3 Alaska Sablefish Assessment for 2007

by

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3.0 Executive Summary

3.0.1 Summary of major changes

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

Model changes: The model has been reconfigured as a split-sex model and now incorporates Gulf of Alaska trawl survey lengths and biomass estimates for depths 500 meters and less.

Input data: Relative abundance and length data from the 2006 longline survey, relative abundance and length data from the 2005 longline and trawl fisheries, and age data from the 2005 longline survey and longline fishery were added to the assessment model. In addition, the new model configuration uses Gulf of Alaska trawl survey abundance and length data.

Assessment results: Sablefish abundance increased during the mid-1960's due to strong year classes from the early 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 53,080 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 dissipated.

The fishery abundance index decreased 4% from 2004 to 2005 (the 2006 data isn't available yet). The survey abundance index increased 8% from 2005 to 2006 and follows a 2.5% decrease from 2004 to 2005. Relative abundance in 2006 is 16% higher than the all-time low in 2000. Spawning biomass is projected to remain stable from 2006 to 2007.

Projected 2007 spawning biomass is 38% of unfished biomass. Abundance has increased from a low of 33% of unfished biomass during 1998 to 2000. The 1997 year class is an important part of the total biomass and is projected to account for 13% of 2006 spawning biomass. The 2000 year class likely is above average and should also account for 13% of spawning biomass in 2007.

Sablefish are managed under Tier 3 of NPFMC harvest rules. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 123,900 t (combined across the EBS, AI, and GOA), 0.092, and 0.109, respectively. Projected spawning biomass (combined areas) for 2007 is 118,800 t (95% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.088 which translates into a 2007 catch (combined areas) of 20,100 t. The OFL fishing mortality rate is 0.104 which translates into a 2007 OFL (combined areas) of 23,750 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

We recommend a 2007 ABC of 20,100 mt. The maximum permissible yield for 2007 from an adjusted $F_{40\%}$ strategy is 20,100 mt. The maximum permissible yield for 2007 is a slight decrease from the 2006 ABC of 21,000 mt. Spawning biomass is projected to remain stable through 2010, and then begin to increase.

Spawning biomass currently is at 38% of the unfished level, and is projected to remain level through 2010. Abundance is projected to remain stable because estimated year classes between and following the strong 1997 and 2000 year classes are near average. The maximum permissible ABC also is projected to be 20,000 mt in 2008 and 19,800 mt in 2009 (using estimated catches, instead of maximum permissible, see Table 3.10).

During the next three years, the probability of spawning biomass falling below MSST ($B_{17.5\%}$) for a Tier 3

stock is near zero. The long-term probability depends on future recruitment, but will be updated each year as new data becomes available.

In December 1999, the Council allocated the 2000 ABC and OFL based on a 5-year exponential weighting of the survey and fishery abundance indices. We used the same algorithm to allocate the 2007 ABC and OFL.

Apportionments are based on survey and fishery information	**2006 ABC Percent**	**2006 Survey RPW**	**2005 Fishery RPW**	**2007 ABC Percent**	**2006 ABC**	**Authors 2007 ABC**	**Change**
Total					21,000	**20,100**	-4%
Bering Sea	15%	16%	13%	15%	3,060	**2,980**	-3%
Aleutians	15%	13%	13%	14%	3,100	**2,810**	-9%
Gulf of Alaska	71%	71%	73%	71%	14,840	**14,310**	-4%
Western	18%	18%	15%	17%	2,670	**2,470**	-7%
Central	43%	45%	39%	43%	6,370	**6,190**	-3%
W. Yakutat	14%	15%	17%	15%	2,090	**2,100**	0%
E. Yakutat / Southeast	25%	23%	29%	25%	3,710	**3,550**	-4%

After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the ABC for West Yakutat is 2,280 mt and for East Yakutat / Southeast is 3,370 mt. This adjustment projected to 2008 is 2,280 mt for W. Yakutat and 3,370 mt for E. Yakutat.

3.0.2 Responses to Council, SSC, and Plan Teams comments

The SSC December 2005 minutes included the following comments:

"The SSC recommends that authors explore more complicated criteria for defining sablefish target catches, such as at least 50% sablefish and not POP or northern rockfish."
We explored defining sablefish target catches using several different methodologies and presented the results in the 2005 SAFE. We now have logbook data for sablefish targeted sets which may also have been observed. We will explore our ability to identify observed sets that were known sablefish target sets from logbook information.

"Given differences in size by sex, the authors might consider whether there is there a need to have a sex-specific model."
For 2006, the model was re-configured to be a sex-specific model. The author's recommended model for this year is a sex-specific model.

"We appreciate the author's efforts to estimate the probability that the stock will fall below threshold biomass levels. However, the historical rationale for using the 30% unfished biomass threshold is no longer relevant and could be dropped."

This year's posterior probability projections were changed to be relative to $B_{35\%}$ (MSY) and $B_{17.5\%}$ (MSST) which are more relevant to NPFMC management quantities.

"The phase-plane plot reference points (p. 311 of the GOA SAFE) should be made relative to $B_{35\%}$ and $F_{35\%}$."
This plot was changed.

"The SSC endorses the list of recommended studies (section 3.6.3, p. 272) and encourages

research on these issues."

Since 2005 many of these studies have been explored and results that are presented here include: configuring the model to use AFSC trawl survey estimates as an index; presenting available pot gear information from observer data; presenting latest estimates of sperm whale depredation on survey catch rates; using female spawning biomass for reference points.

"The apportionment scheme was established as an adjustment for a highly mobile stock. The ½ weighting scheme is applied to the most recent 5 years. The apportionments were originally compared to a migratory movement model. This model has not been updated with more recent tagging information and the SSC requests that the authors consider re-examining movement rates of sablefish given more recent information."

Progress has been ma1de on updating the migration model of Heifetz and Fujioka (1995). It has been recoded into AD Model Builder and is a top priority for sablefish modeling work in 2007.

"The Council encouraged the Alaska Fisheries Science Center Auke Bay Laboratory to develop experimental research in 2006 to determine the effectiveness of different size escape rings and soak times, in conjunction with the development of catch-per-unit-effort (CPUE) indices for sablefish pot fishing. The Council requested that a discussion paper on three potential changes to sablefish pot gear regulations be prepared based on research results. Potential changes include: 1) escape rings; 2) changes to required biodegradable panels; and 3) banning at-sea storage of pots."

1. A comparison of CPUE and size information from pot and longline fisheries is presented in section 3.1.2 of this document.

2. A study of the distribution of sablefish less than 40 cm has been undertaken. Results indicate that juveniles are distributed on the Gulf of Alaska shelf with varying abundance by year. On the Bering Sea shelf, while abundant at times, their presence is much more intermittent (Shotwell 2006).

3. A study of escape rings by the Canadian Department of Fisheries and Oceans (DFO) recommended that: "Escape rings are an effective means of reducing the catch of sub-legal blackcod" (Saunders and Surry 1998). Additional studies by DFO indicate similar results (appendix N in Haist et al. 2003). To attain the sample size to experimentally verify that this would occur in the Bering Sea may require inordinate amount of effort and time due to the intermittent and lower density of sablefish in this area.

4. The Observer Program has begun sampling stomachs of large sablefish taken from pot vessel trips to examine the possibility of cannibalism of small sablefish. Sufficient samples have not been attained at this time.

5. An estimate of size specific RPW's apportioned by area indices can be computed using the longline target fishery selectivity to estimate exploitable biomass to account for the difference in sizes between areas. The Bering Sea which generally has a smaller average fish size would be expected to have a smaller apportionment of exploitable biomass, than if exploitable biomass is estimated by the current depth specific RPW.

6. Information on soak times observed in the Alaska fishery is shown in section 3.1.2. Analyses or studies to determine a maximum soak time have not been initiated on the Alaska fishery. A study by Scarsbrook et al. (1988) in Canadian waters noted significant mortality when soak time extended beyond 10 days.

7. Pot catch rate data available from the Alaska fishery has been compiled (section 3.1.2). Development of pot fishery indices of abundance will be considered after any escape ring and soak time regulations have been stabilized and sufficient observer coverage and time series of data is available.

8. It appears State and Federal regulations already require an 18 inch slash secured with biodegradable twine in all pot gear. Research done in Canada testing the effectiveness of various escape mechanisms in conical pots used in the sablefish fishery found that square or triangular panels were more effective than just a "slash" secured with biodegradable twine (Scarsbrook et al. 1988).

9. Banning at-sea pot storage of pots: Considerations of such regulations have industry wide implications and have implications to various fish species as well as habitat. The expertise and resources needed to evaluate this sufficiently is beyond the capacity of sablefish assessment scientists alone.

3.0.3 Plan team summaries

Area	Year	Biomass (4+)	OFL	ABC	TAC	Catch
GOA	2005	185,000	19,280	15,940	15,940	13,997
	2006	152,000	17,880	14,840	14,840	12,284
	2007	158,000	16,909	14,310		
	2008		15,805	14,239		
BS	2005	32,000	2,950	2,440	2,440	1,050
	2006	34,000	3,680	3,060	3,060	2,720
	2007	34,000	3,521	2,980		
	2008		3,291	2,965		
AI	2005	34,000	3,170	2,620	2,571	1,486
	2006	32,000	3,740	3,100	3,100	1,050
	2007	32,000	3,320	2,810		
	2008		3,104	2,796		

Year	2006				2007		2008	
Region	OFL	ABC	TAC	Catch	OFL	ABC	OFL	ABC
BS	3,680	3,060	3,060	2,720	3,521	2,980	3,291	2,965
AI	3,740	3,100	3,100	1,050	3,320	2,810	3,104	2,796
GOA	17,880	14,840	14,840	12,280	16,909	14,310	15,805	14,239
W	--	2,670	2,670	2,070	--	2,470	--	2,458
C	--	6,370	6,370	5,470	--	6,190	--	6,159
WYAK	--	2,280	2,280	1,650	--	2,280	--	2,269
SEO	--	3,520	3,520	3,090	--	3,370	--	3,353
Total	25,300	21,000	21,000	16,050	23,750	20,100	22,200	20,000

3.1 Introduction

Distribution: Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea (Wolotira et al. 1993). Adult sablefish occur along the continental slope, shelf gullies, and in deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Kreiger 1997). In contrast to the adult distribution, juvenile sablefish (less than 40 cm) spend their first two to three years on the continental shelf of the Gulf of Alaska, and occasionally on the shelf of the southeast Bering Sea. It appears that the Bering Sea shelf is utilized significantly in some years and virtually not used during other years (Shotwell 2006).

Stock structure and management units: Sablefish form two populations based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). A northern population inhabits Alaska and northern British Columbia waters and a 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.

Sablefish are assessed as a single population in Federal waters off Alaska because northern sablefish are highly migratory for at least part of their life (Heifetz and Fujioka 1991; Maloney and Heifetz 1997; Kimura et al. 1998). 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. This corresponds to when sablefish start becoming reproductively viable.

3.1.1 Fishery

Early U.S. fishery, 1976 and earlier

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

Foreign fisheries, 1958 to 1987

Japanese longliners began operations in the eastern Bering Sea in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 mt in 1962 (Table 3.1a, Figure 3.1). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the Aleutian Islands region and the Gulf of Alaska. In the Gulf of Alaska, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 mt overall in 1972. Catches in the Aleutian Islands region 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, due to the passage of the Magnuson-Stevens Act.

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 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 caught sablefish mostly as bycatch in fisheries targeting other species. Two trawl fisheries caught sablefish in the Bering Sea through 1972: the North Pacific trawl fishery which caught sablefish as bycatch to the directed pollock fishery, and the land-based dragnet fishery that sometimes targeted sablefish (Sasaki 1973). The latter fishery mainly targeted rockfishes, Greenland turbot, and Pacific cod, and only a few vessels targeted sablefish (Sasaki 1985). The land-based fishery caught more sablefish, averaging 7,300 mt from 1964 to 1972, compared to the North Pacific trawl fishery, which averaged 4,600 mt. In the Gulf of Alaska, sablefish were caught as bycatch to the directed Pacific Ocean perch fishery until 1972, but some vessels started targeting sablefish in 1972 (Sasaki 1973). 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 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 throughout Alaska. Other countries reporting minor sablefish catches were Republic of Poland, Taiwan, Mexico, Bulgaria, Federal Republic of Germany, and Portugal. The U.S.S.R. gear was factory-type stern trawl and the R.O.K. gear was longlines and traps (Low et al. 1976).

Recent U.S. fishery, 1977 to present

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

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

Season length continued to decrease until Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels in 1995 along with an 8-month season. The season ran from March 15-November 15 until 2003, when the starting date was changed to March 1 to extend the season to 8-1/2 months. The sablefish IFQ fishery is concurrent with the halibut IFQ fishery.

The expansion of the U.S. fishery was helped by exceptional recruitment during the late 1970's. This exceptional recruitment fueled an increase in abundance for the population during the 1980's. Increased abundance led to increased 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 dissipated. Catches also have fallen and in 2000, were about 42% of the 1988 peak. Catches since 2000 have increased, largely due to a strong 1997 year class.

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

The directed fishery primarily is a hook-and-line fishery. Sablefish also are caught as bycatch during directed trawl fisheries for other species groups such as rockfish and deepwater flatfish. Five state fisheries land sablefish outside the IFQ program; the major State fisheries occur in the Prince William Sound, Chatham Strait, and Clarence Strait and the minor fisheries in the northern Gulf of Alaska and Aleutian Islands. The minor state fisheries were established by the State of Alaska in 1995, the same time as the Federal Government established the IFQ fishery, primarily to provide open-access fisheries to fishermen who could not participate in the IFQ fishery. For Federal and State sablefish fisheries combined, the number of longline vessels targeting sablefish (Hiatt and Terry 2005) was:

Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Vessels	871	1,078	613	578	504	450	451	434	432	422	408	383

To calculate the total number of hooks deployed in the Federal fishery, we use observer catch and effort data and extrapolate it to the total catch in the fishery, including unobserved sets. Averages per year are presented for years 1990-1994 and 1995-2000. In 2005, the total number of hooks fished was lower than average for the period 1995 - 2000. These estimates correspond to the low number of observed sablefish sets in this area which affects our ability to estimate total hooks fished. The numbers of hooks (in millions) deployed in the Federal fishery are:

Year	**Aleutians**	**Bering Sea**	**Western Gulf**	**Central Gulf**	**Eastern Gulf**	**Total**
1990-1994	9.2	5.8	6.1	30.8	28.9	80.8
1995-2000	6.3	3.7	6.3	11.9	11.5	39.6
2001	6.6	3.1	6.4	14.3	11.6	42.1
2002	5.8	3.3	7.3	13.5	8.7	38.6
2003	5.8	10.0	9.2	13.0	8.4	46.4
2004	4.1	3.6	9.9	13.9	11.5	43.0
2005	4.5	1.6	9.8	16.6	8.7	41.2

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

Pot fishing for sablefish has increased in the Bering Sea and Aleutian Islands as a response to depredation of longline catches by killer whales. In 2000 the pot fishery accounted for less than ten percent of the fixed gear sablefish catch in the Bering Sea and Aleutian Islands. Since 2004, pot gear has accounted for over half of the Bering Sea fixed gear IFQ catch and 34% of the catch in the Aleutians. The Plan Teams recommended that the different selectivity of pots and longline gear should be explored because of the increased use of pots in the Bering Sea. Limited pot fishery data is available from observer data and is now included in the fishery catch rate section.

Catch

Annual catches in Alaska averaged about 1,700 mt from 1930 to 1957 and exploitation rates remained low until Japanese vessels began fishing for sablefish in the Bering Sea in 1959 and the Gulf of Alaska in 1963. Catches rapidly escalated during the mid-1960's. Annual catches in Alaska reached peaks in 1962, 1972, and 1988 (Table 3.1). 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 and passage of the MSFCMA 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 declined during the 1990's. Catches peaked at 38,406 mt in 1988, fell to about 16,000 mt in the late 1990's, and have been near 20,000 mt recently. The proportion of catch due to pot fisheries in the Bering Sea and the Aleutian Islands has increased starting in 2000 (Table 3.1b) and is discussed further below.

Bycatch and discards

Sablefish discards averaged 473 mt and an average discard rate of 3.4% (of total catch) in all longline fisheries and 590 mt and an average rate of 26% in trawl fisheries during 1994-1999, and from 2000-2006 the discards were similar, averaging 601 mt (3.1%) for all longline fisheries and 610 mt (27%) in the trawl fisheries (Table 3.2). Sablefish discards vary between gear, target fishery, and areas. In the longline fishery for 2003-2006, discards averaged 295 mt with an average rate of 2.3% in the sablefish fishery, 22 mt (22%, BSAI) in the Greenland turbot fishery, and 32 mt (59%, BSAI, WGOA, CGOA) in the Pacific cod fishery. Discards averaged 167 mt (16%) in the rockfish trawl fisheries for 2003-2006, 56 mt (65%) in the deepwater flatfish fishery in the Central Gulf of Alaska, and 127 mt (45%) in the arrowtooth flounder fishery in the Bering Sea, and Western and Central Gulf of Alaska.

Previous management actions

Quota allocation: Amendment 14 to the Gulf of Alaska Fishery Management Plan, allocated the sablefish quota by gear type: 80% to fixed gear (including pots) and 20% to trawl in the Western and Central Gulf of Alaska and 95% to fixed 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 allowances: Maximum retainable allowances for sablefish were revised in the Gulf of Alaska by a regulatory amendment, effective 10 April 1997. The percentage depends on the basis species: 1% for pollock, Pacific cod, Atka mackerel, “other species”, and aggregated amount of non-groundfish species. Fisheries targeting deep flatfish, rex sole, flathead sole, shallow flatfish, Pacific ocean perch, shortraker and rougheye rockfish, other rockfish, northern rockfish, pelagic rockfish, demersal shelf rockfish in the Southeast Outside district, and thornyheads are allowed 7%. Arrowtooth flounder fisheries are not allowed to retain any sablefish.

Allowable gear: Amendment 14 to the Gulf of Alaska Fishery Management Plan banned the use of pots for fishing for sablefish in the Gulf of Alaska, effective 18 November 1985, starting in the Eastern area in 1986, in the Central area in 1987, and in the Western area in 1989. An earlier regulatory amendment was approved in 1985 for 3 months (27 March - 25 June 1985) until Amendment 14 was effective. A later regulatory amendment in 1992 prohibited longline pot gear in the Bering Sea (57 FR 37906). The prohibition on sablefish longline pot gear use was removed for the Bering Sea, except from 1 to 30 June to prevent gear conflicts with trawlers during that month, effective 12 September 1996. Sablefish longline pot gear is allowed in the Aleutian Islands.

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

3.1.2 Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1960-2006
Japanese longline fishery	Effort	1964-1981
U.S. longline fishery	Effort, length	1990-2006
	Age	1999-2005
U.S. trawl fisheries	Length	1990,1991,1999, 2005
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	1990-2006
	Age	1996-2005
NMFS GOA trawl survey	Abundance index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
	Lengths	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005

Fishery

Catch, effort, and length data are collected from sablefish fisheries. The catch data covers several decades. Length and effort data were collected from the Japanese and U.S. longline fisheries (Table 3.3). Length data were collected from the Japanese and U.S. trawl fisheries. The Japanese data were collected by fishermen trained by Japanese scientists (L-L. Low, Alaska Fisheries Science Center, 25 August 1999). The U.S. fishery data were collected by at-sea and plant observers. No age data were systematically collected from the fisheries until 1999 because of the difficulty of obtaining representative samples from the fishery and because a limited number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A of the 2002

SAFE.

The catches used in this assessment (Table 3.1) include catches from minor state waters fisheries in the northern Gulf of Alaska and in the Aleutian Islands region because fish caught in these state waters are reported using the area code of the adjacent Federal waters in Alaska Regional Office catch reporting system (G. Tromble, 12 July 1999), the source of the catch data used in this assessment. Minor state fisheries catches averaged 180 mt from 1995-1998 (ADFG), about 1% of the average total catch. 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 (Table 3.4, Figures 3.2 and 3.3). We tried to estimate the amount of unreported catches by comparing reported catch to another measure of sablefish catch, sablefish imports to Japan, the primary buyer of sablefish. However the trends of reported catch and imports were similar, so we decided to change our approach for catch reporting in the 1999 assessment. We assumed that non-reporting is due to at-sea discards and apply discard estimates from 1994 to 1997 to inflate U.S. reported catches before 1994 (2.9% for hook-and-line and 26.6% for trawl).

One problem with the fishery data has been low length sample sizes for the trawl fishery (Table 3.3). From 1992 to 1998, few lengths were collected each year and the resultant length frequencies were inadequate and could not be used in the assessment model. The problem was that sablefish often are caught with other species like rockfish and deepwater flatfish, but are not the predominant species. The observer sampling protocol called for sampling the predominant species, so sablefish were poorly sampled. We communicated this problem to the observer program and together worked out revised sampling protocols. The revision greatly improved the sample size, so that the 1999 length data for the trawl fishery can be used for the assessment. The sample size was low from 2000- 2004 and length compositions for these years were not used for the assessment. The trawl fishery had a greatly improved sample size in 2005 of 2,306 lengths so the 2005 length data were used in the assessment.

Longline fishery catch rate analysis

Fishery information is available from longline and pot vessels which target sablefish in the IFQ fishery. Records of catch and effort for these vessels is collected by observers and by vessel captains in voluntary and required logbooks. Fishery data from the Observer Program is available since 1990. Vessels between 60 and 125 feet carry an observer 30% of the time and vessels over 125 feet are 100% observed. Logbooks are required for vessels over 60 feet beginning in 1999. Vessels under 60 feet are not required to carry observers or submit logbooks but many do participate in a voluntary logbook program formed in 1997. Logbook participation by vessels under 60 feet has increased greatly in recent years. In 2005, vessels under 60 feet accounted for 66% of all logbooks submitted. Both voluntary and required logbooks are used in catch rate analyses. For the logbook program, the International Pacific Halibut Commission (IPHC) is contracted to collect both voluntary and required logs through dockside sampling and to enter the data into an electronic format. Information from the log is edited by IPHC samplers and is considered confidential between the vessel and the IPHC. To ensure confidentiality, the IPHC masks the identity of the vessel when the data is provided to assessment scientists. A strong working relationship between the IPHC and fishermen has improved logbook participation by volunteer vessels in recent years.

Only sets targeting sablefish are included in catch rate analyses. For observer data, a sablefish targeted set is defined as a set where sablefish weight was greater than any other species (see 2005 SAFE, "Target Species Determination", page 254). The logbook targets are declared by the captain but the reported weights are usually approximate because the captain typically estimates the catch for each set while at sea 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 for both data sets 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). 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.

