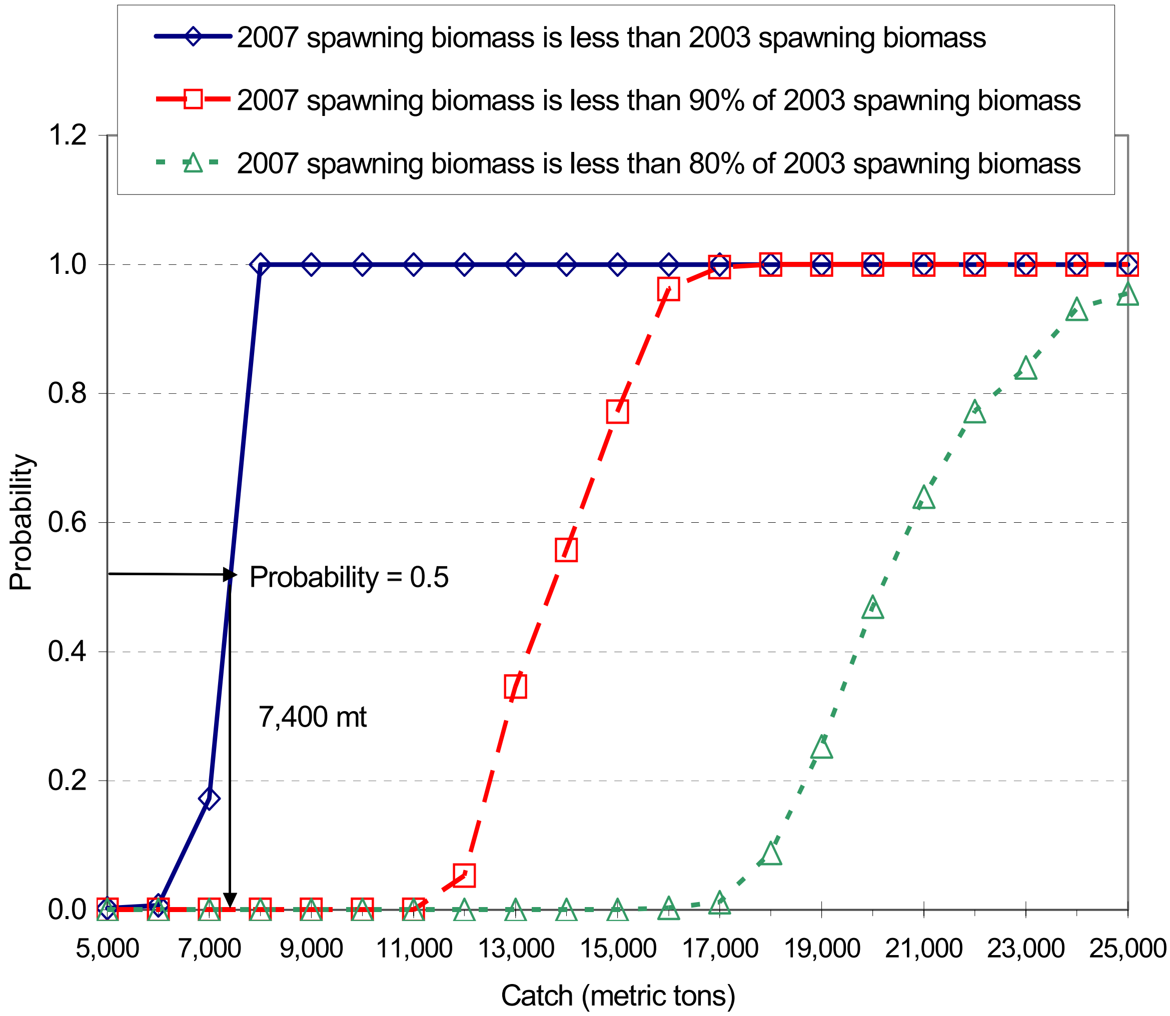

Figure 5.15.–Probability that a given catch will reduce 2007 spawning biomass to less than 100%, 90%, and 80% of 2003 spawning biomass.

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

Fishery data

For all years, let

w_k = weight at length k,

A_m = Areal size of strata.

For each year, let

Y_m = catch in weight for strata m,

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

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

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

then

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

We estimate A_{50} separately for the longline survey, short open-access "derby" fishery (1985-1994), long open-access (1960-1984) and IFQ fishery (1995-present), and trawl fishery. A single β was estimated for all selectivity functions, implying that the ascending slope of the selectivity functions are similar. Longline selectivity was restricted to be asymptotic. Dome-shape selectivity was allowed for the trawl fishery. Until this year, we allowed A_{50} to vary with season length using a function

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

where *s* is season length in months, and A_{50}, β, and m_{50} are estimated. Estimated selectivity by year fell into two groups, one for 1960-1984 and 1995-present, the other for 1985-1994, so we simplified the representation of selectivity to estimate one selectivity function for each group. The change little affected estimated abundance.

A predicted abundance index in numbers is

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

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

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

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

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

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

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

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

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

Data weighting

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

Appendix C.--Sablefish longline survey - fishery interactions, 1995-2002

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. Fifty-two 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

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, 2001, and 2002. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance.

Michael Sigler and Chris Lunsford, Alaska Fisheries Science Center 16 October 2002

Appendix D.--Research survey catches (kg) by survey type, 1977-2000.

Year	Echo integration trawl	Trawl	Japan US longline survey	Domestic longline survey	Total
1977		3,126			3,126
1978	23	14,302			14,325
1979		27,274	103,839		131,113
1980		69,738	114,055		183,793
1981	813	87,268	150,372		238,452
1982		107,898	239,696		347,595
1983	44	45,780	235,983		281,807
1984		127,432	284,431		411,864
1985		185,692	390,202		575,894
1986	80	123,419	395,851		519,350
1987		116,821	349,424		466,245
1988		14,570	389,382	302,670	706,622
1989		3,711	392,624	367,156	763,491
1990	94	25,835	272,274	366,236	664,439
1991		3,307	255,057	386,212	644,576
1992	168	10	281,380	392,607	674,165
1993	34	39,275	280,939	407,839	728,088
1994	65	852	270,793	395,443	667,153
1995				386,169	386,169
1996	0	12,686		426,479	439,165
1997	0	1,080		396,266	397,347
1998	5	25,528		310,564	336,096
1999	0	43,224		293,149	293,149
2000	0	2,316		271,654	271,654
2001	2	11,411		304,125	315,538
2002	154	3,197		293,010	295,617