Extensive filtering of the logbook and observer data occurs before the catch information for a set is included in the analysis. The set was excluded, when data was missing for a set and a catch rate could not be calculated or assigned to a season, area, or a year. All sets that experienced killer whale depredation were excluded in the observer fishery catch rate analysis since any depredation would bias CPUE downward. From 1990-2005 an average of 24% of observed sets in the Bering Sea were affected by whale depredation. However, the total number of observed sablefish sets in the Bering Sea since 1997 ranges from only 10 to 37. Whale presence or depredation is not recorded in logbooks and therefore can not be corrected for in the catch rate analyses. For logbooks, some sets have multiple gear configurations with more than one hook spacing. Calculating a catch rate is difficult because the number of sablefish caught on each configuration is unknown. Because catch rates cannot be effectively calculated, logbook sets with multiple configurations were excluded. A small number of sets were eliminated from the logbook data because skipper estimated trip weight was very different than the IFQ reported trip weight. Error in the captain's estimate of trip weight was analyzed and we found that captains underestimated their true trip weight 63% of the time and this was most common on vessel's over 100 feet. However, errors by individual captains were variable between trips, indicating no bias in catch estimation was occurring.

Longline sample sizes: Observer coverage of longline vessels in the GOA was adequate in all years (Table 3.5). In the Aleutians, observer coverage was adequate for most years, however only 23 longline sets were observed in 2005. In the Bering Sea, fewer than 10 sets were observed since 2002 (Table 3.5). Logbook data also has fewer sets in these areas but the sample sizes are larger than the observer data. Low sample sizes in the Bering Sea and Aleutians are likely a result of increased pot fishing effort, poor observer coverage for sablefish directed trips, and difficulty in defining a target because of the Greenland turbot and Pacific cod fisheries. Additionally, 24% of sets in the Bering Sea that target sablefish are affected by killer whale depredation and are eliminated from the analysis. Logbook samples increased sharply in 2004 in all areas primarily because a new contractor was used to edit and enter logbooks electronically.

Longline catch rates: Catch rates and trends are similar for both the observer and logbook data. In all years catch rates are generally highest in the East Yakutat/Southeast and West Yakutat areas and are lowest in the Bering Sea and Aleutian Islands (Table 3.5, Figures 3.4, 3.5). Catch rates are most similar to each other in the Central Gulf and are likely due to the high sample sizes in this area in both data sets. In the Western Gulf, catch rates have increased since 2003 for both data sets. Catch rates have also increased recently in the Bering Sea but sample sizes are extremely low. In the Aleutians, observer catch rates have declined since 2002 whereas logbook catch rates have remained steady. However, error bars are large in this area for both data sets likely due to lower sample sizes. In East Yakutat/Southeast and West Yakutat catch rates are similar in the observer and logbook data in all years.

Fishery catch rates show similar trends to survey catch rates in most areas (Figure 3.4). Survey catch rates are generally higher than fishery catch rates in the Central Gulf and Western Gulf but lower in the other areas. In the Aleutians, survey rates are stable since 1996 whereas the observer trend is down and the logbook trend is up, although the fishery data sample sizes are low in the Aleutians. In the Bering Sea, all trends are slightly up since 2002. In the Western Gulf, survey catch rates went up in 2000 but fishery catch rates didn't increase until 2004. Survey catches were largely affected by the 1997 year class which would not have entered the fishery until after 2000. In the Central Gulf, all catch rates for recent years were increasing until 2005, when all three catch rates decreased. West Yakutat fishery and survey trends have been similar since 1998. East Yakutat/Southeast area trends were similar until 2002 when fishery catch rates increased while survey trends continued to decrease until 2004 and 2005.

Longline spatial and temporal patterns: Changes in spatial or temporal patterns of the fishery may cause fishery catch rates to be unrepresentative of abundance. For example, fishermen sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). Overfishing of northern (Newfoundland) cod likely was made worse by an incorrect interpretation of fishery catch rates: assessment scientists did not realize that the area occupied by the stock was diminishing while the fishery catch rates remained level (Rose and Kulka 1999). We examined fishery longline data for seasonal and annual differences in effort and catch rate. We also examined longline data for spatial changes in fishing patterns from year to year and by season using mapping software. Such changes may cause fishery catch rates to be unrepresentative of abundance. In the longline data, seasonal changes in effort were minimal across years. The majority of effort occurs in the spring and less in the summer and fall. Also, no significant seasonal changes in catch rates were detected. The majority of the longline effort is located along the continental slope and in deep cross-gullies. Likewise, areas of high catch rates occur throughout the fishing area and did not appear to change over time. Overall, no substantial changes in the fishery were detected over time or on a seasonal basis.

Pot fishery catch rate analysis

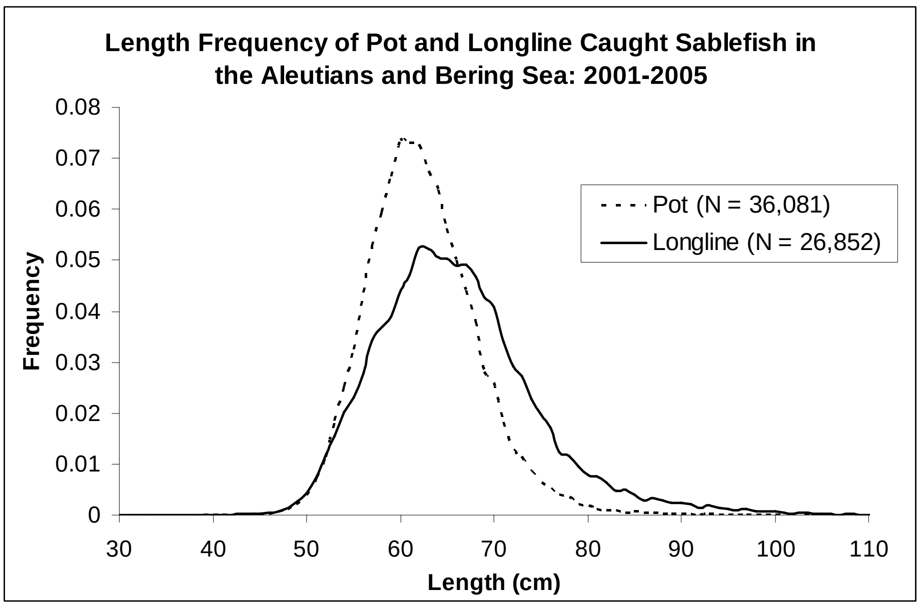
Sablefish pot fishing has increased dramatically in the Aleutian Islands and the Bering Sea since 1999. Since 2004, pot gear has accounted for over half of the Bering Sea fixed gear IFQ catch and 34% of the catch in the Aleutians. Fishery catch and effort data for pot gear is available from observer data from 1999-2005. However, due to confidentiality agreements, we can not present these numbers publicly because the data used in this analysis were from less than three vessels. Pot fishery data is also available from logbooks from 2004-2005; however, this data is still being analyzed and is not yet available.

Pot sample sizes: The number of observed sets and the number of pots fished has increased through time. Even though the number of sets has been increasing, the number of vessels observed in recent years is still sparse. Despite 374 sets in 2005 in the Aleutians, only three vessels were observed. Over all years, the average number of pots used per set was 63.

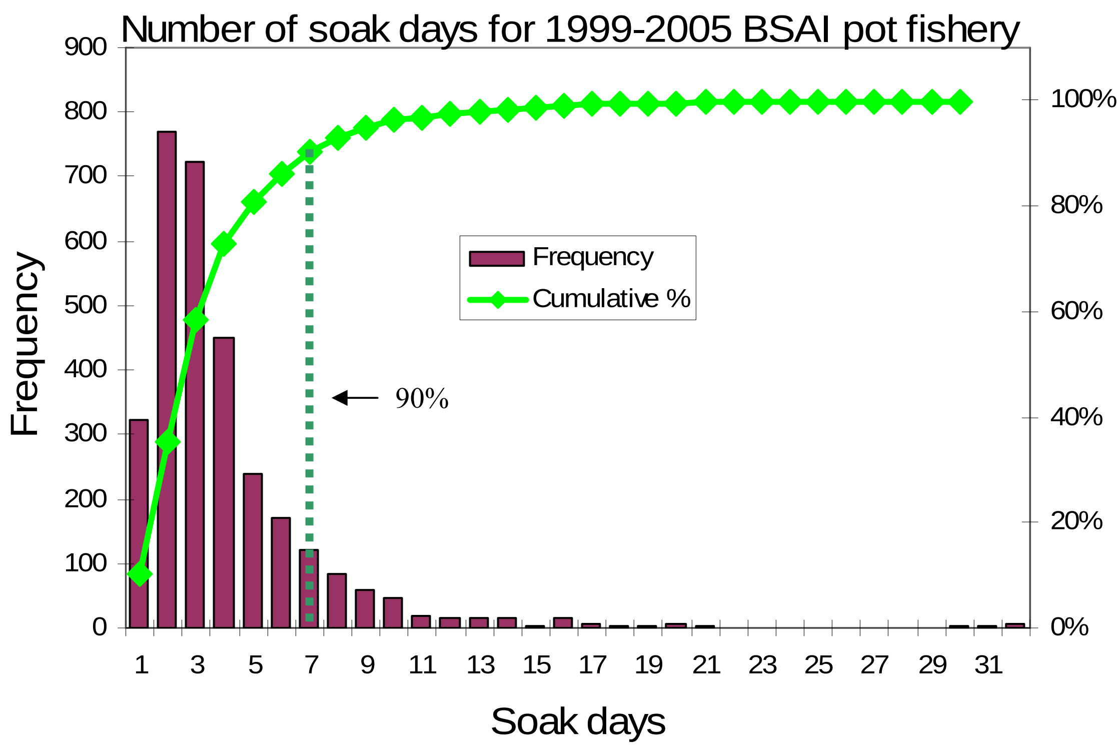
Pot catch rates: Catch rate for pots is calculated as the ratio of pounds per pot. There is more uncertainty for catch rates from 1999-2001 because there were few observed vessels during this period. In the Aleutians, catch rates ranged from 14-22 pounds per pot, except for 1999 where only 14 sets were observed. In the Bering Sea, catch rates ranged from 13-28 pounds per pot. Catch rates were similar between areas and are not significantly different from each other in any years. For both areas, no trend in catch rates is discernable. The composition of species caught in pots in the Bering Sea and the Aleutians was similar. Sablefish comprised most of the catch weight (Bering = 60%, Aleutians = 69%) and the next most abundant fish by weight was arrowtooth flounder (Bering = 13%, Aleutians = 10%). Other species of fish and invertebrates contributed no more than 6% each to the total catch weight.

Pot spatial and temporal patterns: Seasonal changes in effort were examined closely, but no distinct trends were found. The patterns in seasonal effort were erratic and were largely driven by individual vessel fishing patterns because observed data is limited. It should be noted that sample sizes for this analysis are low and only three to seven vessels were observed during each year. Data from 2002-2005 were mapped using GIS to determine if pot fishing grounds were similar to longline fishing grounds. Fishing grounds overlapped but pot fishing effort appeared to be more spatially concentrated than longline effort. In the Bering Sea pot fishing effort was concentrated near a popular fishing area north of Akutan Island. In the Aleutians preferable fishing grounds overlapped for both longline and pot gear. Pot gear was generally concentrated in three areas which also had high longline effort. In 2003 pot effort expanded to new fishing areas in both the Aleutians and the Bering Sea but by 2005 had concentrated back to preferred fishing grounds. Catch rates in the new areas were generally lower than catch rates from the preferred grounds. However, much of these observations may be influenced by the few number of boats observed and may not be representative of the entire pot fleet.

Pot length frequencies: We compared the length frequencies recorded by observers from the 2001-2005 longline and pot fisheries. The average length of sablefish in the Aleutian Islands and in the Bering Sea was smaller for pot caught sablefish (62.4 cm) than longline gear (66.0 cm), but the difference was minor. In all years the difference between the two gear types was greatest in the Aleutian Islands. Pot and longline gear is set at similar depths in the Aleutians and Bering Sea and sex ratio of the catch is 1:1 in both gears. We do not believe that the difference in lengths is significant enough to affect population recruitment and did not see any indication that undersized fish were being selected by pots. In 2006, a special project was initiated through the observer program to examine the stomachs of sablefish caught in pot gear to determine if larger fish are cannibalizing on smaller fish while in the pots. Data from this study are not available at this time but this study will provide information to help indicate if pot gear is selecting undersized fish.



Pot soak times: Some questions have been raised about storing pots at sea, escape rings and biodegradable panels. While we have not analyzed the consequences of these potential regulatory issues, we have examined the current soak times of the observed pot sets and plotted them below:



In an experiment examining escape mechanisms for Canadian sablefish, Scarsbrook et al. (1988) showed in their control traps that fish in the trap had only 5% mortality up to 10 days; in the current fishing environment, 90% of the pot sets were fished for 7 days or less.

Longline surveys

Catch, effort, age, length, weight, and maturity data are collected during sablefish longline surveys. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000). Japan and the United States conducted a cooperative longline survey for sablefish in the Gulf of Alaska annually from 1978 to 1994, adding the Aleutians Islands region in 1980 and the eastern Bering Sea in 1982 (Sasaki 1985, Sigler and Fujioka 1988). Since 1987, the Alaska Fisheries Science Center has conducted annual longline surveys of the upper continental slope, referred to as domestic longline surveys, designed to continue the time series of the Japan-U.S. cooperative survey (Sigler and Zenger 1989). The domestic longline survey began annual sampling of the Gulf of Alaska in 1987, biennial sampling of the Aleutian Islands in 1996, and biennial sampling of the eastern Bering Sea in 1997 (Rutecki et al. 1997). The domestic survey also samples major gullies of the Gulf of Alaska in addition to sampling the upper continental slope. The order in which areas are surveyed was changed in 1998 to reduce interactions between survey sampling and short, intense fisheries. Before 1998, the order was Aleutians and/or Bering Sea, Western Gulf, Central Gulf, Eastern Gulf. Starting in 1998, the Eastern area was surveyed before the Central area. Longline survey catches are tabled in appendix B.

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

Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to

1990, while the domestic survey increased (Table 3.4). Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

Interactions between marine mammals and fisheries include competition for prey (catch), marine mammal entanglement in fishing gear, and removal of some or all of the catch off fishing gear (depredation). We estimated the magnitude of sperm whale depredation on sablefish longline catches, a major fishery in the northeast Pacific Ocean.

Sperm whale depredation may affect longline catches in the Gulf of Alaska. Data on apparent sperm whale depredation has been recorded since the 1998 longline survey (Table 3.6). Sperm whales have been observed on 16% of survey sampling days, and were most common in the central and eastern Gulf of Alaska (98% of sightings). Catches were commonly preyed upon when sperm whales were present (65% of sightings). Apparent sperm whale depredation is defined as sperm whales are present and damaged sablefish are retrieved. In the 2002 SAFE, an analysis was done using longline survey data from 1998-2001 and found that sablefish catches were significantly less at stations affected by sperm depredation. This work was redone in 2006 using additional data from 2002-2004 and was analyzed by fitting the data to a general linear model (Sigler et al. in review). Neither sperm whale presence ($p = 0.71$) or depredation rate ($p = 0.78$) increased significantly from 1998 to 2004. Catch rates were about 2% less at locations where depredation occurred, but the effect was not significant ($p = 0.34$). A previous study using data collected by fisheries observers in Alaskan waters also found no significant effect (Hill et al. 1999). Another study using data collected in southeast Alaska, found a small, significant effect comparing longline fishery catches between sets with sperm whales present and absent (3% reduction, t-test, 95% CI of (0.4 – 5.5%), $p = 0.02$, Straley et al. 2005).

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^o W and 175^o 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. Portions of the gear affected by killer whale depredation during domestic longline surveys already are excluded from the analysis of the survey data.

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

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

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted approximately triennially since 1979 in the Bering Sea, 1980 in the Aleutians, and 1984 in the Gulf of Alaska, and biennially since 1999. Trawl surveys of the Eastern Bering Sea shelf are conducted annually. Trawl survey abundance indices were not previously used in the sablefish assessment because they were not considered good indicators of the sablefish relative abundance. However, there is a long time series of data available and given the trawl survey's ability to sample smaller fish, it may be a better indicator of recruitment than the longline survey. There is some difficulty with combining estimates from the Bering Sea and Aleutian Islands with the Gulf of Alaska estimates since they occur on alternating years. A method could be developed to combine these indices, but it leaves the problem of how to use the length data to predict recruitment since it would give mixed signals on year class strength. At this point we have experimented with using only the Gulf of Alaska trawl survey biomass estimates (<500 m) and length data (<500 m) as an index for the whole population (since the largest proportion of the population is located there).

Trawl survey catches are tabled in Appendix B.

Relative abundance trends – long-term

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 3.4, Figures 3.2 and 3.3). The post-1970 decrease likely is due to heavy fishing. The 1985 peak likely is due to the exceptional late 1970's year classes. Since 1988, relative abundance has decreased substantially. Regionally, abundance decreased faster in the Eastern Bering Sea, Aleutian Islands, and western Gulf of Alaska and more slowly in the central and eastern Gulf of Alaska (Figure 3.6). These regional abundance changes likely are due to size-dependent migration. Small sablefish typically migrate westward, while large sablefish typically migrate eastward (Heifetz and Fujioka 1991). The recruitment of the strong late 1970s year classes accounted for the sharp increase in overall abundance during the early 1980s. During the late 1980s as sablefish moved eastward, abundance fell quickly in the western areas, fell slowly in the Central area, and remained stable in the Eastern area. The size-dependent migration and pattern of regional abundance changes indicate that the western areas are the outer edges of sablefish distribution and less favored habitat than the apparent center of sablefish abundance, the central and eastern Gulf of Alaska.

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

In the East Yakutat/Southeast area, sablefish abundance decreased for many years until 2002, when the fishery but not the survey index increased (Figure 3.4). The survey index continued to generally decrease through 2003, but stabilized in the 2004 and 2005 surveys, and increased in 2006. This long-term decline in abundance for this area that is considered a part of the main spawning area (central and eastern Gulf of Alaska) will be monitored closely.

Relative abundance trends – short-term

The fishery abundance index decreased 4% from 2004 to 2005 (the 2006 data isn't available yet). The relative fishery abundance in 2005 is at the same level as 1999. The survey abundance index increased 8% from 2005 to 2006 and follows a 2% decrease from 2004 to 2005 (Table 3.4). This year's increase makes the relative abundance 16% higher than the all-time low in 2000 but 4% lower than the recent high in 2002.

3.2 Analytic approach

3.2.1 Model structure

The sablefish population is represented with an age-structured model. The analysis presented here extends earlier age structured models developed by Kimura (1990) and Sigler (1999). New model runs presented in this document follow a more complex version of the Gulf of Alaska Pacific ocean perch model with split sexes to attempt to more realistically represent the underlying population dynamics of sablefish (Hanselman et al. 2005). The population dynamics and likelihood equations are described in Box 1. The analysis was completed using AD model builder software, a C++ based software for development and fitting of general nonlinear statistical models (Otter Research 2000).

Parameters estimated independently

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 a length of about 45 cm fork length. 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, and catching small sablefish is hindered by the large bait and hooks on longline gear.

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. Sablefish had been previously estimated to reach average maximum lengths and weights of 69 cm and 3.4 kg for males and 83 cm and 6.2 kg for females.

For the 2006 assessment we estimated new growth relationships because much more age data were available. We divide the data into two time periods based on a change in sampling design that occurred in 1995. Age-1 fish were used in the analysis from known-age tag releases to estimate early tag releases. It appears that sablefish maximum length and weight has decreased slightly over time. The resulting growth curves are shown in Figure 3.8b. Weight-at-age and weight-at-length curves were estimated for the whole time period. The resultant growth parameters are:

	Length-at-age LVB			Weight-at-length		Weight-at-age LVB		
	L_∞	κ	t_0	α	β	W_∞	κ	t_0
Males 1981-1995	69.1	0.230	-2.35	0.000013	2.96	3.16	0.356	-1.13
Males 1996-2004	67.3	0.379	-0.716	0.000013	2.96	3.16	0.356	-1.13
Females 1981-1995	83.0	0.160	-2.89	0.000010	3.01	5.46	0.238	-1.38
Females 1996-2004	79.3	0.265	-0.959	0.000010	3.01	5.46	0.238	-1.38

Data previously used in the model to populate the age-length transition matrices were observed lengths at ages (Figure 3.9). It was thought that using a growth curve with normal error around each length-at-age would better describe the underlying population dynamics. However, many trials with different growth models and error structures revealed that the model generally fit worse using growth models. The older growth data naturally fits the data better because it is confounded with the way the abundance indices are created. For this assessment, we show model runs with updated age-length matrices based on the full data set of lengths-at age, but not fit to a curve (Figure 3.9). Updated LVB fits to weight-at-age by sex were used in some model runs, as opposed to average weight-at-age in the 2005 assessment. For the recommended model in this assessment, we continue to use the older information as the growth appeared more complicated than expected. Therefore, the growth analyses in this assessment are preliminary, and AFSC is supporting a University of Alaska graduate student to conduct a comprehensive analysis of sablefish growth and maturity over time. We look forward to utilizing results from the comprehensive growth analysis currently being conducted.

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).

Fifty percent of females mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.5 years for females and 5 years for males (Table 3.8). Maturity parameters were estimated independently of the assessment model and then incorporated into the assessment model as fixed values. The maturity (M) - length function is $m_l = 1 / (1 + e^{-0.40 (L - 57)})$ for males and $m_l = 1 / (1 + e^{-0.40 (L - 65)})$ 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). In the previous assessment, average male and female maturity was used to compute spawning biomass. For the new models in this assessment, it was necessary to use female-only maturity to compute spawning biomass. Female maturity-at-age from Sasaki (1985) is described by the logistic fit of $m_a = 1/(1+e^{-0.84(a-6.60)})$. We also did a preliminary analysis on visual scan maturity data from the domestic longline survey from 1998-2003. The maturity curve from Sasaki (1985) for females is similar to the new preliminary data, but both are significantly to the right of the average maturity curve used in previous assessments (Figure 3.8a). Research on updated maturity-at-age from recently collected visual scans and histological collections are under way and will hopefully be incorporated soon.

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.

Natural mortality has been modeled in a variety of ways in previous assessments. For sablefish assessments before 1999, natural mortality was assumed to equal 0.10. For assessments from 1999 to 2003, natural mortality was estimated rather than assumed to equal 0.10; the estimated value was about 0.10. For the 2004 assessment, a more detailed analysis of the posterior probability showed that natural mortality was not well-estimated by the available data. The posterior distribution of natural mortality was very wide, ranging to near-zero. The acceptance rate during MCMC runs was low, 0.10-1.15. Parameter estimates even for MCMC chains thinned to every 1000th value showed some serial correlation. For the 2005 assessment we assumed that we knew the approximate value of natural mortality very precisely (c.v. = 0.001 for prior probability distribution) and that the approximate value was 0.10. At this level of prior precision, it was essentially a fixed parameter. Using such a precise prior on a relatively unknown parameter to fix it is of no use except to acknowledge that we do not know the parameter value exactly. However, it creates confusion and is an improper use of Bayesian priors, so for 2006 we return to fixing the parameter at 0.10.

Parameters estimated conditionally

The age range for the model is 2 to 31, where 31 is a pooled group including all ages 31 and greater. Abundances for years 1960 to 2006 are estimated.

Selectivity is represented using a function and is separately estimated for longline survey, longline fishery, trawl fishery and the trawl survey. Selectivity for the longline surveys and longline fishery is restricted to be asymptotic by using the logistic function. Selectivity for the trawl fishery and trawl survey are allowed to be dome-shaped by using the exponential-logistic function (Thompson 1994). Selectivity for the longline fishery is estimated separately depending on 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 or depths that produce the most abundant catches.

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, U.S. longline fishery and the NMFS GOA trawl survey. 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 that indicated that the fishery and survey data differ in their hook spacing, but otherwise are similar. In the 2005 assessment, we used the hook spacing data to create prior distributions which linked the catchability estimates for the surveys and fisheries. For new model runs in this assessment we set the starting values equal to the 2005 assessment catchability values, but allow the parameters to move freely. We set an imprecise prior mean of catchability for the trawl survey at 0.3 to reflect the limited depth range and the use of Gulf of Alaska data only.

Bayesian analysis

Since the 1999 assessment, we developed a limited Bayesian analysis that considered uncertainty in the value of natural mortality as well as survey catchability. In this assessment, we developed a full Bayesian analysis that additionally considers uncertainty in the remaining model parameters, as well as natural mortality and survey catchability. The multidimensional posterior distribution is mapped by Bayesian integration methods. The posterior distribution was computed based on 5 million Monte-Carlo Markov chain simulations drawn from the posterior distribution and thinned to 4,000 parameter "draws" to remove serial correlation between successive "draws" and a burn-in of 1 million draws was removed from the beginning of the chain.

Decision analysis

We estimated the posterior probability that projected abundance will fall below thresholds of 17.5% (MSST), and 35% (MSY) of the unfished spawning biomass based on the posterior probability estimates. Abundance was projected for 14 years. In the projections, future recruitments varied over the estimated range for the 1977-2003 year classes.

In previous assessments, the decision analysis thresholds were based on Mace and Sissenwine (1993). However, in the North Pacific Fishery Management Council setting we have thresholds that are more meaningful to management. These are when the spawning biomass falls below MSY or $B_{35\%}$ (overfishing) and when the spawning biomass falls below ½ MSY or $B_{17.5\%}$ which calls for a rebuilding plan under the Magnuson-Stevens Act. For the previous analysis based on Mace and Sissenwine (1993), see Hanselman et al. 2005b.

In previous assessments, two recruitment time series have been used to project abundance, the 1977 and onward year classes and the 1982 and onward year classes. We excluded the 1977-1981 year classes from the second time series because these strong year classes were much stronger than successive year classes until the strong 1997 year class appeared. The average year class strength (number at age 2) is 44 million for the 1977-1981 year classes and 13 million for the 1982-1996 year classes. However the short-term difference in abundance projections between the two recruitment scenarios that was compared in previous assessments (1977 and onward vs. 1982 and onward) was small. **Thus in this year's assessment, we continue to project abundance only with the 1977 and onward year classes.**

Box 1	Model Description
Y	Year, $y=1, 2,\ldots T$
T	Terminal year of the model
A	Model age class, $a = a_0, a_0+1, \ldots, a_+$
a_0	Age at recruitment to the model
a_+	Plus-group age class (oldest age considered plus all older ages)
L	Length class
Ω	Number of length bins (for length composition data)
G	Gear-type (g = longline surveys, longline fisheries, or trawl fisheries)
X	Index for likelihood component
$w_{a,s}$	Average weight at age a and sex s
φ_a	Mature female population proportion at age
μ_r	Average log-recruitment
μ_f	Average log-fishing mortality
$\phi_{y,g}$	Annual fishing mortality deviation
τ_y	Annual recruitment deviation ~ (0, σ_r)
σ_r	Recruitment standard deviation
$N_{y,a,s}$	Numbers of fish at age a in year y of sex s
M	Natural mortality
$F_{y,a,g}$	Fishing mortality for year y and age class a and gear g ($=s_a^g \mu_f e^{\phi_y}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=\Sigma F_{y,a,g}+M$)
R_y	Recruitment in year y
B_y	Spawning biomass in year y
$s_{a,s}^g$	Selectivities at age a for gear type g and sex s
$A_{50\%}, d_{50\%}$	Age at 50% selection and age at 50% “deselection” for descending limb
δ, φ	Slope and shape parameters for different logistic curves
$\mathbf{A}$	Ageing-error matrix dimensioned $a_+ \times a_+$
$\mathbf{A}^l$	Age to length transition matrix dimensioned $a_+ \times \Omega$
q_g	Abundance index catchability coefficient by gear
λ_x	Statistical weight (penalty) for component x
$I_y, \hat{I}_y$	Observed and predicted survey index in year y
$P_{y,l,s}^g, \hat{P}_{y,l,s}^g$	Observed and predicted proportion at length l for gear g in year y of sex s
$P_{y,a,s}^g, \hat{P}_{y,a,s}^g$	Observed and predicted proportion at observed age a for gear g in year y of sex s
ψ_y^g	Sample size assumed for gear g in year y (for multinomial likelihood)
n_g	Number of years that age (or length) composition is available for gear g
$q_{\mu,g}, \sigma_{q,g}$	Prior mean catchability coefficient for gear g
M_μ, σ_M	Prior mean, standard deviation for natural mortality
$\sigma_{r_\mu}, \sigma_{\sigma_r}$	Prior mean, standard deviation for recruitment variability

Equations describing state dynamics	**Model Description** (continued)
$N_{1,a}=\begin{cases} R_1, & a=a_0 \\ e^{\left(\mu_r+\tau_{a_0-a+1}\right)}e^{-(a-a_0)M}, & a_0<a<a_+ \\ e^{(\mu_r)}e^{-(a-a_0)M}\left(1-e^{-M}\right)^{-1}, & a=a_+ \end{cases}$	Initial year recruitment and numbers at ages.
$N_{y,a}=\begin{cases} R_y, & a=a_0 \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}}, & a_0<a<a_+ \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}}+N_{y-1,a}e^{-Z_{y-1,a}}, & a=a_+ \end{cases}$	Subsequent years recruitment and numbers at ages
$R_y=e^{\left(\mu_r+\tau_y\right)}$	Recruitment
Selectivity equations	
$s_{a,s}^g=\left(1+e^{\left(-\delta_{g,s}\left(a-a_{50\%,g,s}\right)\right)}\right)^{-1}$	Logistic selectivity
$s_{a,s}^g=\left(1+e^{\left(-\delta^1_{g,s}\left(a-a_{50\%,g,s}\right)\right)}\right)^{-1}\left(1-\left(1+e^{\left(-\delta^2_{g,s}\left(a-d_{50\%,g,s}\right)\right)}\right)^{-1}\right)$	Double logistic selectivity
$s_{a,s}^g=\left(1-\varphi_s^g\right)^{-1}\left(\frac{\left(1-\varphi_s^g\right)}{\varphi_s^g}\right)^{\varphi_s^g}\frac{\left(e^{\left(\delta_{g,s}\varphi_s^g\left(a_{50\%,g,s}-a\right)\right)}\right)}{\left(1+e^{\left(\delta_{g,s}\left(a_{50\%,g,s}-a\right)\right)}\right)}$	Exponential-logistic selectivity
Observation equations	
$\hat{C}_{y,g}=\sum_1^g\sum_1^s w_{a,s}N_{y,a,g,s}F_{y,a,g,s}\left(1-e^{-Z_{y,a,g,s}}\right)Z_{y,a,g,s}^{-1}$	Catch biomass in year *y*
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\frac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}w_{a,s}$	Survey biomass index (RPW)
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\frac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}$	Survey biomass index (RPN)
$\hat{P}_{y,\cdot,s}^g=N_{y,a,s}s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s$	Vector of fishery or survey predicted proportions at age
$\hat{P}_{y,\cdot,s}^g=N_{y,\cdot,s}s_s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s^l$	Vector of fishery or survey predicted proportions at length

Posterior distribution components	**Model Description** (continued)
$L_C=\lambda_c\sum_1^g\sum_y\left(\ln C_{g,y}-\ln\hat{C}_{g,y}\right)^2/\left(2\sigma_C^2\right)$	Catch likelihood
$L_I=\lambda_I\sum_1^g\sum_y\left(\ln I_{g,y}-\ln\hat{I}_{g,y}\right)^2/\left(2\sigma_I^2\right)$	Survey biomass index likelihood
$L_{age}=\lambda_{age}\sum_{i=1}^{n_g}-\psi_y^g\sum_{a_0}^{a_+}\left(P_{i,a}^g+\nu\right)\ln\left(\hat{P}_{i,a}^g+\nu\right)$	Age composition likelihood
	Length composition likelihood

$L_{length} = \lambda_{length} \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l}^g + v\right) \ln\left(\hat{P}_{i,l}^g + v\right)$	(ψ_y^g =sample size, n_g = number of years of data for gear *g*, *i* = year of data availability, *v* is a constant set at 0.001)
$L_q = \left(\ln \hat{q}^g - \ln q_\mu^g\right)^2 / 2\sigma_q^2$	Prior on survey catchability coefficient for gear *g*
$L_M = \left(\ln \hat{M} - \ln M_\mu\right)^2 / 2\sigma_M^2$	Prior for natural mortality
$L_{\sigma_r} = \left(\ln \hat{\sigma}_r - \ln \sigma_{r_\mu}\right)^2 / 2\sigma_{\sigma_r}^2$	Prior distribution for σ_r
$L_\tau = 0.1 \sum_{y=1}^{T} \frac{\tau_y^2}{2\hat{\sigma}_r^2} + n \ln \hat{\sigma}_r$	Prior on recruitment deviations
$L_f = \lambda_f \sum_{1}^{g} \sum_{y=1}^{T} \phi_{y,g}^2$	Regularity penalty on fishing mortality
$L_{Total} = \sum_x L_x$	Total objective function value

3.3 Model evaluation

For this assessment we present a suite of alternate models and recommend a new split-sex model for determining ABC for 2007 and 2008 (Model 3). To compare new models with the base model from last year's assessment (Model 1) we continue with identical assumed variances on data sets and only compare the fit to the common data components when we add more data (trawl survey data). Many model runs were attempted, and better fitting models were found by adding various data and features to the model, but for this year we only choose to move forward with a new model that is split-sex and incorporates trawl survey estimates. The basic features of the model runs presented in the document are described in the following table:

Model Number	Model Description
1 (Base case)	Model from Hanselman et al. 2005, the base single-sex model, no trawl survey data
Model 2	Split-sex model, flexible selectivity options, female-only maturity, split male and female weight-at-age
Model 3	Model 2 plus GOA trawl survey biomass estimates from 1984-2005 and trawl survey length compositions from 1984-2005
Model 4	Model 3 plus length-age matrices using all data from 1981-2005, new LVB fit weight-at-ages by sex
Model 5	Model 4 plus sex-ratio from longline surveys
Model 6	Model 5 plus all selectivities free to go dome-shaped

For conciseness in the primary document we only compare Model 1 with Model 3 in the figures.

Each model after Model 3 fit the common data components better as additional data and features were added (Box 2) as judged by the smaller data component to the objective function (the objective function is the negative log-likelihood, thus lower is more likely, given the data). We present these runs to show that there is room for improvement in the model, but believe that further evaluation is required before taking them forward. We also decided that until a comprehensive growth analysis has been conducted, we will stay with the status quo growth data in the model. One exception is that to move to a split-sex model projecting female only biomass, it was necessary to split the weight-at-age and maturity-at-age by sex. This is the same data as before, but not averaged across sexes (Table 3.8). A brief evaluation of the additional models that we explored follows:

Box 2: Model comparison of six sablefish models by contribution to the objective function (negative log-likelihood values) and key parameters.

Model Likelihood Components (Data)	CV/Sample Size (ψ)	Base model, from 2005 assess Model 1	Split-sex, female only maturity Model 2	Add trawl survey bio and lengths Model 3	Updated wt-at-age and l-at-age Model 4	Proportion of males in LL surveys Model 5	Allow dome-shape in all select. Model 6
Catch	CV = 3%	4	3	3	3	3	3
Domestic LL survey RPW	CV = 5%	34	36	36	32	33	36
Domestic LL survey RPN	CV = 5%	17	28	30	23	19	22
Japanese LL survey RPW	CV = 5%	56	23	22	19	19	18
Japanese LL survey RPN	CV = 5%	44	23	22	20	19	15
Domestic LL fishery RPW	CV = 5%	12	13	14	14	14	11
Japanese LL fishery RPW	CV = 5%	56	39	38	26	26	25
NMFS GOA trawl survey	CV = 8-15%	0	0	38	35	35	38
Domestic LL survey ages	ψ = 250	416	425	431	434	438	389
Domestic LL fishery ages	ψ = 50	38	39	38	38	38	38
Domestic LL survey lengths	ψ = 49	86	86	88	99	91	90
Japanese LL survey lengths	ψ = 49	96	78	80	108	108	92
NMFS trawl survey lengths	ψ = 35-65	0	0	207	78	79	94
Domestic LL fishery lengths	ψ = 49	86	81	82	55	55	59
Domestic trawl fishery lengths	ψ = 10	19	20	20	15	16	14
Sum of common *L*		963	894	902	886	878	811
Total objective function value		972	909	1161	1014	1008	958
Key parameters							
B_{2006} *(Female spawning biomass)*		103	117	116	104	105	86
$B_{40\%}$ *(Female spawning biomass)*		101	124	124	110	112	111
B_{1960} *(Female spawning biomass)*		135	160	158	147	146	61
$B_{0\%}$ *(Female spawning biomass)*		253	311	310	276	280	277
SPR% current		41%	38%	38%	38%	37%	31%
$F_{40\%}$		0.11	0.09	0.09	0.10	0.10	0.11
ABC *adjusted Tier 3b*		22.8	20.3	20.1	17.6	17.5	14.5
$q_{Domestic\ LL\ survey}$		8.1	7.1	7.1	8.1	8.0	7.9
$q_{Japanese\ LL\ survey}$		6.0	5.6	5.7	6.5	6.5	4.0
$a_{50\%\ (domestic\ LL\ survey)}$		3.8	3.8	3.9	4.0	3.8	3.9
$a_{50\%\ (IFQ\ fishery)}$		4.4	4.4	4.7	4.5	4.4	4.4
μ_r *(average recruitment)*		20.78	22.5	22.0	19.4	19.4	19.9

Model 1: This is the general modeling framework that has been used with some modifications since Sigler (1999). It is a combined-sex model, but fits both male and female lengths by combining them into an overall numbers-at-age matrix. It uses average weight-at-age for males and females, and average maturity for males and females. Recruitment is fit in a CAGEAN style with no constraints on the magnitude of recruitment deviations.

Model 2: Sablefish have quite different life-history parameters between sexes in terms of growth and maturity. In such cases, it is common to model the sexes separately in a stock assessment to attempt to better represent the dynamics of each sex. During internal review and comments by the SSC, it was suggested that we attempt to use a split-sex model for sablefish. Model 2 moves the base model into a split-sex framework. In this model we use separate maturity-at-age and weight-at-age for males and females. Selectivity is estimated by sex. Since there are substantial growth differences between males and females, there is likely a selectivity difference. Recruitment is expected to be equal for the two sexes at the age of recruitment, but then their subsequent numbers at age will differ as different fishing mortality and selectivity are applied to each sex. Recruitment variability was constrained by the likelihood equation in Box 1, and was profiled across values from 0.1-2 and found to be optimum at 1.2. Model 2 fits the data components significantly better than Model 1 (Box 2). The resultant female spawning biomass is higher than Model 1. This is because female maximum weight estimates are higher now that the sexes are estimated separately. ABC is lower than Model 1; this is primarily because of two factors: (1) Using female maturity only (they mature at a later age than males) causes $F_{40\%}$ to be lower, and (2) the model estimates female spawning biomass to be slightly further below estimated $B_{40\%}$ than Model 1, so the applied Tier 3b adjustment to $F_{40\%}$ is further downward.

Model 3: Model 3 is identical to Model 2, except that we added trawl survey biomass and length compositions from the Gulf of Alaska. The biomass estimates are used as an index and only biomass and lengths from strata with depths of 500 m or less were used. The impetus for adding trawl survey data was because the trawl survey should be a better estimate of recruitment, because it tends to catch smaller fish than the longline survey. Only depths less than 500 m were included to standardize the survey across years where different depths where sampled. The sampling variance was used for the biomass estimates, but was up-weighted by four so that the trawl survey index was not completely masked by the other six indices with coefficients of variation of 5%. We set an imprecise prior for catchability with a mean of 0.3 to reflect that the index was not sampling the whole population, either by depth or region. The observed and predicted trawl survey biomass estimates for Model 3 are shown in Figure 3.10. In general, the model fits the estimates well with exception of the low and precise biomass estimate in 1999. Overall the model fit all data components quite similarly to Model 2. Fits to the trawl survey length compositions were not as good as later models when we used new growth information. However, the length data does show the presence of some of the year-classes currently thought to be important. Figure 3.11 shows an abundance of probable 2-year olds in the 1999 survey, while the 2003 survey shows a bimodal distribution indicating likely presence of the 1997 year class and the 2000-01 year classes. Model 1 and Model 3 fit the longline survey and fishery age composition data quite similarly (Figure 3.12). The 2005 age composition from the longline survey shows a high proportion of the 2000 year class (Figure 3.12a). Progressing from Model 1 through Model 3, we see different patterns of recruitment in the years prior to 1977, and an increased precision in many of the more uncertain recruitments in Model 1.

Model 4: Model 4 is model 3, with new lognormal LVB fit weight-at-age relationships for each sex, and updated observed length-at-age transition matrices using data from 1981-2004, as opposed to 1981-1993. Using the updated growth information had several key effects. First, it lowered estimated female spawning biomass, this reflects a lower maximum length and weight of females in updated growth data. Second, the fit to the trawl survey length compositions was much better, while the fit to the older Japanese longline survey length data worsened (which was where the previous growth data was derived from). Finally it increased $F_{40\%}$ upward slightly as a result of new growth data moving the selectivity curve away from the maturity curve, because of fish being smaller at age. Because of the large drop in female spawning biomass the ABC is less than Models 1-3.

Model 5: Model 5 is Model 4 with the addition of a time series of sex-ratio for the longline surveys. This ratio was used to adjust the prediction of RPWs and RPNs over time to reflect a modestly changing proportion of males in the survey catch. This change resulted in a slightly better fit to the domestic longline RPN and the domestlic longline length compositions. The female spawning biomass and projected adjusted ABC were lower.

Model 6: Model 6 is model 5 allowing all selectivity curves to move freely, including becoming dome-shaped. One reason for attempting such a model were some strong residual patterns in the length data that could not be resolved by changing the growth data alone (Figure 3.13). This model had a significantly better fit to the data than any of the other models, but was rejected because some of the selectivity curves were biologically implausible. However, the improvement in fit shows that some of our current asymptotic selectivity curves may not appropriately describe the survey or fishery, and future research will focus on resolving selectivities and residual patterns.

Summary: We recommend Model 3 for setting ABC for 2007. It provides a significantly better fit to the data than the base model. Since our biological reference points are formulated by considering number of female spawners per recruit, this split-sex model gives a more appropriate spawning biomass estimate to apply these benchmarks. In the majority of fisheries, preserving female spawning biomass is essential, not only because males can inseminate multiple females, but because in most instances females become mature later than males. Therefore, females are the limiting factor in reproduction and should be the benchmark of future population sustainability. Splitting the sexes is appropriate given the differences in growth between males and females. Finally, between splitting the sexes and adding the trawl survey index and lengths, we have more certainty in our recruitment predictions. However, Model 3 is not an endpoint but a stepping stone to future models that will incorporate a comprehensive growth analysis, more rigorous use of appropriate error assumptions in data components, and choosing more biologically based selectivities.

We realize we are recommending a model for 2007 that lowers the ABC when survey abundance indices were up in the previous year. We recognize this disconnect, but have several overreaching concerns on raising the recommended ABC as would have been possible under the former modeling framework. First, the data indeed showed an increase this year for the longline survey; however last year's survey RPW were near all-time lows. The projection from last year's model showed substantial drops in ABC for 2007 because of the trends in recruitment and survey abundance indices. The recommended ABC from Model 3 is substantially higher than those forecasts, but lower than that which would be recommended by the previous model. The reasoning behind this decrease from the former model is not a superficial change in modeling approach, but an important step in preserving a sustainable spawning biomass. We would expect that on average, spawning stock biomass would fluctuate around our target threshold of $B_{40\%}$, but recent assessment's estimates of abundance have been unable to exceed the target threshold and has been relying on individual year classes to maintain the current level of fishing mortality. Our main cause for a more precautionary ABC is using female maturity to estimate spawning biomass. If we imprudently marched on with an average maturity based on males and females, Model 3 predicts an increase in ABC of 10%. However, in a split sex framework this is not biologically reasonable. Preliminary results from recent visual scan maturity data show a similar maturity curve to the curve used in this assessment (Figure 3.8a).

A second reason for precaution is that the second piece of data on the horizon appears to be a potential change in growth (Figures 3.8b). If we are indeed using size-at-age data from a time period where the fish were larger to predict current harvest scenarios, then there are several, possibly compounding, consequences:

1) If fish are not as large at length and/or age, this will have a direct downward scalar effect on the current estimated spawning biomass, thus lowering ABC.

2) If fish are shorter at age than the assumed length-age transition matrix, this will artificially increase estimates of recruitment, while yielding a poor fit to both length and age data. For example, if in the old length-age transition matrix, a 75 cm female sablefish is 15 years old, and an 80 cm female sablefish is 30 years old (e.g. Figure 3.9), the model will attempt to distribute recruitments so the appropriate amount of fish are in the age groups dictated by their abundance in each observed length group. But if fish are similarly sized in ages 15-30 at 75 cm, the model using the older data will predict that there are many more fish in the younger age groups and few in the older age groups, as there are not many fish that reach 80 cm in the data. These predictions will result in higher estimated recruitment to attempt to explain this high level of estimated middle-aged fish. The model will then fit better with a dome-shaped selectivity pattern because the observed length compositions suggest that there are less older-age fish than expected. Therefore, when the recent years are fit with a length-age transition matrix that does not coincide with the current growth parameters and asymptotic selectivity, it will create residual patterns (see Figure 3.13) and inflate past recruitment estimates. If these data are changed to more accurately reflect the underlying growth patterns, then it appears this will lower spawning biomass and the accompanying recommended harvest rate (see Model 5).

Our analysis of current growth data is highly preliminary, but so far it looks like changes to our growth assumptions may have a negative impact to spawning biomass estimates. We believe that there is much that can be done to attempt to more thoroughly analyze the growth data, particularly to isolate when things may have changed and if there is a mechanism that might be identified. One possibility that can not be overlooked is that growth is slowing from density dependent processes because the population is actually increasing, such as the case of changes in Pacific halibut assessments. In such a case, we would have to determine why the surveys are not observing a marked increase. Environmental changes could be moving denser aggregations of sablefish away from the fixed station survey. Giant grenadiers may be interfering with sablefish catches in deeper depths on the survey. If the depth distribution of sablefish has compressed into a smaller depth interval, there might be hook saturation in the depths stratum with the highest sablefish density. Another possibility is that other species with large biomasses in the Gulf of Alaska are out-competing sablefish for prey, such as the arrowtooth flounder (see section 3.6.1). We raise these possibilities to point out that the current data we are investigating may have a negative impact on the current estimates of the sablefish spawning stock biomass, but there are many ways in which other information may come to light to suggest otherwise. In light of current information we support a stable, slightly lower ABC while these questions are more thoroughly studied.

3.4 Model results

A comparison of the results and trends of the base model (Model 1) and the recommended model (Model 3) follows:

Abundance trends

Models 1 and 3 both fit abundance trends similarly and well (Figure 3.2). The primary difference between the two was a superior fit by Model 3 to the Japanese fishery RPW that follows the peaks in 1968 and 1971 much more closely. The domestic fishery RPW fits are so close you can barely discern there are two lines. Model 3 fits the Japanese longline RPNs slightly better (Figure 3.3).

Sablefish abundance increased during the mid-1960's (Table 3.9, Figure 3.14a) due to strong year classes the early 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 53,080 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 dissipated. Model 3 predicts that spawning biomass did not decrease as much as the previous models predicted in the 1990s, but was not at as high a peak in 1988. Both Model 1 and Model 3 show an increasing trend since the all-time low in 2000.

Spawning biomass is projected to increase slightly from 2006 to 2007. Spawning biomass in 2006 is 116,000 mt and is projected to be 118,000 mt in 2007 (Table 3.10). **Sablefish abundance in 2006 spawning biomass is 38% of unfished biomass.** Abundance has increased from a low of 33% of unfished biomass during 1998 to 2000 due to the strong 1997 year class and a similar sized 2000 year class. These two year classes are an important part of the total biomass and are projected to account for 26% of 2007 spawning biomass.

Recruitment trends

Recruitment estimates are fairly consistent from 1977-present (Figure 3.14b) between last year's results, Model 1 and Model 3. Annual estimated recruitment varies widely (Figure 3.15). Revisions from Model 1 through Model 3 show improved certainty about year class strength as judged by the 95% MCMC credible intervals. Model 3 shows moderately more certainty in some year classes with addition of the trawl survey lengths (e.g. 2005) from Model 2. Year classes were classified as "weak" if <80% of average and "strong" if >120% of average and compared between Model 1 and Model 3. Since the distribution of recruitment is skewed, a new criterion for what recruitments are strong and weak will be evaluated next year that is based on quantiles or the median instead of the mean.

Model 1

Strong	1961	1965	1968	1977	1978	1980	1981	1984	1997	2000
Average	1988	1990	1991	1995	2003					
Weak	1960	1962	1963	1964	1966	1967	1969	1970	1971	1972
	1973	1974	1975	1976	1979	1982	1983	1985	1986	1987
	1989	1992	1993	1994	1996	1998	1999	2001	2002	

Model 3

Strong	1959	1960	1961	1963	1964	1967	1968	1977	1978	1980
	1981	1983	1997	2000						
Average	1966	1974	1979	1988	1990	1998				
Weak	1962	1965	1969	1970	1971	1972	1973	1975	1976	1982
	1983	1985	1986	1987	1989	1991	1992	1993	1994	1995
	1996	1999	2001	2002	2003					

The general recruitment patterns are similar between Models 1 and 3. The extremely large recruitment predicted by Model 1 in 1961 has been distributed around several above-average year classes between 1959 and 1964 in Model 3. Two recent strong year classes are the 1997 and 2000 year classes and are pervasive between all model runs. The 2003 year class appeared to be an average year class in Model 1, but that recruitment appears weak in Model 3. Several more years of data are needed to assess the strength of such a recent year class. Although the 2001 year class is still showing up as weak in the assessment model, the regional age compositions for the 2005 survey show a large amount of age 4 fish in the Bering Sea (Figure 3.7). This year class may become more prominent in the coming years as they move to the Gulf of Alaska.

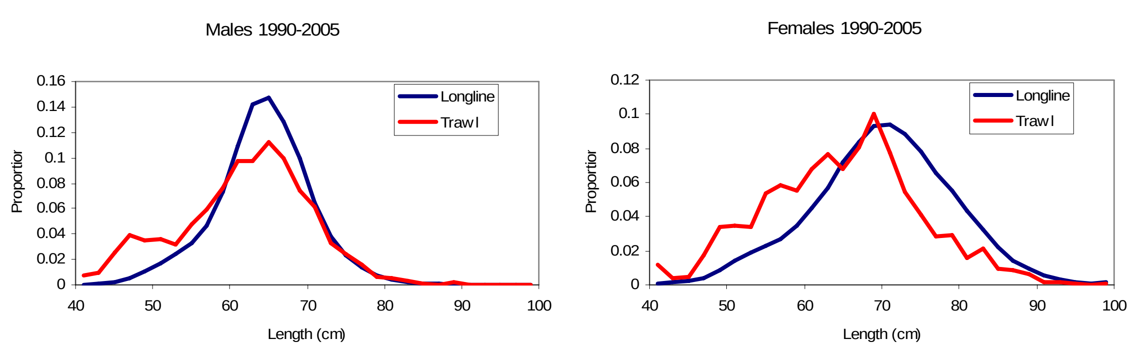
Average recruitment for the 1977-2003 year classes is 22.0 million 2-year old sablefish per year which is at the same level as the average recruitment for the 1957-2003 year classes. Estimates of recruitment strength during the 1960's are uncertain because they depend on less data and because the abundance index is the fishery catch rate, which may be a biased measure of abundance.

Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1 juveniles likely indicate a strong year class. Abundant age-1 juveniles were reported for the 1960 (J. Fujioka & H. Zenger, NMFS, approximate year), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, ADFG), and the 1998 year class near Kodiak Island (D. Jackson, ADFG, personal communication).

Sablefish recruitment varies greatly from year to year (Figure 3.15), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success also is related to recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1961, 1977, and 1984 year classes also were strong. Some of the largest year classes of sablefish occurred when abundance was near the historic low, the 1977-1978 and 1980-1981 year classes. These strong year classes followed the 1976/1977 North Pacific regime shift. The 1977 year class was associated with the Pacific Decadal Oscillation (PDO) phase change and the 1977 and 1981 year classes were associated with warm water and unusually strong northeast Pacific pressure index (NEPI, Hollowed and Wooster 1992). Some species such as walleye pollock and sablefish may exhibit increased production at the beginning of a new environmental regime, when bottom up forcing prevails and high turnover species compete for dominance, which later shifts to top down forcing once dominance is established (Bailey 2000; Hunt et al. 2002). The large year classes of sablefish indicate that the population, though low, still was able to take advantage of favorable environmental conditions and produce large year classes.

Fishery selectivity and fishery catch rates

The age of 50% selection is 3.9 years for the longline survey and 4.4 years for the IFQ longline fishery in Model 1. For Model 3, the longline survey selectivity stayed the same but IFQ longline fishery increased to 4.7 (Box 2, Figure 3.16). Selectivity is asymptotic for the longline survey and fisheries and dome-shaped for the trawl survey and 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). Small fish are more vulnerable and older fish are less vulnerable to the trawl fishery (see following figure) because trawling often occurs on the continental shelf and < 300 m water of the continental slope that young sablefish inhabit.



Fishery catch rate data are available from 1990-2005. Catchability was separately estimated for the "derby" (through 1994) and IFQ (1995 and later) fisheries. On average, fishery catchability is 1.8 times greater during the IFQ fishery, the same as estimated in an independent analysis of the effects of individual quotas on catching efficiency in the fishery (Sigler and Lunsford 2001). Like the selectivity effect, lower catching efficiency during the "derby" fishery likely occurred due to crowding of the fishing grounds, so that fishermen were pushed to fish areas where sablefish densities were less. Fishermen also fished the same area repeatedly, with associated decreases in catch rates due to "fishing down" the area.

Fishery catch rates often are biased estimates of relative abundance (e.g. Crecco and Overholtz 1990). We examined possible biases in US fishery catch rate data (see section 3.1.2). We also tested the effect of including fishery catch rates in the assessment model. Both Japan and US fishery catch rate data are used in the assessment model. However we only tested the effect of US fishery catch rate data because there was no alternative abundance index during most years of the Japanese longline fishery, unlike the US fishery, which overlaps the longline surveys. Including US fishery catch rates has little effect on spawning biomass estimates, increasing spawning biomass estimates <1% for 1990-2004, the years of US fishery catch rate data.

3.5 Projections and harvest alternatives

Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2007 spawning biomass, are shown in the summary table, section 3.7. Reference biomass values always were computed using the average recruitment from the 1977-2003 year classes. Projected 2007 spawning biomass is 38% of unfished spawning biomass and 95% of $B_{40\%}$. A downward adjustment to the reference fishing mortality rates is required to set the maximum Acceptable Biological Catch under Tier 3b. Recent reference point values for fishing mortality are less than previous assessments. For example, $F_{40\%}$ is 0.092 for the 2006 assessment, but was 0.112 in the 2005 assessment.

Reference fishing values are less for the 2006 assessment primarily because of the use of a female-only maturity ogive instead of including male maturity in prior assessments.

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 2006 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. 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 after 2006 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 2007, 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 2007 recommended in the assessment to the *max* F_{ABC} for 2007. (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.) In this scenario we use the most recent catch as an estimate of catches for 2007 and 2008, then maximum permissible thereafter. This was suggested to help produce more accurate projections for fisheries that do not utilize all of the TAC.

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 2002-2006 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 2007 and above its MSY level in 2017 under this scenario, then the stock is not overfished.)

Scenario 7: In 2007 and 2008, 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 2019 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass currently is at 38% of the unfished level, and is projected to remain level through 2010. Abundance is projected to remain stable because estimated year classes between and following the strong 1997 and 2000 year classes are near average. The maximum permissible ABC also is projected to be 20,000 mt in 2008 and 19,800 mt in 2009 (using estimated catches, instead of maximum permissible, see table footnote below).

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 3.10). The difference for this assessment for projections is in Scenario 2 (Author's F); we use prespecified catches to increase accuracy of short-term projections in fisheries (such as sablefish) where the catch is much less than the ABC. For catch in Scenario 2, we use the estimated catch for 2006 as the estimated catch for 2007 and 2008, and then use maximum permissible ABC thereafter.

Status determination

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

Bayesian analysis

The estimates of ending spawning biomass are well-defined by the available data. Most of the probability lies between 110,000 and 126,000 mt (Figure 3.18). The probability changes smoothly and is well-mapped.

Scatter plots of selected model parameters were plotted pair-wise to evaluate the shape of the posterior distribution (Figure 3.19). The plots indicate that the parameters are reasonably well-defined by the data.

Decision analysis

The maximum permissible 2007 catch is 20,100 mt falling to 20,000 mt in 2008 (Table 3.10). The choice of threshold affects the determination of which ABC leaves enough spawning biomass for successive generations to replace or surpass each other on average. Spawning biomass was compared to key biological reference points for each MCMC run and the probability that spawning biomass falls below these reference points was estimated (Figure 3.20a). During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of being below $B_{40\%}$ is 0.60, and the probability of falling below $B_{35\%}$ is 0.19 (Figure 3.20b).

Management path

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. In this "management path" we plot estimated fishing mortality relative to the (current) limit value and the estimated spawning biomass relative to the (current) limit spawning biomass. Figure 3.21 suggests that management has generally constrained fishing mortality below the limit rate, but has not been able to always keep the stock in the 'optimum' quadrant where $B/B_{35\%}$ exceeds one and $F/F_{35\%}$ continues to stay below one. In 2005 and 2006, we are currently in the 'optimum' quadrant.

Acceptable biological catch

We recommend a 2007 ABC of 20,100 mt. The maximum permissible yield for 2007 from an adjusted $F_{40\%}$ strategy is 20,100 mt. The maximum permissible yield for 2007 represents a slight decrease from the 2006 ABC of 21,000 mt.

Spawning biomass currently is at 38% of the unfished level, and is expected to remain there through 2010 (Scenario 2). The maximum permissible ABC also is projected to decline to 20,000 mt in 2008 and 19,800 mt in 2009 using prespecified catches (Table 3.10). This decline is small and mainly based on the selectivity of the fisheries.

During the next three years, the probability of spawning biomass falling below MSST for a Tier 3 stock of $B_{17.5\%}$ is near zero. The probability of falling below the MSY level of $B_{35\%}$ in three years is small (0.19). Thus the risk that maximum permissible yield will reduce spawning biomass below the replacement level is low. The long-term probability depends on future recruitment and whether the catch is close to the maximum permissible ABC, but will be updated each year as new data becomes available. The following table shows the maximum permissible ABC, and ABCs recommended by the stock assessment authors, Plan Teams, SSC, and NPFMC, by fishing year 1997-2006.

Year	Maximum permissible	Authors	Plan Teams	SSC	NPFMC
1997	23,200	17,200	19,600	17,200	17,200
1998	19,000	16,800	16,800	16,800	16,800
1999	15,900	15,900	15,900	15,900	15,900
2000	17,300	17,000	17,300	17,300	17,300
2001	16,900	16,900	16,900	16,900	16,900
2002	21,300	17,300	17,300	17,300	17,300
2003	25,400	18,400	18,400	20,900	20,900
2004	25,400	23,000 or 20,700	23,000	23,000	23,000
2005	21,000	21,000	21,000	21,000	21,000
2006	21,000	21,000	21,000	21,000	21,000

Area allocation of harvests

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of inter-annual changes in the allocation. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of biomass distribution, while adapting to current information about biomass distribution. 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. Exponential weighting is implied under certain conditions by the Kalman filter. The exponential factor is the measurement error variance divided by the prediction error variance (Meinhold and Singpurwalla 1983). Prediction error variance depends on the variances of the previous year's estimate, the process error, and the measurement error. When the ratio of measurement error variance to process error variance is r, the exponential factor is equal to $1-2/(\sqrt{4r+1}+1)$ (Thompson 2004). For sablefish we do not estimate these values, but instead use the exponential weighting with the exponential factor set at ½, so that the weight of each year's value is ½ the weight of the following year. The weights are year index 5: 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000. 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.). Because mixing rates for sablefish are sufficiently high and fishing rates sufficiently low, moderate variations of biomass based apportionment would not significantly change overall sablefish yield unless there are strong differences in recruitment, growth, and survival by area (Heifetz et al. 1997).

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 continue to use survey and fishery data to allocate the 2007 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: 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.

Apportionments are based on survey and fishery information	2006 ABC Percent	2006 Survey RPW	2005 Fishery RPW	2007 ABC Percent	2006 ABC	Authors 2007 ABC	Change
Total					21,000	**20,100**	-4%
Bering Sea	15%	16%	13%	15%	3,060	**2,980**	-3%
Aleutians	15%	13%	13%	14%	3,100	**2,810**	-9%
Gulf of Alaska	71%	71%	73%	71%	14,840	**14,310**	-4%
Western	18%	18%	15%	17%	2,670	**2,470**	-7%
Central	43%	45%	39%	43%	6,370	**6,190**	-3%
W. Yakutat	14%	15%	17%	15%	2,090	**2,100**	0%
E. Yakutat / Southeast	25%	23%	29%	25%	3,710	**3,550**	-4%

This year's apportionment reflects an increase in fishery RPWs across all regions in the Gulf of Alaska, while survey abundance was less consistent, and only West Yakutat had a large increase in both indices (Figure 3.22a). The standard weighted average approach described above includes values from 2002-2006 for survey RPWs and 2001-2005 for fishery RPWs greatly alleviates the effect of an individual year's change in RPW (Figure 3.22b). Changes in apportionment for this year are much more modest compared to the large changes seen in last year's assessment (see above table). The largest relative change this year occurred in the West Yakutat area due to sizeable increases in both the survey CPUE in 2006 and the fishery CPUE in 2005. The current apportionment is characteristic of most prior years except for 2004 (Figure 3.22c).

Overfishing level (OFL)

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b results in a value of 23,750 mt for the combined stock. The OFL is apportioned by region, Bering Sea (3,525 mt), Aleutian Islands (3,319 mt), and Gulf of Alaska (16,906 mt), by the same method as the ABC apportionment.

3.6 Ecosystem considerations

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

3.6.1 Ecosystem effects on the stock

Prey population trends: Young-of-the-year sablefish prey mostly on euphausiids (Sigler et al 2001), while juvenile and adult sablefish are opportunistic feeders. Larval sablefish abundance has been linked to copepod abundance (McFarlane and Beamish 1992) and young-of-the-year abundance may be similarly affected by euphausiid abundance because of their apparent dependence on a single species. 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 is available on copepod and euphausiid abundance, so there predictions of sablefish abundance based on this predator-prey relationship are not possible.

Juvenile and adult sablefish feed opportunistically so their diets differ throughout their range. In general, sablefish < 60 cm FL consume more euphausiids, shrimp, and cephalopods, while sablefish > 60 cm FL consume more fish (Yang and Nelson 2000). In the Gulf of Alaska, fish constituted 3/4 of the stomach content weight of adult sablefish, with the remainder invertebrates (Yang and Nelson 2000). Of the fish found in the diets of adult sablefish, pollock were the most abundant diet item while eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and flatfish also were found. Squid were the most important invertebrate and euphausiids and jellyfish were also present. Off the coast of Oregon and California, fish made up 76 percent of the diet (Laidig et al 1997), while euphausiids dominated the diet off the southwest coast of Vancouver Island. Off Vancouver Island, herring and other fish were increasingly important as sablefish size increased (Tanasichuk 1997). 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 could affect growth or survival of juvenile and adult sablefish is by overall changes in ecosystem productivity.

Predators/Competitors: The main sablefish predators are adult coho and chinook salmon, which prey on young-of-the-year sablefish during their pelagic stage. Sablefish were the fourth most commonly reported prey species in the salmon troll logbook program from 1977 to 1984 (Wing 1985), however the effect of salmon predation on sablefish survival is unknown. The only other fish species reported to prey on sablefish in the Gulf of Alaska is Pacific halibut; however, sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999). Juvenile sablefish may not be prominent prey in food habitat studies because of their relatively low and sporadic abundance compared to other prey items.

Fish are an important part of sperm whale diet in some parts of the world, including the northeastern Pacific Ocean (Kawakami 1980). Cephalopods are an important prey in sperm whale diets in the western Aleutians and Bering Sea, and fish have appeared in the diets of sperm whales in the eastern Aleutians and Gulf of Alaska. Although fish species was not identified in Alaska sperm whale diets, sablefish were found in 8.3% of sperm whale stomachs off California (Kawakami 1980).

Sablefish distribution is typically thought to be on the upper continental slope in deeper waters than most groundfish. However, during the first two to three years of their life sablefish inhabit the continental shelf (Figure 3.23 a-d). Length samples from the NMFS bottom trawl survey suggest that the range of juvenile sablefish on the shelf varies dramatically from year to year. In particular, juveniles utilize the Bering Sea shelf extensively in some years (Figure 3.23a), while not at all in others (Shotwell 2006). On the continental shelf, juvenile sablefish share residence with arrowtooth flounder, halibut, Pacific cod, bigmouth sculpin, big skate, and Bering skate, which are the main piscivorous groundfishes in the Gulf of Alaska and may potentially prey on juvenile sablefish (Yang et al. 2006). Juvenile sablefish (< 60 cm FL) prey items overlap with the diet of small arrowtooth flounder. On the continental shelf of the Gulf of Alaska, both species consumed euphausiids and shrimp predominantly, and these prey are prominent in the diet of many other groundfish species. This diet overlap may cause competition for resources between small sablefish and other groundfish.

Changes in the physical environment: Mass water movements and temperature changes 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 recruitment is above average.

3.6.2 Fishery effects on the ecosystem

Fishery-specific contribution to bycatch of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species: The sablefish fishery catches significant portions of the spiny dogfish and unidentified shark total catch, but there is no distinct trend through time (see table at the end of this section). The sablefish fishery catches the majority of grenadier total catch (average 71%) and the trend is stable. The catch of seabirds in the sablefish fishery averages 10% of the total catch. The trend in seabird catch is variable but appears to be decreasing, presumably due to widespread use of measures to reduce seabird catch. Sablefish fishery catches of the remaining species is minor.

The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of sablefish is minimal or temporary in the current fishery management regime based on the criteria that sablefish are currently above Minimum Stock Size Threshold (MSST), however caution is warranted. Sablefish are substantially dependent on benthic prey (18% of diet by weight) which may be adversely affected by fishing. Little is known about sablefish spawning habitat and effects of fishing on that habitat. Habitat requirements for growth to maturity are better understood, but are not complete. Although sablefish do not appear substantially dependent on physical structure, living structure and coral are substantially reduced in much of the area where sablefish are concentrated. In three areas comprising of 88% of the sablefish fish habitat, living structure has been reduced by 6-15% and hard coral has been reduced by 29-55% (Aleutian Islands Deep is 6% of sablefish habitat, Gulf of Alaska Deep Shelf is 41%, and Gulf of Alaska Slope is 41%). Other anthropogenic effects, such as coastal development, may impact juvenile sablefish habitat. Additionally, effects of fishing other than slope habitat destruction may reduce juvenile survivorship, such as fishing on the continental shelf and juvenile sablefish bycatch in other fisheries. These issues are a concern in areas of the Bering Sea and Gulf of Alaska where juvenile sablefish are concentrated and bottom trawl fishing intensity is high.

The shift from an open-access to an IFQ fishery has nearly doubled catching efficiency which has reduced the number of hooks deployed (Sigler and Lunsford 2001). Although the effects of longline gear on bottom habitat are poorly known, the reduced number of hooks deployed during the IFQ fishery must reduce the effects on benthic habitat. The IFQ fishery likely has also reduced discards of other species because of the slower pace of the fishery and the incentive to maximize value from the catch.

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

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 13% of the total catch, often catches small and medium fish. The trawl fishery typically occurs on the continental shelf where juvenile sablefish occur. Catching these fish as juveniles reduces the yield available from each recruit.

Fishery-specific contribution to discards and offal production: Discards of sablefish in the longline fishery are small, typically less than 5% of total catch (Table 3.2). The catch of sablefish in the longline fishery typically consists of a high proportion of sablefish, 90% or more. However at times grenadiers may be a significant catch and they are usually discarded.

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 13% 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 the trawl fishery currently catches only a small portion of the total sablefish caught.

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

Catch of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species such as sharks in sablefish directed fisheries. Percent of catch refers to that attributable to directed sablefish fisheries in all areas of Alaska.

Biota	2003	2004	2005	Average	Average Catch (mt)
Birds	17.1%	10.8%	16.1%	14.9%	0.12
Brittle Stars	0.6%	0.0%	0.7%	0.5%	0.18
Corals	0.9%	1.6%	1.1%	1.1%	0.31
Eelpouts	0.7%	0.9%	1.8%	1.0%	1.32
Grenadier	64.7%	62.8%	65.3%	64.2%	3,232.75
Sculpin	0.0%	0.0%	0.3%	0.1%	3.53
Octopus	0.1%	0.0%	0.0%	0.0%	0.12
Anemone	0.2%	0.2%	0.1%	0.2%	0.23
Sea Star	0.0%	0.1%	0.0%	0.0%	1.40
Shark	3.7%	1.4%	5.4%	3.5%	19.10
Sleeper	6.3%	1.6%	1.0%	3.1%	10.48
Salmon	0.3%	1.9%	0.0%	0.5%	0.23
Dogfish	0.4%	2.9%	39.6%	8.9%	8.40
Skate	0.5%	0.3%	0.6%	0.5%	96.89
Big	0.0%	0.0%	0.5%	0.2%	2.44
Longnose	0.1%	1.0%	3.5%	2.8%	11.77
Other	0.5%	0.3%	0.5%	0.4%	82.68
Snails	1.5%	0.5%	3.5%	1.4%	2.92
Sponge	0.1%	0.4%	0.4%	0.3%	0.65

3.6.3 Data gaps and research priorities

There is little information on early life history of sablefish and recruitment processes. Better estimation of recruitment and year class strength would improve assessment of the sablefish population. Better fishery coverage in the Bering Sea and Aleutian Islands would provide additional data to monitor the emerging pot fishery in these areas and would improve the fishery catch rate analyses. Improving coverage of trawl vessels catching sablefish would help verify discard rates and to obtain the size of fish discarded. Not enough size information has been collected in recent years for the length data from the trawl fisheries to be usable, except for the improved sample size in 2005.

Future sablefish research is going to focus on several new directions:

1) Explore the utility of using environmental satellite information in determining recruitment estimates for sablefish.
2) Consider different ways to estimate selectivity, including varying selectivity over time.
3) Examine the effects of using relative population numbers and relative population weights in the model and the potential confounding effects of changes in growth on the way RPWs are calculated.
4) The sablefish migration model (Heifetz and Fujioka 1991) has been translated into an AD Model Builder program. We are now looking forward to assembling the entire data set which has expanded in size considerably since the 1991 analysis. Once we have revisited and updated these

migration rates, we will evaluate the appropriateness of the current apportionment scheme.

5) Continue to monitor increased catch by pot gear in the Bering Sea and Aleutian Islands and compare selectivity differences in gear types and spatial differences in fishing locations.
6) Improve knowledge of sperm whale depredation during the longline survey and its effect on survey catch rates.
7) A sablefish maturity study has been initiated and will provide updated maturity estimates from visual and histological methods.
8) A sablefish growth study has been initiated and will provide updated growth parameters and examine growth changes over time.
9) Initiate studies that will explore the comparability and standardization of auto-bait gear and hand-bait gear on the longline survey vessels.
10) Evaluate appropriateness of current variance assumptions about data components, including those included in the apportionment scheme.

3.7 Summary

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

Age at 50% selection for survey	3.9
Age at 50% selection for "derby" fishery	3.9
Age at 50% selection for IFQ fishery	4.7
Age at 50% selection for trawl fishery	2.8
Natural mortality (M)	0.10
Tier	3b
Equilibrium unfished spawning biomass	310
Reference point spawning biomass, $B_{40\%}$	124
Reference point spawning biomass, $B_{35\%}$	108
Spawning biomass	118
Total (age-4+) biomass	224
Maximum permissible fishing level	
$F_{40\%}$	0.092
$F_{40\%}$ adjusted	0.088
$F_{40\%}$ adjusted Yield	20.1
Overfishing level	
$F_{35\%}$	0.109
$F_{35\%}$ adjusted	0.104
$F_{35\%}$ adjusted Yield	23.8
Authors' recommendation	
F	0.088
ABC	20.1

3.8 Literature Cited

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Tables

Table 3.1a--Alaska sablefish catch (mt). The values include landed catch and discard estimates. Discards were estimated for U.S. fisheries before 1993 by multiplying reported catch by 2.9% for fixed gear and 26.9% for trawl gear (1994-1997 averages) because discard estimates were unavailable. Eastern includes both West Yakutat and East Yakutat / Southeast.

		BY AREA								BY GEAR	
Year	Grand total	Bering Sea	Aleu-tians	Western	Central	Eastern	West Yakutat	East Yakutat/ Soeast.	Un-known	Fixed	Trawl
1956	773	0	0	0	0	773			0	773	0
1957	2,059	0	0	0	0	2,059			0	2,059	0
1958	477	6	0	0	0	471			0	477	0
1959	910	289	0	0	0	621			0	910	0
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,433	668	2,080	739	11,971	9,975	4,619	5,356	0	22,912	2,521
1994	23,760	694	1,726	555	9,495	11,290	4,497	6,793	0	20,797	2,963
1995	20,954	990	1,333	1,747	7,673	9,211	3,866	5,345	0	18,342	2,612
1996	17,577	697	905	1,648	6,772	7,555	2,899	4,656	0	15,390	2,187
1997	14,922	728	929	1,374	6,237	5,653	1,928	3,725	0	13,287	1,635
1998	14,108	614	734	1,435	5,877	5,448	1,969	3,479	0	12,644	1,464
1999	13,575	677	671	1,487	5,873	4,867	1,709	3,158	0	11,590	1,985
2000	15,919	828	1,314	1,587	6,172	6,018	2,066	3,952	0	13,906	2,013
2001	14,097	878	1,092	1,589	5,518	5,020	1,737	3,283	0	10,863	1,783
2002	14,789	1,166	1,139	1,863	6,180	4,441	1,550	2,891	0	10,852	2,261
2003	16,432	1,006	1,081	2,110	7,090	5,145	1,822	3,323	0	14,370	2,062
2004	17,782	1,179	974	2,168	7,428	6,033	2,243	3,790	0	16,137	1,645
2005	16,537	1,064	1,147	1,923	6,688	5,385	1,823	3,562	0	14,981	1,556

Table 3.1b—Retained Alaska sablefish catch (mt) in the Aleutian Islands and the Bering Sea by gear type. Both CDQ and non-CDQ catches are included. Catches in 1991-1999 are averages.

Aleutian Islands				
Year	Pot	Trawl	Longline	Total
1991-1999	6	73	1,210	1,289
2000	147	33	989	1,169
2001	170	39	953	1,161
2002	164	45	1,045	1,253
2003	316	42	761	1,119
2004	384	32	543	959
2005	601	115	738	1,453
Bering Sea				
1991-1999	5	189	539	733
2000	53	290	471	814
2001	131	357	419	907
2002	546	304	471	1,321
2003	354	231	413	999
2004	434	293	311	1,038
2005	582	273	218	1,072

Table 3.2--Discarded catches of sablefish (amount [mt] and percent of total catch) by target fishery, gear (H&L=hook & line, TWL=trawl), and management area. Average of annual discard amount and annual percent discard are shown for 1994-1999. Annual values for 1994-1999 are shown in previous sablefish SAFE chapters.

		Eastern Bering Sea		Aleutian Islands		Western		Central		West Yakutat		East Yakutat/ Southeast	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Sablefish (H&L)	1994-1999	5.8	2.7	15.2	2.2	42.3	3.0	128.8	2.7	54.5	2.3	108.7	2.5
	2000	2	1	7	1	49	4	168	4	46	2	159	3
	2001	9	5	16	2	34	2	133	3	33	2	53	2
	2002	5	2	5	2	32	2	109	3	33	2	79	3
	2003	2	1	8	1	41	2	145	3	76	5	127	4
	2004	0	0	1	0	43	2	179	3	54	3	128	4
	2005	0	0	4	1	23	1	73	1	28	2	60	2
	2006	1	1	1	0	24	1	74	2	23	2	66	3
Greenland turbot (H&L)	1994-1999	63.3	30.8	11.3	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2000	27	15	15	14	0	-	0	-	0	-	0	-
	2001	36	25	0	1	0	-	0	-	0	-	0	-
	2002	84	67	0	2	0	-	0	-	0	-	0	-
	2003	43	33	1	4		-		-		-		-
	2004	10	14	0	0		-		-		-		-
	2005	5	8	6	34		-		-		-		-
	2006	23	33	2	23		-		-		-		-
Pacific cod (H&L)	1994-1999	11.7	51.8	4.5	16.3	1.8	32.3	20.7	25.3	0.0	0.3	0.0	0.0
	2000	54	79	3	15	0	23	34	81	0	-	1	100
	2001	34	57	9	23	1	9	7	27	0	-	0	5
	2002	36	61	2	3	20	81	12	44	0	-	0	-
	2003	64	97	1	10	1	89	2	31		-		-
	2004	17	89	0	1	12	96	1	59		-		0
	2005	11	52	1	73	1	100	7	55		-		-
	2006	5	27	3	8	1	100		0		-		-
All other (H&L)	1994-1999	0.5	31.8	0.5	14.8	0.0	0.7	0.7	16.2	0.8	17.2	2.0	17.2
	2000	1	100	0	2	0	-	0	5	0	-	0	-
	2001	0	42	0	10	0	100	2	28	1	49	90	38
	2002	0	29	0	2	0	27	2	18	10	98	11	49
	2003	5	12	6	4	3	3	36	13	1	5	8	12
	2004	1	1	1	1	1	1	3	1	0	0	5	3
	2005	1	3	0	0	5	5	20	4	4	3	2	1
	2006	1	3	1	1	1	1	13	2	1	1	9	4
Total H&L	1994-1999	81.5	16.8	31.2	3.8	44.0	3.5	150.2	3.2	55.5	2.3	110.7	2.5
	2000	83	20	26	3	49	4	213	4	52	2	240	4
	2001	80	20	25	3	35	2	142	3	34	2	1243	2
	2002	125	27	27	3	52	3	123	3	43	3	91	3
	2003	113	27	16	2	44	2	183	3	77	5	135	4
	2004	28	9	2	0	56	3	182	3	54	3	133	4
	2005	17	8	11	2	29	2	100	2	32	2	61	2
	2006	30	10	7	1	26	1	88	2	23	2	74	3

Table 3.2 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)	1994-1999	2.2	4.8	0.2	1.7	0.0	0.0	12.2	13.0	0.3	0.5	0.0	0.0
	2000	0	-	0	-	0	2	0	-	0	-	0	-
	2001	0	-	0	-	0	-	0	-	0	-	0	-
	2002	0	-	0	-	0	-	0	-	17	23	0	-
	2003		-		-		-		0		-		
	2004	0	0		-		-		0		0		
	2005		0		-		-		0		-		
	2006		-		-		-		0		0		
Rockfish (TWL)	1994-1999	0.2	0.8	1.8	4.0	0.7	1.8	150.8	17.7	20.0	10.8	0.0	0.2
	2000	0	-	0	-	1	2	155	18	1	1	0	-
	2001	0	-	1	3	0	-	191	25	30	0	0	-
	2002	0	4	0	1	24	25	433	36	2	3	0	-
	2003		0	0	0	5	11	275	26	12	8		
	2004		0	12	39	50	32	44	5	2	5		
	2005		-		0	2	4	132	15		0		
	2006	0	1	5	9	3	6	121	21	4	5		
Arrowtooth (TWL)	1994-1999	1.8	5.7	0.0	0.0	7.7	29.3	96.3	69.5	0.0	0.0	0.0	0.0
	2000	4	5	0	-	60	48	115	64	0	-	0	-
	2001	10	13	0	-	7	93	7	93	0	-	0	-
	2002	18	19	0	-	69	63	55	57	0	-	0	-
	2003	14	22		-	134	80	147	77		-		
	2004	37	33		-	0	1	29	62		-		
	2005	9	8		-	14	53	23	31		-		
	2006	1	1		-	78	100	24	24		-		
Deepwater	1994-1999	0.0	0.0	0.0	0.0	0.0	0.0	106.7	44.5	10.3	35.0	23.3	22.0
flatfish (TWL)	2000	0	-	0	-	0	-	3	13	0	4	0	-
	2001	0	-	0	-	17	41	17	41	4	32	0	-
	2002	0	-	0	-	0	-	18	57	0	-	0	-
	2003		-		-		-	51	68		-		
	2004		-		-		-	54	63	5	58		
	2005		-		-		-		0		-		
	2006		-		-		-		0		-		
Shallow water	1994-1999	0.0	0.0	0.0	0.0	0.0	0.0	12.8	30.0	0.0	0.0	0.0	0.0
flatfish (TWL)	2000	0	-	0	-	0	-	34	67	2	100	0	-
	2001	0	-	0	-	34	86	34	86	0	-	0	-
	2002	0	-	0	-	0	-	8	54	0	-	0	-
	2003	0	20		-	0	46	3	56		-		
	2004	1	13		-	0	100	3	62		-		
	2005	0	7		-	7	78	0	4		-		
	2006	0	36		-		0	6	73		-		

Table 3.2 cont.

		Eastern Bering Sea		**Aleutian Islands**		**Western**		**Central**		**West Yakutat**		**East Yakutat/ SEO**	
Target fishery	Year	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
Rex sole (TWL)	1994-1999	0.0	0.0	0.0	0.0	5.8	16.8	39.0	19.7	10.7	28.5	0.0	0.0
	2000	0	-	0	-	40	58	82	62	0	-	0	-
	2001	0	-	0	-	119	73	119	73	0	-	0	-
	2002	0	-	0	-	58	32	58	32	0	-	0	-
	2003		-		-	2	14	50	57		-		
	2004		-		-	1	8	3	19		-		
	2005		-		-		0	1	12		-		
	2006		-		-		-	4	11		-		
Greenland turbot (TWL)	1994-1999	8.7	4.7	4.3	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2000	0	-	0	-	0	-	0	-	0	-	0	-
	2001	0	-	0	-	0	-	0	-	0	-	0	-
	2002	2	5	0	-	0	-	0	-	0	-	0	-
	2003		0		-		-		-		-		
	2004		0		-		-		-		-		
	2005		0		-		-		-		-		
All other (TWL)	1994-1999	16.8	35.3	2.8	32.7	9.5	52.2	46.0	41.0	0.2	6.5	0.0	0.0
	2000	48	37	0	23	11	98	108	75	0	-	0	-
	2001	16	10	1	100	37	53	37	53	0	-	0	-
	2002	30	21	1	9	1	4	1	4	0	-	0	-
	2003	71	54	1	18	16	41	26	56		-		
	2004	30	28	0	34	0	0	5	42		-		
	2005	19	16	1	8	0	4	0	5		0		
	2006	0	2	1	16		0	1	9		-		
Total TWL	1994-1999	29.3	14.0	8.8	16.5	23.7	23.2	463.7	30.2	41.2	19.8	23.3	19.7
	2000	54	19	0	-	112	45	496	36	3	4	0	-
	2001	26	7	2	4	405	37	405	37	4	2	0	-
	2002	51	17	1	2	575	37	575	37	19	15	0	-
	2003	86	38	1	4	157	59	552	38	12	8		
	2004	68	25	12	39	51	29	137	14	8	5		
	2005	28	11	1	1	23	25	157	16		0		
	2006	1	2	6	10	81	61	156	21	4	4		
Sablefish Pot	2003	4.0	1	2.0	1								
	2004	4.4	1	10.0	3								
	2005	4.3	1	22.9	3								
	2006	0.4	0	1.0	0								
Pacific Cod Pot	2003	0.2	75										
	2004	1.1	100										
	2005	0.1	100										
	2006	5.9	100										
All Gear total	1994-1999	111.7	16.8	40.2	4.5	67.7	4.8	614.3	9.2	96.5	3.8	133.8	3.2
	2000	138	19	26	3	161	10	709	11	55	3	240	4
	2001	106	14	27	3	116	7	547	10	38	2	66	2
	2002	176	23	27	3	149	8	697	11	62	4	91	3
	2003	240	23	20	2	201	9	734	10	90	5	135	4
	2004	107	10	24	3	107	5	320	4	62	3	133	4
	2005	52	5	36	2	53	3	257	4	32	2	61	2
	2006	40	4	14	1	107	6	244	5	27	2	74	3

Table 3.3.--Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from the observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data.

	LENGTH							AGE		
	U.S. NMFS trawl survey (GOA)	**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	16,222									
1985								1,294		
1986										
1987	13,032							1,057		
1988										
1989								655		
1990	4,124			1,229	33,822		101,530			
1991				721	29,615		95,364	902		
1992				0	21,000		104,786			
1993	7,121			468	23,884		94,699	1,178		
1994				89	13,614		70,431			
1995				87	18,174		80,826			
1996	4,650			239	15,213		72,247		1,175	
1997				0	20,311		82,783		1,211	
1998				35	8,900		57,773		1,183	
1999	5,588			1,268	26,662		79,451		1,188	1,145
2000				472	29,240		62,513		1,236	1,152
2001	* partial			473	30,362		83,726		1,214	1,023
2002				526	35,380		75,937		1,136	1,061
2003	5,680			503	37,386		77,678		1,198	1,128
2004				694	31,746		82,767		1,185	1,029
2005	6,265			2,306	33,914		74,433		1,187	1,040
2006							78,625			

Table 3.4.--Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. Relative population number equals catch per effort in numbers weighted by respective strata areas. Relative population weight equals catch per effort measured in weight multiplied by strata areas. Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands 1979, 1995, 1997, 1999, 2001, 2003, and 2005 and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004 and 2006.

	RELATIVE POPULATION NUMBER		**RELATIVE POPULATION WEIGHT**			
Year	**Cooperative longline survey**	**Domestic longline survey**	**Japanese longline fishery**	**Cooperative longline survey**	**Domestic longline survey**	**U.S. fishery**
1964			1,452			
1965			1,806			
1966			2,462			
1967			2,855			
1968			2,336			
1969			2,443			
1970			2,912			
1971			2,401			
1972			2,247			
1973			2,318			
1974			2,295			
1975			1,953			
1976			1,780			
1977			1,511			
1978			942			
1979	413		809	1,075		
1980	388		1,040	968		
1981	460		1,343	1,153		
1982	613			1,572		
1983	621			1,595		
1984	685			1,822		
1985	903			2,569		
1986	838			2,456		
1987	667			2,068		
1988	707			2,088		
1989	661			2,178		
1990	450	649		1,454	2,141	1,201
1991	386	593		1,321	2,071	1,066
1992	402	511		1,390	1,758	908
1993	395	563		1,318	1,894	904
1994	366	489		1,288	1,882	822
1995		501			1,803	1,243
1996		520			2,017	1,201
1997		491			1,764	1,341
1998		466			1,662	1,130
1999		511			1,740	1,316
2000		461			1,597	1,139
2001		533			1,798	1,110
2002		559			1,916	1,152
2003		532			1,759	1,218
2004		544			1,738	1,357
2005		533			1,695	1,307
2006		576			1,848	

Table 3.5.--Average catch rate (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. The standard error is not available when vessel sample size equals one.

Aleutian Islands-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.53	0.05	0.10	193	8
1991	0.50	0.03	0.07	246	8
1992	0.40	0.06	0.15	131	8
1993	0.28	0.04	0.14	308	12
1994	0.29	0.05	0.18	138	13
1995	0.30	0.04	0.14	208	14
1996	0.23	0.03	0.12	204	17
1997	0.35	0.07	0.20	117	9
1998	0.29	0.05	0.17	75	12
1999	0.38	0.07	0.17	305	14
2000	0.29	0.03	0.11	313	15
2001	0.26	0.04	0.15	162	9
2002	0.32	0.03	0.11	245	10
2003	0.26	0.04	0.17	170	10
2004	0.21	0.04	0.21	138	7
2005	0.15	0.05	0.34	23	6

Bering Sea-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.72	0.22	0.15	42	8
1991	0.28	0.11	0.20	30	7
1992	0.25	0.21	0.43	7	4
1993	0.09	0.07	0.36	4	3
1994	0.35	0.31	0.45	2	2
1995	0.41	0.14	0.17	38	10
1996	0.63	0.38	0.30	35	15
1997					0
1998	0.17	0.06	0.18	28	9
1999	0.29	0.18	0.32	27	10
2000	0.28	0.18	0.31	21	10
2001	0.31	0.05	0.07	18	10
2002	0.10	0.05	0.22	8	4
2003	0.16	0.09	0.29	8	2
2004	0.17	0.11	0.31	9	4
2005	0.23	0.07	0.16	9	6

Western Gulf-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.64	0.28	0.22	178	7
1991	0.44	0.11	0.13	193	16
1992	0.38	0.10	0.14	260	12
1993	0.35	0.06	0.09	106	12
1994	0.32	0.07	0.10	52	5
1995	0.51	0.09	0.09	432	22
1996	0.57	0.11	0.10	269	20
1997	0.50	0.10	0.10	349	20
1998	0.50	0.07	0.07	351	18
1999	0.53	0.13	0.12	244	14
2000	0.49	0.13	0.13	185	12
2001	0.50	0.10	0.10	273	16
2002	0.51	0.10	0.09	348	15
2003	0.45	0.09	0.10	387	16
2004	0.47	0.16	0.17	162	10
2005	0.58	0.07	0.13	447	13

Central Gulf-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.54	0.08	0.07	653	32
1991	0.62	0.11	0.09	303	24
1992	0.59	0.11	0.09	335	19
1993	0.60	0.08	0.07	647	32
1994	0.65	0.12	0.09	238	15
1995	0.90	0.14	0.08	457	41
1996	1.04	0.14	0.07	441	45
1997	1.07	0.17	0.08	377	41
1998	0.90	0.11	0.06	345	32
1999	0.87	0.17	0.10	269	28
2000	0.93	0.10	0.06	319	30
2001	0.70	0.08	0.06	347	31
2002	0.84	0.13	0.08	374	29
2003	0.99	0.14	0.07	363	34
2004	1.08	0.19	0.09	327	29
2005	0.89	0.06	0.07	518	32

West Yakutat-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.95	0.47	0.25	75	9
1991	0.65	0.14	0.10	164	12
1992	0.64	0.35	0.27	98	6
1993	0.71	0.15	0.10	241	12
1994	0.65	0.35	0.27	81	8
1995	1.02	0.20	0.10	158	21
1996	0.97	0.15	0.07	223	28
1997	1.16	0.22	0.09	126	20
1998	1.21	0.20	0.08	145	23
1999	1.20	0.31	0.13	110	19
2000	1.28	0.20	0.08	193	32
2001	1.03	0.14	0.07	184	26
2002	1.32	0.26	0.10	155	23
2003	1.36	0.20	0.07	216	27
2004	1.23	0.19	0.08	210	24
2005	1.32	0.09	0.07	352	24

East Yakutat/SE-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990					0
1991	0.52	0.37	0.71	17	2
1992	0.87			20	1
1993	1.02	0.19	0.19	26	2
1994	0.36			5	1
1995	1.45	0.20	0.14	101	19
1996	1.20	0.11	0.09	137	24
1997	1.10	0.14	0.13	84	17
1998	1.27	0.12	0.10	140	25
1999	0.94	0.12	0.13	85	11
2000	0.84	0.13	0.16	81	14
2001	0.84	0.08	0.09	110	14
2002	1.20	0.23	0.19	121	14
2003	1.29	0.13	0.10	113	19
2004	1.08	0.10	0.09	135	17
2005	1.18	0.13	0.11	181	16

Table 3.5 cont.

Logbook Fishery Data

Aleutian Islands-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	0.29	0.09	0.15	167	15
2000	0.24	0.10	0.21	265	16
2001	0.38	0.32	0.41	36	5
2002	0.48	0.37	0.39	33	5
2003	0.36	0.22	0.30	139	10
2004	0.45	0.11	0.25	102	7
2005	0.46	0.15	0.33	109	8

Bering Sea-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	0.56	0.16	0.14	291	43
2000	0.21	0.09	0.22	169	23
2001	0.35	0.23	0.33	61	8
2002	0.24	0.30	0.63	5	2
2003	0.24	0.26	0.53	25	6
2004	0.38	0.09	0.24	202	8
2005	0.36	0.07	0.19	86	10

Western Gulf-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	0.64	0.12	0.09	245	27
2000	0.60	0.10	0.09	301	32
2001	0.47	0.09	0.10	109	24
2002	0.60	0.16	0.13	78	14
2003	0.39	0.08	0.11	202	24
2004	0.65	0.06	0.09	766	26
2005	0.78	0.08	0.11	571	33

Central Gulf-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	0.80	0.09	0.06	817	60
2000	0.79	0.08	0.05	746	64
2001	0.74	0.12	0.08	395	52
2002	0.83	0.12	0.07	276	41
2003	0.87	0.14	0.08	399	45
2004	1.08	0.05	0.05	1676	80
2005	0.98	0.07	0.07	1154	63

West Yakutat-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	1.08	0.16	0.08	233	36
2000	1.04	0.12	0.06	270	42
2001	0.89	0.19	0.11	203	29
2002	0.99	0.14	0.07	148	28
2003	1.26	0.20	0.08	104	23
2004	1.27	0.06	0.05	527	54
2005	1.13	0.05	0.04	1158	70

East Yakutat/SE-Logbook

Year	CPUE	SE	CV	Sets	Vessels
1999	0.91	0.15	0.08	183	22
2000	0.98	0.15	0.08	190	26
2001	0.98	0.17	0.09	109	21
2002	0.83	0.12	0.07	108	22
2003	1.13	0.19	0.09	117	22
2004	1.19	0.05	0.04	427	55
2005	1.15	0.05	0.05	446	77

Table 3.6.–Sablefish abundance (relative population weight, RPW) from annual sablefish longline surveys (domestic longline survey only) and number of stations where sperm whale (SW) and killer whale (KW) depredation of sablefish catches occurred. Some stations were not sampled all years, indicated by "na". Recording of sperm whale depredation began with the 1998 survey.

Year	Bering			Aleutians			Western		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	na	na	na	Na	na	na	244,164	na	0
1991	na	na	na	Na	na	na	203,357	na	1
1992	na	na	na	Na	na	na	94,874	na	1
1993	na	na	na	Na	na	na	234,169	na	2
1994	na	na	na	Na	na	na	176,820	na	0
1995	na	na	na	Na	na	na	198,247	na	0
1996	na	na	na	186,270	na	1	213,126	na	0
1997	160,300	na	3	Na	na	na	182,189	na	0
1998	na	na	na	271,323	0	1	203,590	0	0
1999	136,313	0	7	na	na	na	192,191	0	0
2000	na	na	na	260,665	0	1	242,707	0	1
2001	248,019	0	4	na	na	na	294,277	0	0
2002	na	na	na	292,425	0	1	256,548	0	4
2003	232,996	0	7	na	na	na	258,996	0	3
2004	na	na	na	267,065	0	0	178,709	0	4
2005	262,385	0	2	na	na	na	267,938	0	4
2006	na	na	na	239,644	0	1	230,841	0	3

Year	Central			West Yakutat			East Yakutat / Southeast		
	RPW	SW	KW	RPW	SW	KW	RPW	SW	KW
1990	684,738	na	0	268,334	na	0	393,964	na	0
1991	641,693	na	0	287,103	na	0	532,242	na	0
1992	568,474	na	0	316,770	na	0	475,528	na	0
1993	639,161	na	0	304,701	na	0	447,362	na	0
1994	603,940	na	0	275,281	na	0	434,840	na	0
1995	595,903	na	0	245,075	na	0	388,858	na	0
1996	783,763	na	0	248,847	na	0	390,696	na	0
1997	683,294	na	0	216,415	na	0	358,229	na	0
1998	519,781	0	0	178,783	4	0	349,350	0	0
1999	608,225	3	0	183,129	5	0	334,516	4	0
2000	506,368	0	0	158,411	2	0	303,716	2	0
2001	561,168	3	0	129,620	0	0	290,747	2	0
2002	643,363	4	0	171,985	3	0	287,133	2	0
2003	605,417	1	0	146,631	1	0	245,367	2	0
2004	633,717	3	0	175,563	4	0	253,182	6	0
2005	478,685	0	0	131,546	2	0	300,710	8	0
2006	589,642	2	1	192,017	4	0	303,109	2	0

Table 3.7a.– Ages that above average year classes became abundant by region (Figure 3.7, relative population number greater than 10,000). "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska. Age data was not available for the Western areas until 1985. The 1984 year class never was abundant in the Eastern area. The 1995 year class was only moderately abundant in the Central and Eastern areas. The 2000 year class has shown up in all areas but is now considered an average year class.

Year class	Western	Central	Eastern
1977	na	4	4
1980-81	5	6	6
1984	5	9	na
1990	6	7	7
1995	4	7	7
1997	4	4	5
2000	4	5	5

Table 3.7b– Years that the above average 1995 and 1997 year classes became abundant by region. "Western" includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska. The 2000 year class has shown up in all areas but is now considered an average year class.

Year class	Western	Central	Eastern
1995	1999	2002	2002
1997	2001	2001	2002
2000	2004	2005	2005

Table 3.8.--Sablefish fork length (cm), weight (kg), and proportion mature by age and sex.

Age	Fork length (cm)		Weight (kg)		Fraction mature	
	Male	Female	Male	Female	Male	Female
2	50	52	1.3	1.4	0.059	0.006
3	53	56	1.5	1.8	0.165	0.024
4	55	59	1.7	2.1	0.343	0.077
5	57	62	1.9	2.4	0.543	0.198
6	59	64	2.1	2.7	0.704	0.394
7	61	66	2.3	3.0	0.811	0.604
8	62	68	2.5	3.3	0.876	0.765
9	63	70	2.6	3.6	0.915	0.865
10	64	71	2.7	3.8	0.939	0.921
11	65	72	2.8	4.1	0.954	0.952
12	65	74	2.9	4.3	0.964	0.969
13	66	75	3.0	4.5	0.971	0.979
14	66	76	3.1	4.7	0.976	0.986
15	67	76	3.1	4.8	0.979	0.990
16	67	77	3.2	5.0	0.982	0.992
17	67	78	3.2	5.1	0.984	0.994
18	67	78	3.2	5.2	0.985	0.995
19	68	79	3.3	5.3	0.986	0.996
20	68	79	3.3	5.4	0.987	0.997
21	68	80	3.3	5.5	0.988	0.997
22	68	80	3.3	5.6	0.988	0.998
23	68	80	3.4	5.7	0.989	0.998
24	68	81	3.4	5.7	0.989	0.998
25	68	81	3.4	5.8	0.989	0.998
26	68	81	3.4	5.8	0.990	0.998
27	68	81	3.4	5.9	0.990	0.999
28	69	81	3.4	5.9	0.990	0.999
29	69	82	3.4	5.9	0.990	0.999
30	69	82	3.4	6.0	0.990	0.999

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

Year	Age 4+ biomass	Spawning biomass	Number (millions) at age 2	Catch	Catch / Age 4+ biomass
1960	305	158	5.7	3.1	0.010
1961	285	151	43.0	16.1	0.057
1962	254	140	74.3	26.4	0.109
1963	246	126	37.5	16.9	0.069
1964	268	124	1.6	7.3	0.027
1965	314	134	28.6	8.7	0.028
1966	353	151	66.4	15.6	0.044
1967	375	167	3.4	19.2	0.051
1968	369	179	20.8	31.0	0.084
1969	369	183	40.9	36.8	0.100
1970	367	184	28.1	37.8	0.103
1971	355	181	7.9	43.5	0.123
1972	324	174	12.9	53.0	0.163
1973	311	161	2.8	36.9	0.119
1974	289	152	0.5	34.6	0.120
1975	257	140	2.4	29.9	0.116
1976	220	126	25.7	31.7	0.144
1977	196	109	14.7	21.4	0.109
1978	188	96	2.6	10.4	0.055
1979	186	91	61.8	11.9	0.064
1980	200	88	47.4	10.4	0.052
1981	227	90	24.2	12.6	0.056
1982	266	96	32.5	12.0	0.045
1983	306	109	58.8	11.8	0.039
1984	338	126	17.1	14.1	0.042
1985	367	145	4.5	14.5	0.040
1986	374	162	42.9	28.9	0.077
1987	360	173	11.5	35.2	0.098
1988	334	176	14.1	38.4	0.115
1989	312	172	7.7	34.8	0.111
1990	289	166	18.0	32.1	0.111
1991	264	158	11.6	27.0	0.102
1992	247	150	23.4	24.9	0.101
1993	232	142	16.6	25.4	0.110
1994	222	133	7.1	23.8	0.107
1995	212	126	8.7	20.9	0.099
1996	205	120	12.2	17.6	0.086
1997	197	116	16.4	14.9	0.076
1998	192	112	9.7	14.1	0.074
1999	190	108	34.0	13.6	0.072
2000	189	105	21.0	15.9	0.084
2001	195	102	16.1	14.1	0.072
2002	203	102	36.4	14.8	0.073
2003	212	104	15.9	16.5	0.078
2004	218	108	7.9	17.6	0.081
2005	223	112	8.9	16.6	0.074
2006	224	116	26.5	16.6	0.074

Table 3.10--Sablefish spawning biomass (kilotons), fishing mortality, and yield (kilotons) for seven harvest scenarios. Abundance projected using 1977-2003 year classes. Sablefish are not classified as overfished because abundance currently exceeds $B_{35\%}$.

Year	Maximum permissible F	Author's F (prespecified catch 2006)*	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass (kt)							
2006	115.9	115.9	115.9	115.9	115.9	115.9	115.9
2007	118.8	118.8	118.8	118.8	118.8	118.8	118.8
2008	117.5	119.3	122.1	119.0	127.1	115.7	117.5
2009	115.5	117.1	124.2	118.3	134.7	112.3	115.5
2010	114.6	115.9	126.8	118.4	143.1	110.3	112.9
2011	115.1	116.2	130.3	119.9	152.9	109.9	112.1
2012	116.4	117.3	134.0	122.1	163.5	110.4	112.1
2013	117.9	118.6	138.0	124.4	174.3	111.2	112.5
2014	119.3	119.8	142.5	126.7	184.7	112.0	113.0
2015	120.5	120.9	146.2	128.7	194.5	112.6	113.4
2016	121.6	121.9	150.6	130.6	203.9	113.2	113.8
2017	122.6	122.9	154.3	132.3	212.7	113.8	114.2
2018	123.5	123.8	157.2	133.9	221.0	114.4	114.7
2019	124.4	124.5	160.8	135.4	228.8	114.9	115.1
Fishing mortality							
2006	0.068	0.068	0.068	0.068	0.068	0.068	0.068
2007	0.088	0.070	0.044	0.073	-	0.104	0.104
2008	0.087	0.088	0.045	0.073	-	0.101	0.101
2009	0.085	0.086	0.046	0.073	-	0.098	0.098
2010	0.084	0.085	0.046	0.073	-	0.096	0.096
2011	0.084	0.085	0.046	0.073	-	0.096	0.096
2012	0.085	0.085	0.046	0.073	-	0.096	0.096
2013	0.085	0.085	0.046	0.073	-	0.096	0.096
2014	0.085	0.086	0.046	0.073	-	0.097	0.097
2015	0.085	0.086	0.046	0.073	-	0.097	0.097
2016	0.086	0.086	0.046	0.073	-	0.097	0.097
2017	0.086	0.086	0.046	0.073	-	0.097	0.097
2018	0.086	0.086	0.046	0.073	-	0.098	0.098
2019	0.086	0.086	0.046	0.073	-	0.098	0.098
Yield (kt)							
2006	16.2	16.2	16.2	16.2	16.2	16.2	16.2
2007	20.1	16.2	10.2	16.9	-	23.7	20.1
2008	19.4	20.0	10.7	16.7	-	22.2	19.4
2009	19.3	19.8	11.3	17.1	-	21.6	22.8
2010	19.5	20.0	11.8	17.5	-	21.6	22.5
2011	20.0	20.3	12.2	18.0	-	21.8	22.5
2012	20.4	20.6	12.6	18.3	-	22.1	22.6
2013	20.7	20.9	13.0	18.6	-	22.4	22.8
2014	21.0	21.1	13.3	18.9	-	22.6	22.9
2015	21.2	21.3	13.6	19.1	-	22.8	23.0
2016	21.5	21.5	13.9	19.3	-	23.0	23.1
2017	21.7	21.8	14.1	19.6	-	23.2	23.3
2018	21.9	21.9	14.3	19.7	-	23.4	23.4
2019	22.0	22.0	14.5	19.9	-	23.4	23.5

* Projections in Author's F are based on an estimated catch of 16,200 mt used in place of maximum permissible ABC for 2007. This was done in response to management requests for a more accurate one-year projection.

Table 3.11.--Regional estimates of sablefish age-4+ biomass (kt). 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	Western Gulf of Alaska	Central Gulf of Alaska	West Yakutat	East Yakutat/ Southeast	Alaska
1960							305
1961							285
1962							254
1963							246
1964							268
1965							314
1966							353
1967							375
1968							369
1969							369
1970							367
1971							355
1972							324
1973							311
1974							289
1975							257
1976							220
1977							196
1978							188
1979	35	38	17	55	16	24	186
1980	36	50	19	51	17	27	200
1981	41	54	24	52	21	35	227
1982	48	57	33	66	25	37	266
1983	55	67	45	75	25	39	306
1984	63	78	50	81	26	39	338
1985	74	82	53	91	28	39	367
1986	78	79	52	92	32	41	374
1987	55	81	50	97	34	43	360
1988	44	66	45	103	33	43	334
1989	45	65	37	94	32	39	312
1990	41	51	33	91	31	40	289
1991	27	44	29	84	34	46	264
1992	21	35	24	85	36	45	247
1993	13	32	27	78	37	45	232
1994	16	31	28	71	34	41	222
1995	17	27	25	69	31	43	212
1996	18	22	23	73	28	40	205
1997	17	20	21	73	26	40	197
1998	17	25	22	65	23	39	192
1999	16	28	21	66	21	38	190
2000	15	29	25	63	20	37	189
2001	21	30	29	63	17	35	195
2002	25	32	29	66	18	33	203
2003	27	33	30	71	18	32	212
2004	28	34	27	76	20	32	218
2005	32	34	32	70	19	36	223
2006	34	32	30	71	21	36	224

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

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

Figures

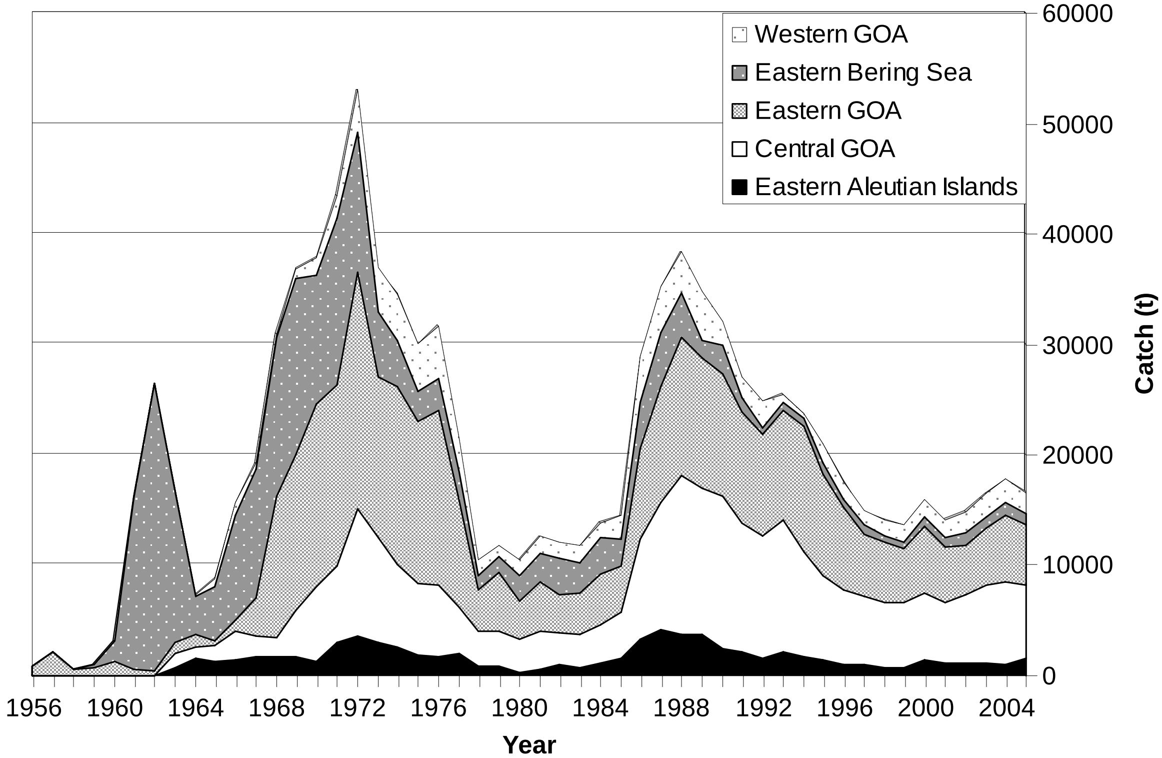


Figure 3.1–Sablefish fishery total reported catch (t) by North Pacific Fishery Management Council area and year.

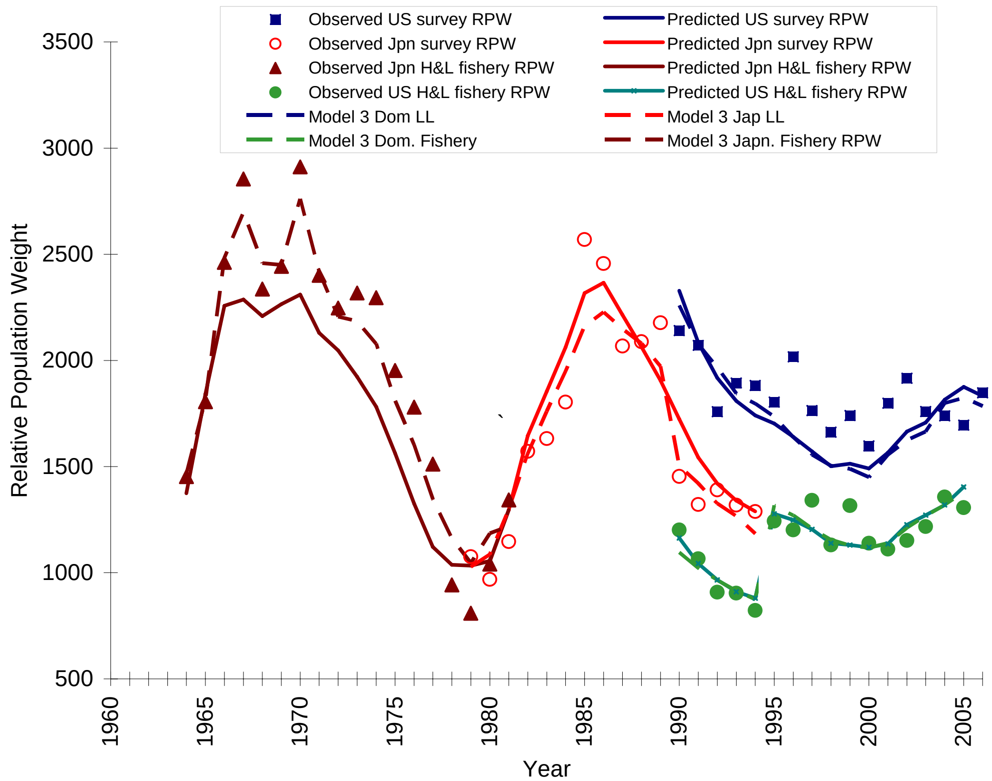


Figure 3.2.--Observed and predicted sablefish relative population weight versus year. Solid lines are from Model 1 while dashed lines are from Model 3.

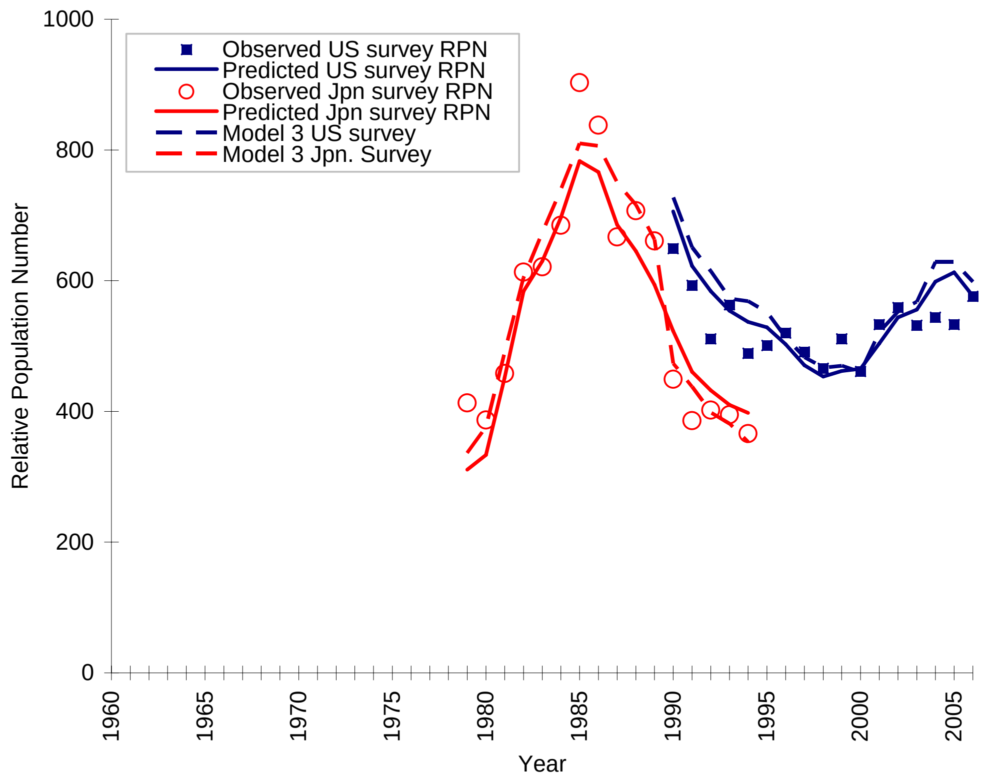


Figure 3.3.--Observed and predicted sablefish relative population number versus year. Solid lines are from Model 1, while dashed lines are from Model 3.

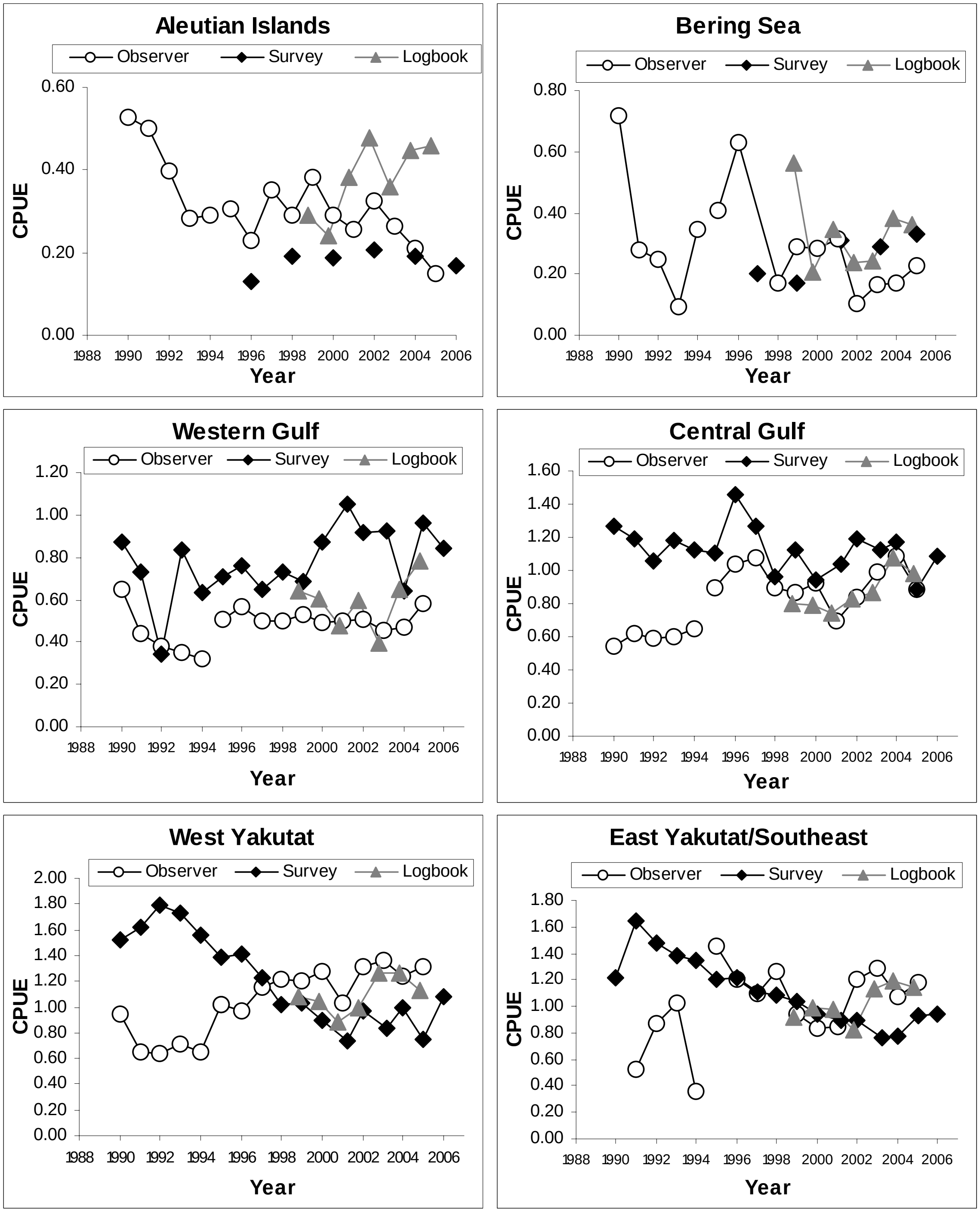


Figure 3.4.–Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

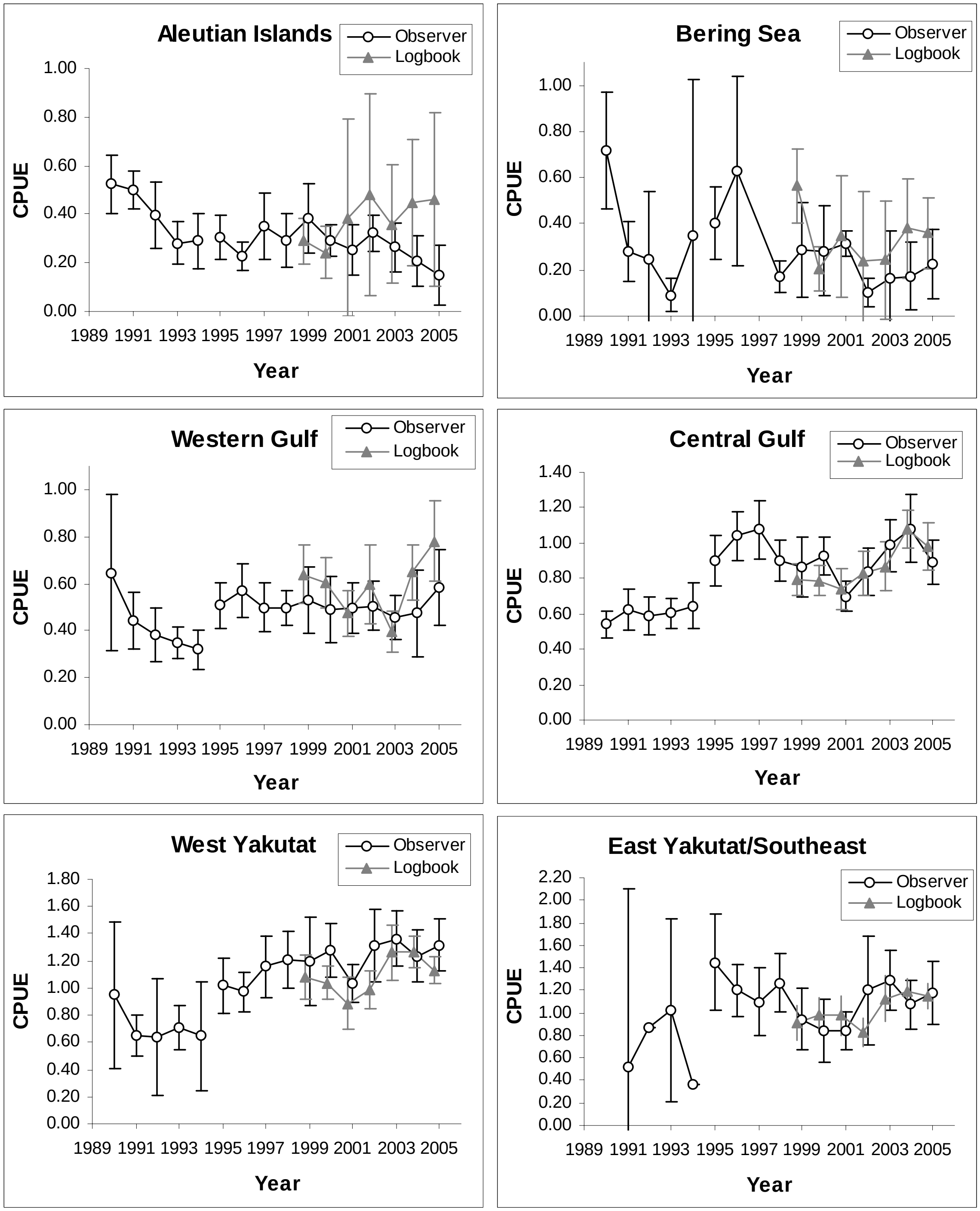


Figure 3.5.–Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

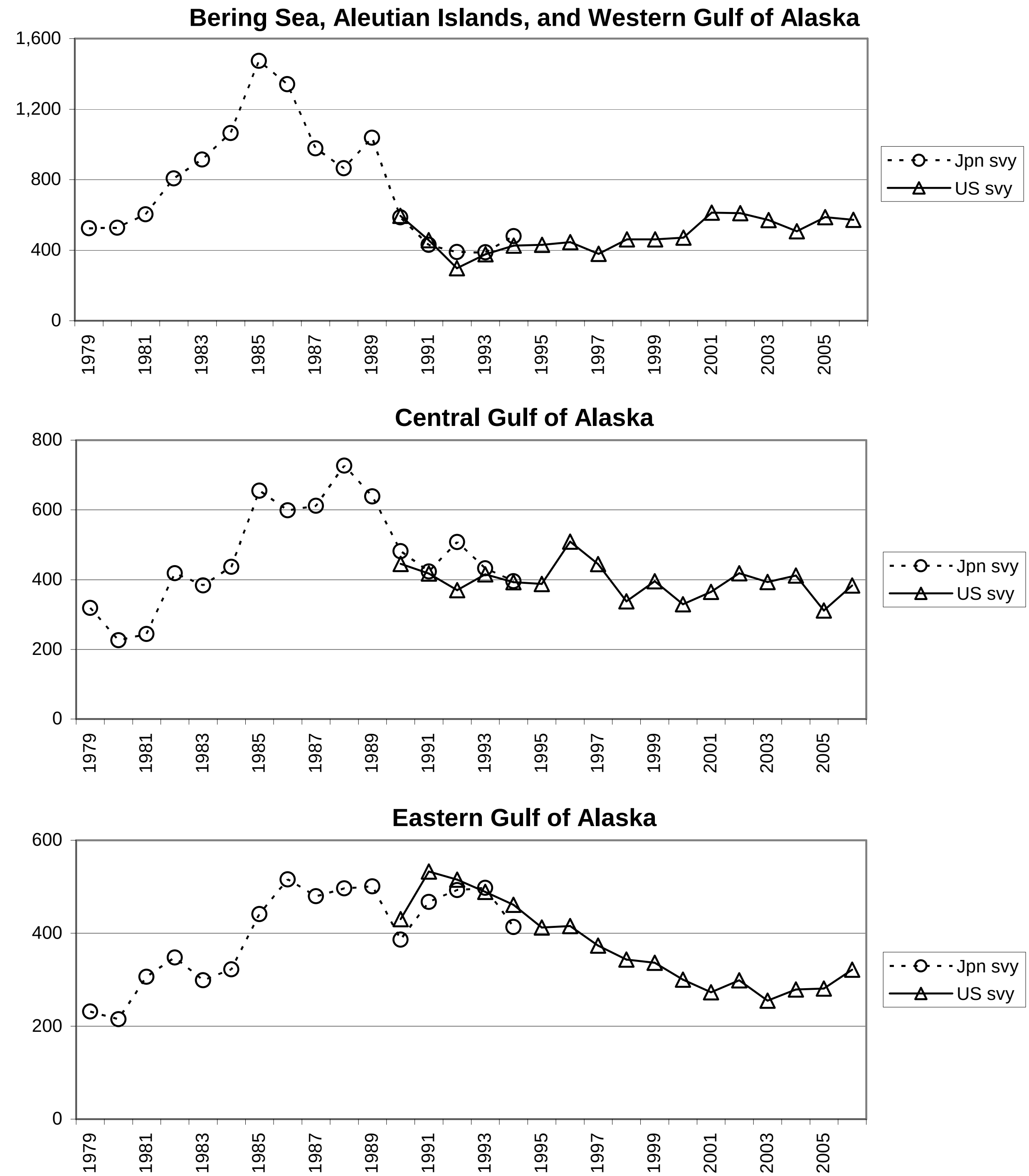


Figure 3.6.—Relative abundance (weight) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the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

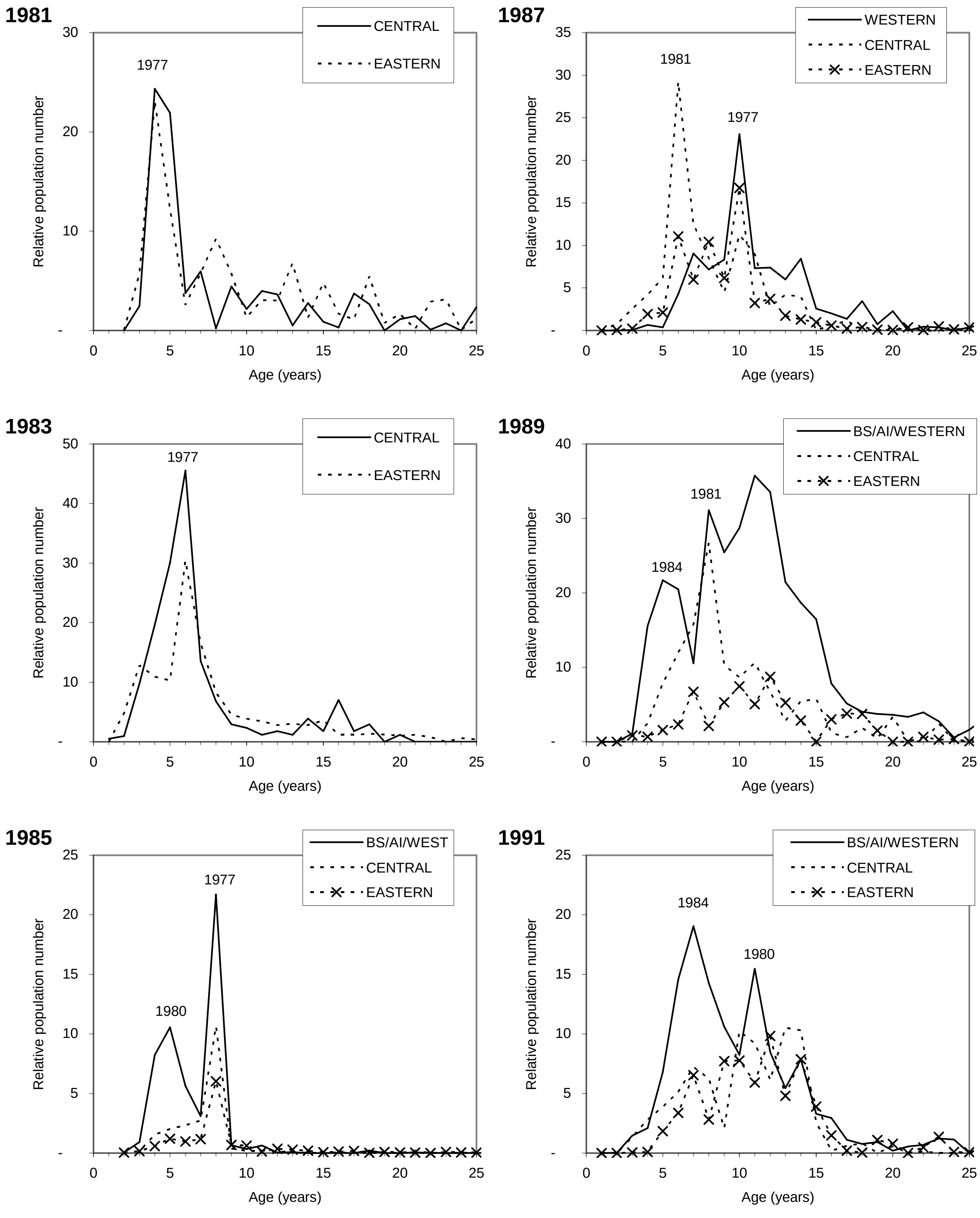


Figure 3.7.—Relative abundance (number in thousands) by age and region from two surveys, the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

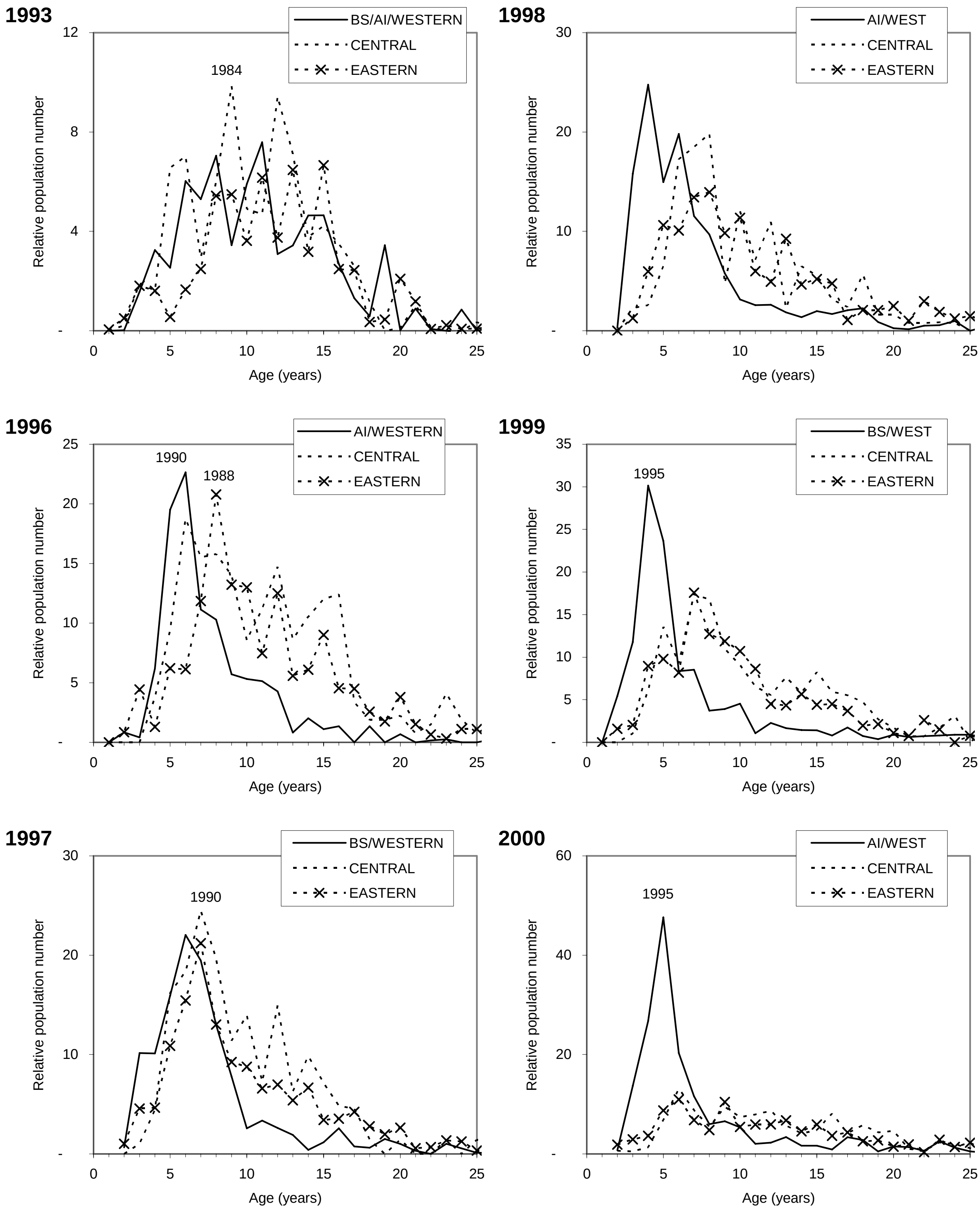


Figure 3.7 cont.

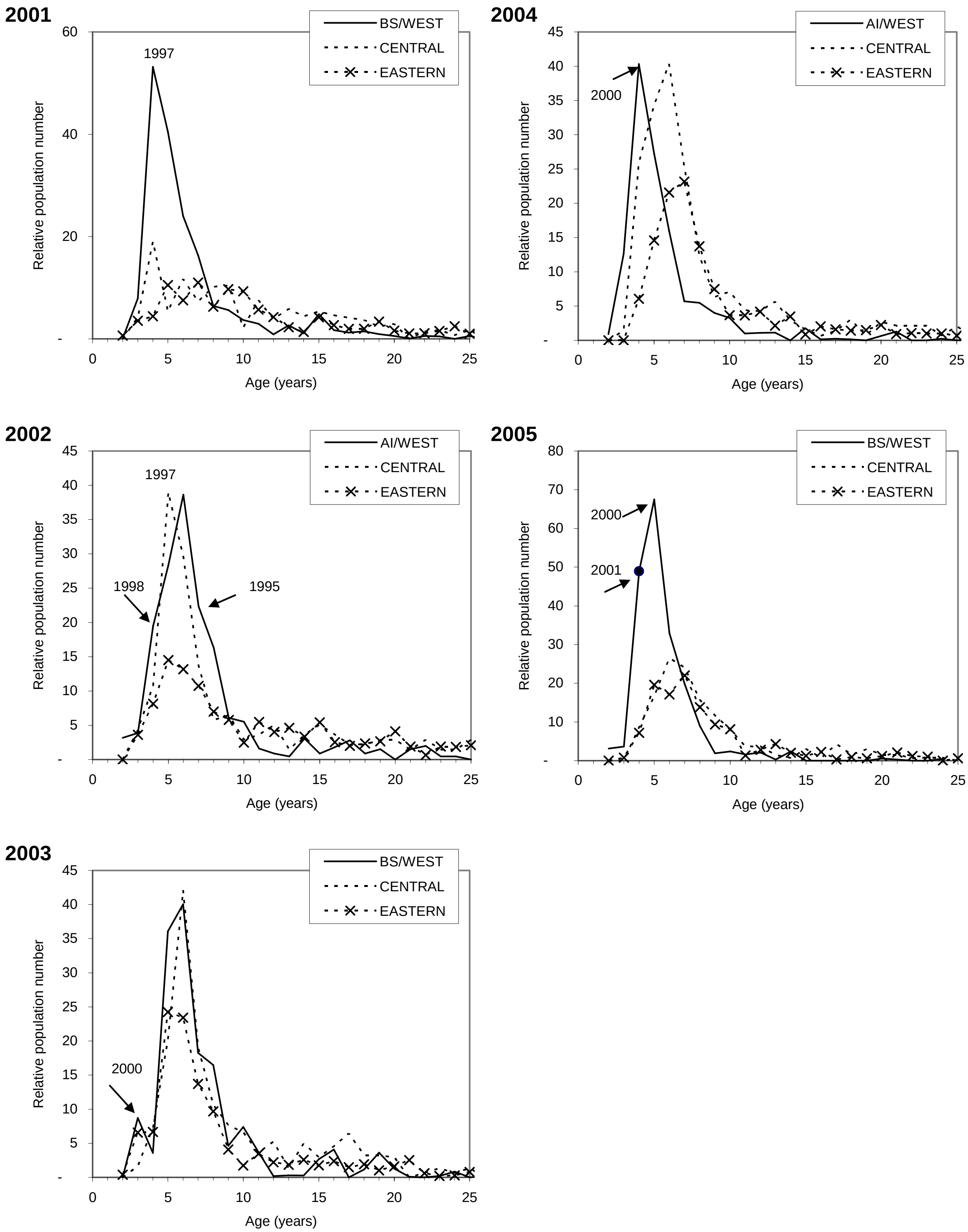


Figure 3.7 cont.

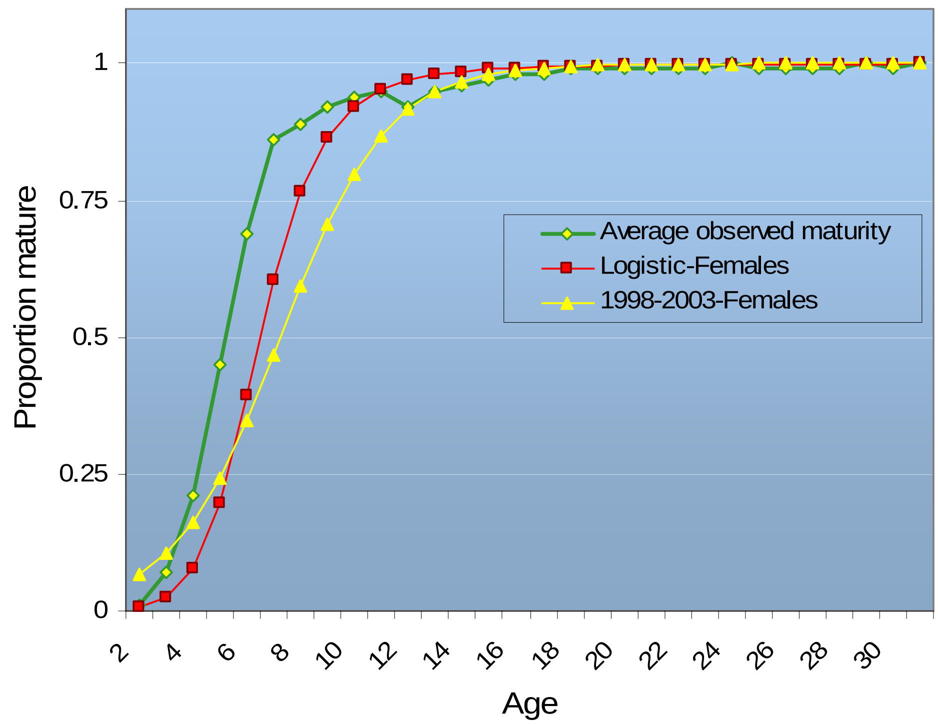


Figure 3.8a. Estimated maturity curves for sablefish. Green line with diamonds is average male and female maturity from Sasaki (1985), Red line with squares are logistic fit to female maturity from Sasaki (1985). Yellow triangles are from a preliminary analysis of visual scan data from the longline survey data.

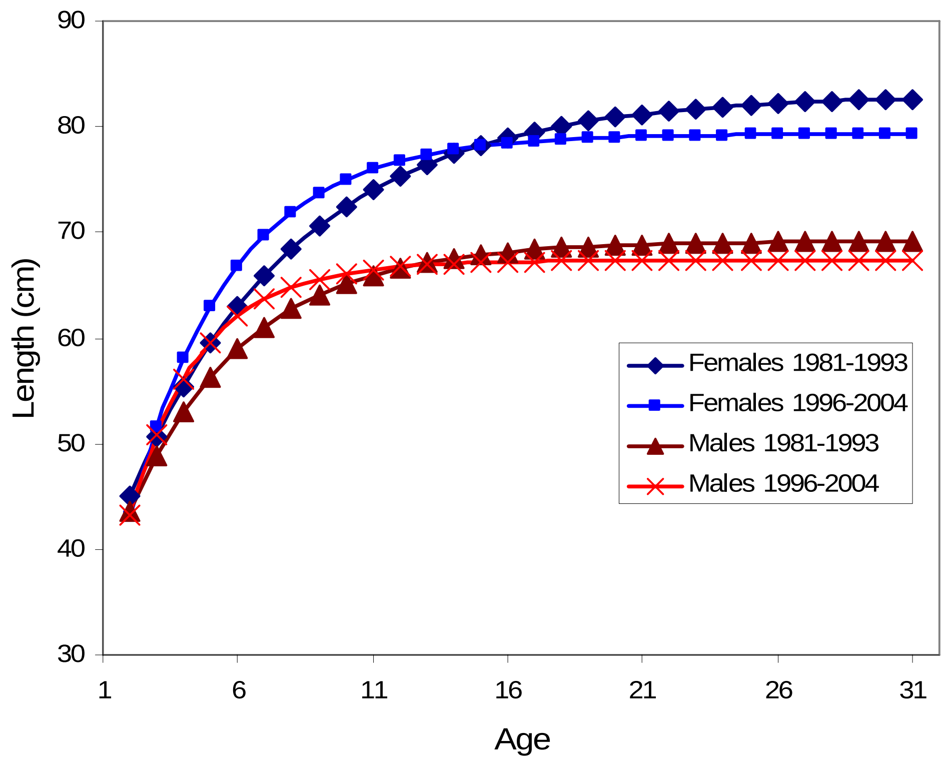


Figure 3.8b. Updated LVB growth curves for sablefish for two time periods. Break point was based on a change in survey design, not a biological reason.

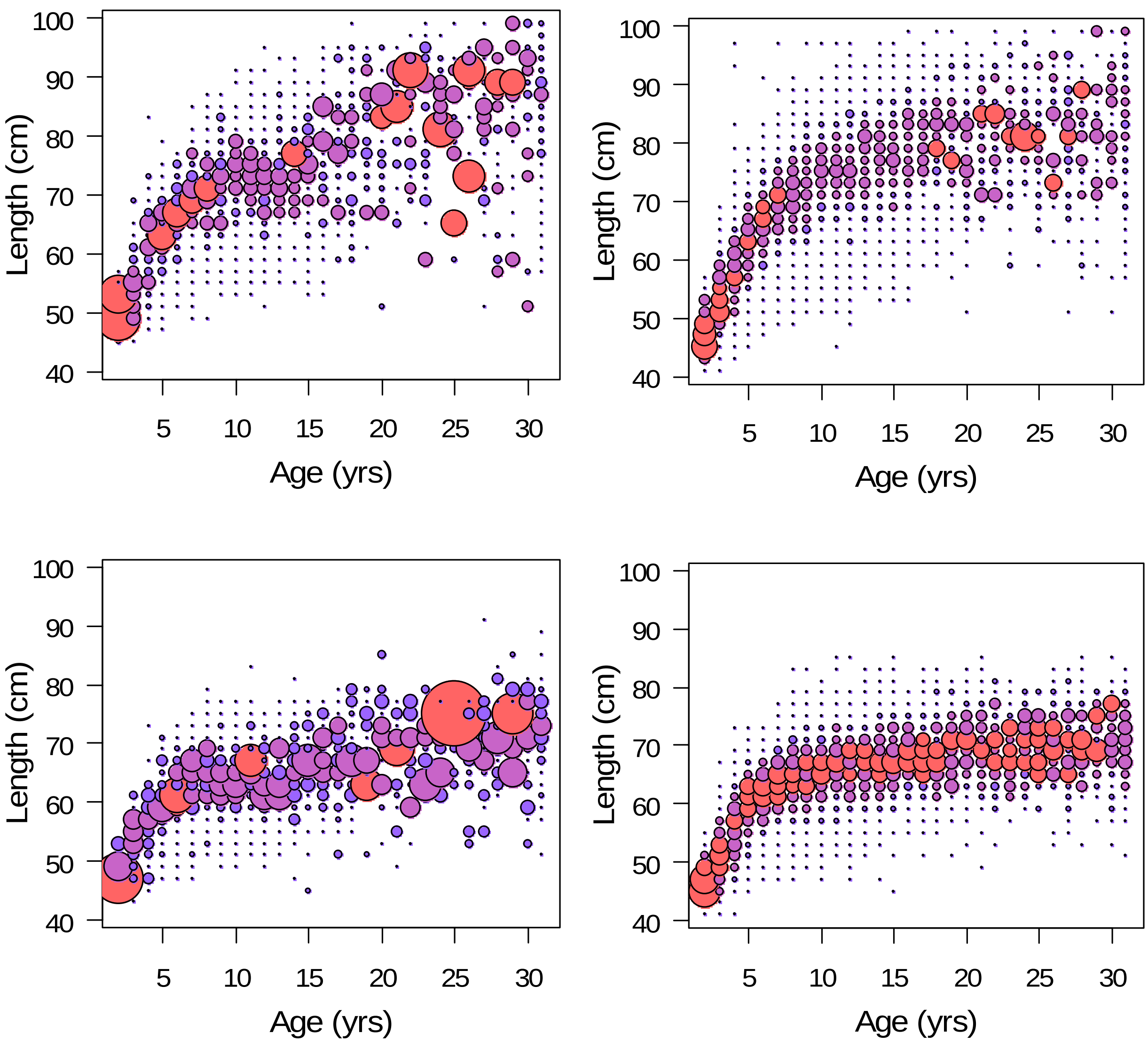


Figure 3.9. Age length transition matrices, left panels are using age-length data from 1981-1993 for females on top and males on bottom, while right panels use all data from 1981-2004.

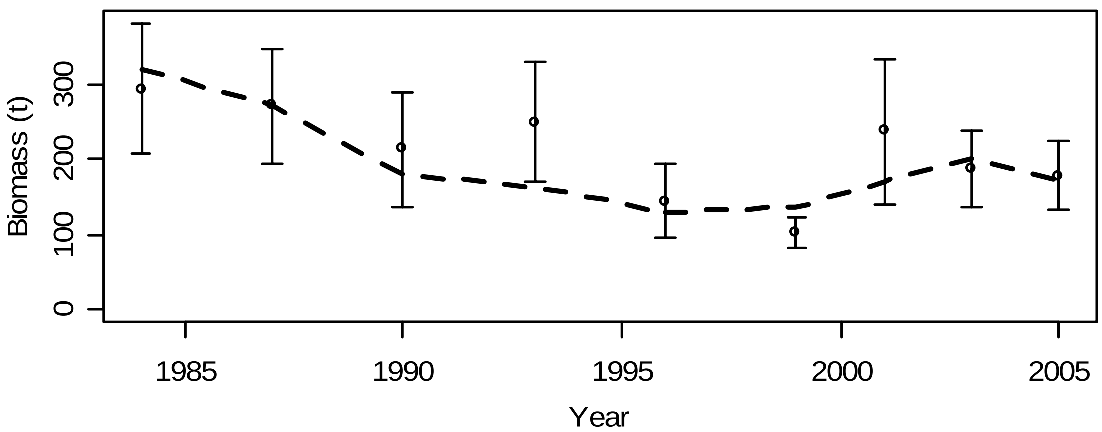


Figure 3.10: Gulf of Alaska trawl survey biomass estimates for sablefish from depths of 500 meters and less with predicted as a dashed line from Model 3. Error bars are approximate normal 95% confidence intervals.

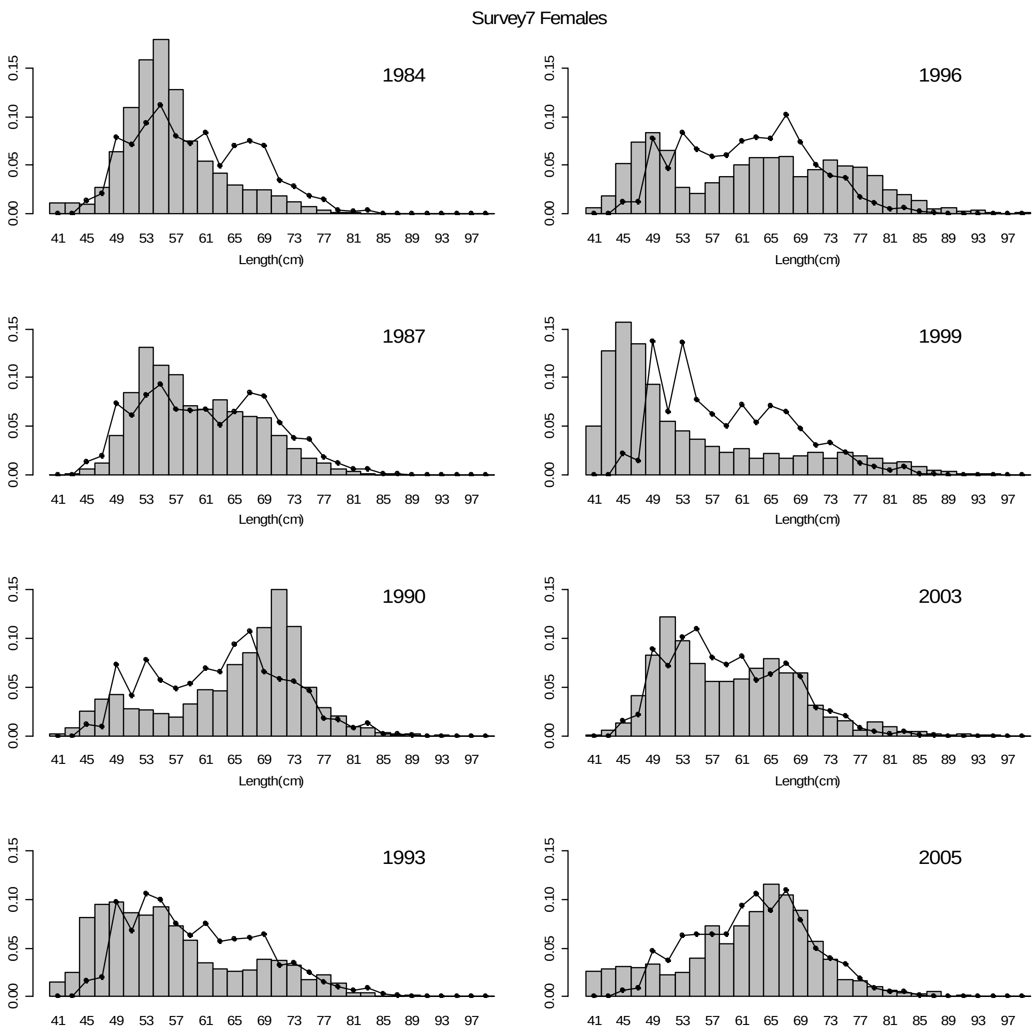


Figure 3.11a. Gulf of Alaska bottom trawl survey lengths for female sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

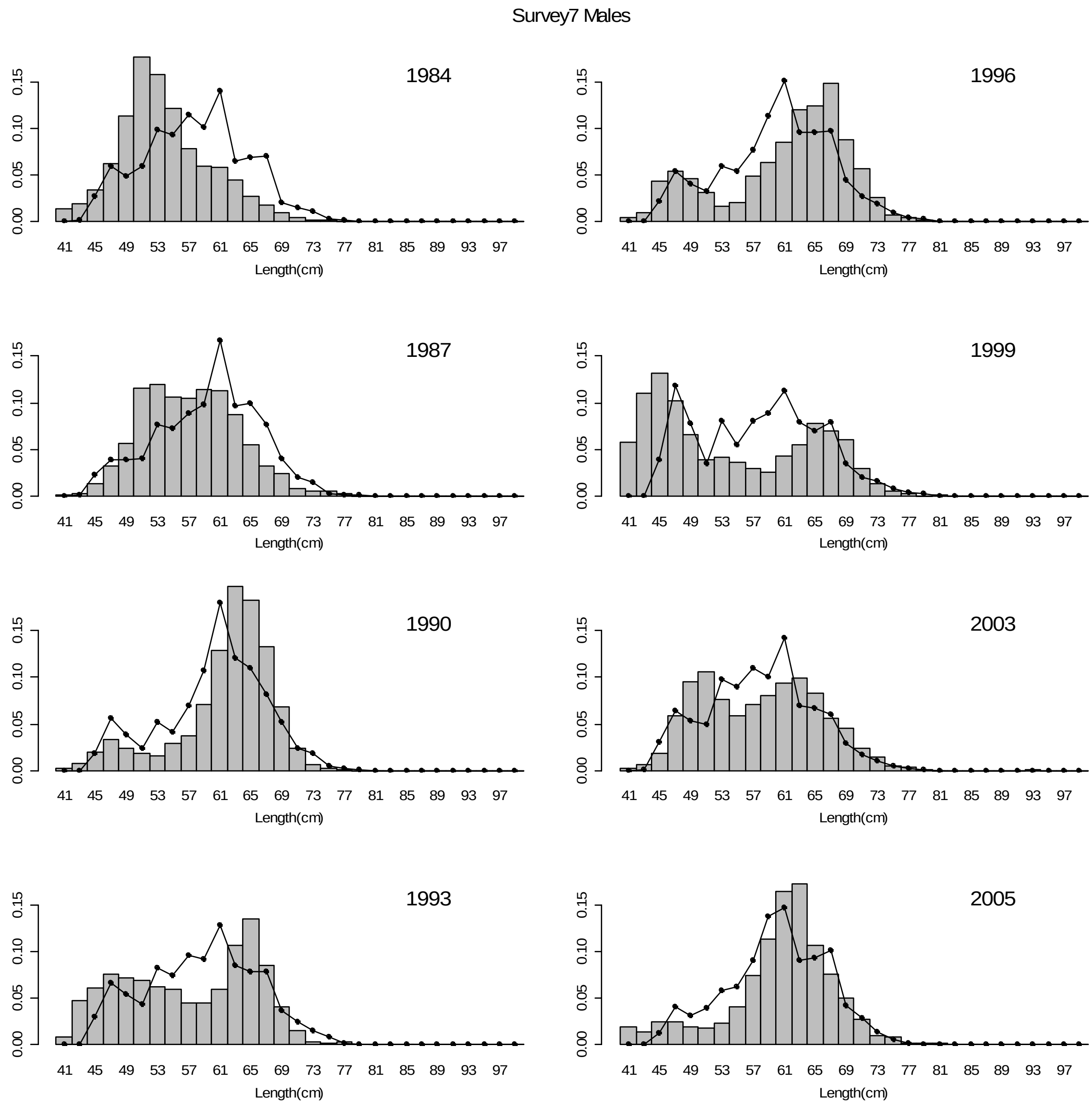


Figure 3.11b. Gulf of Alaska bottom trawl survey lengths for male sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

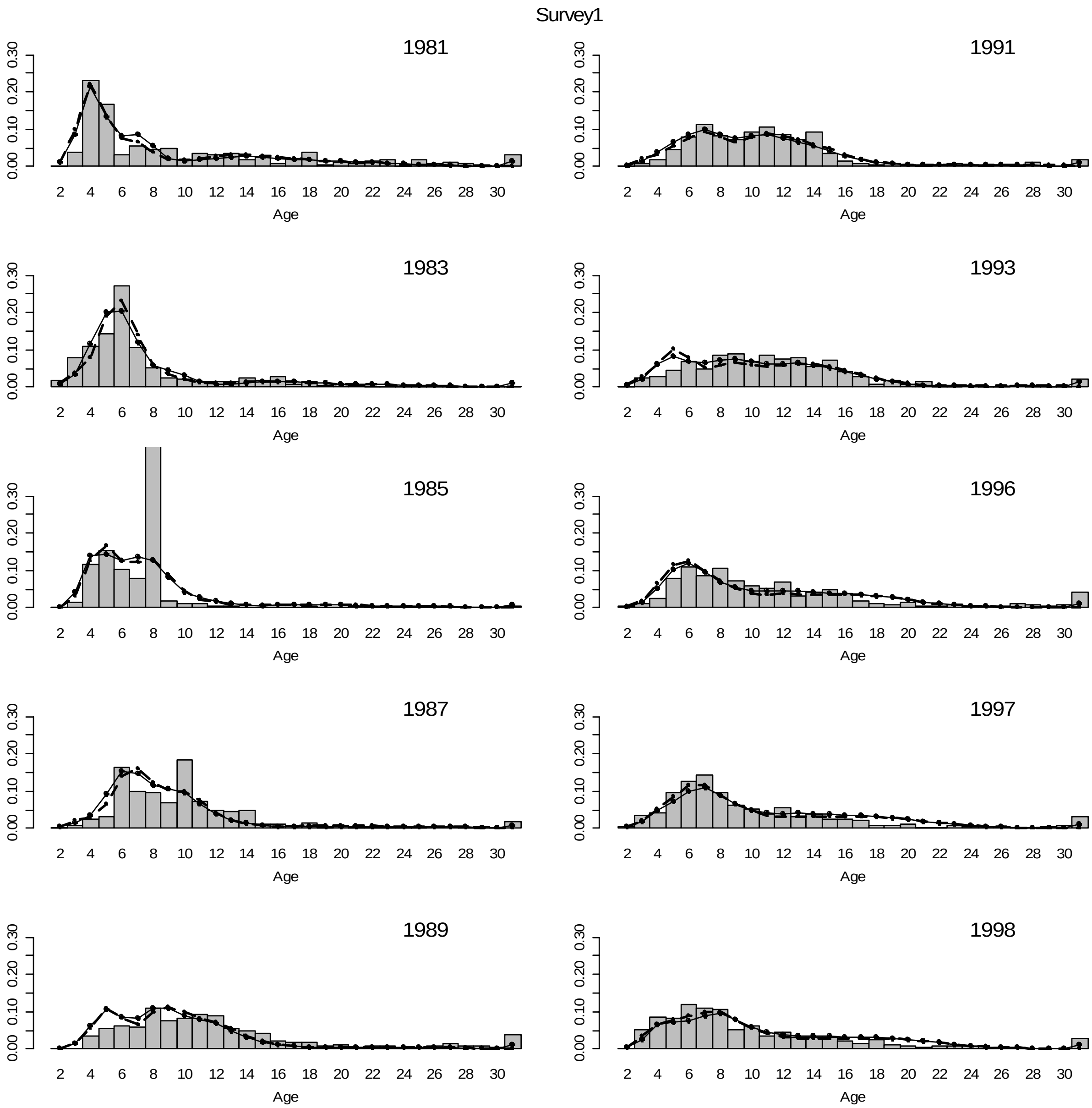


Figure 3.12a.—Observed (bar) and predicted (line) sablefish survey age frequency by age group and year. Dashed line is the 2005 model (Model 1) and the solid line is the 2006 recommended model (Model 3).

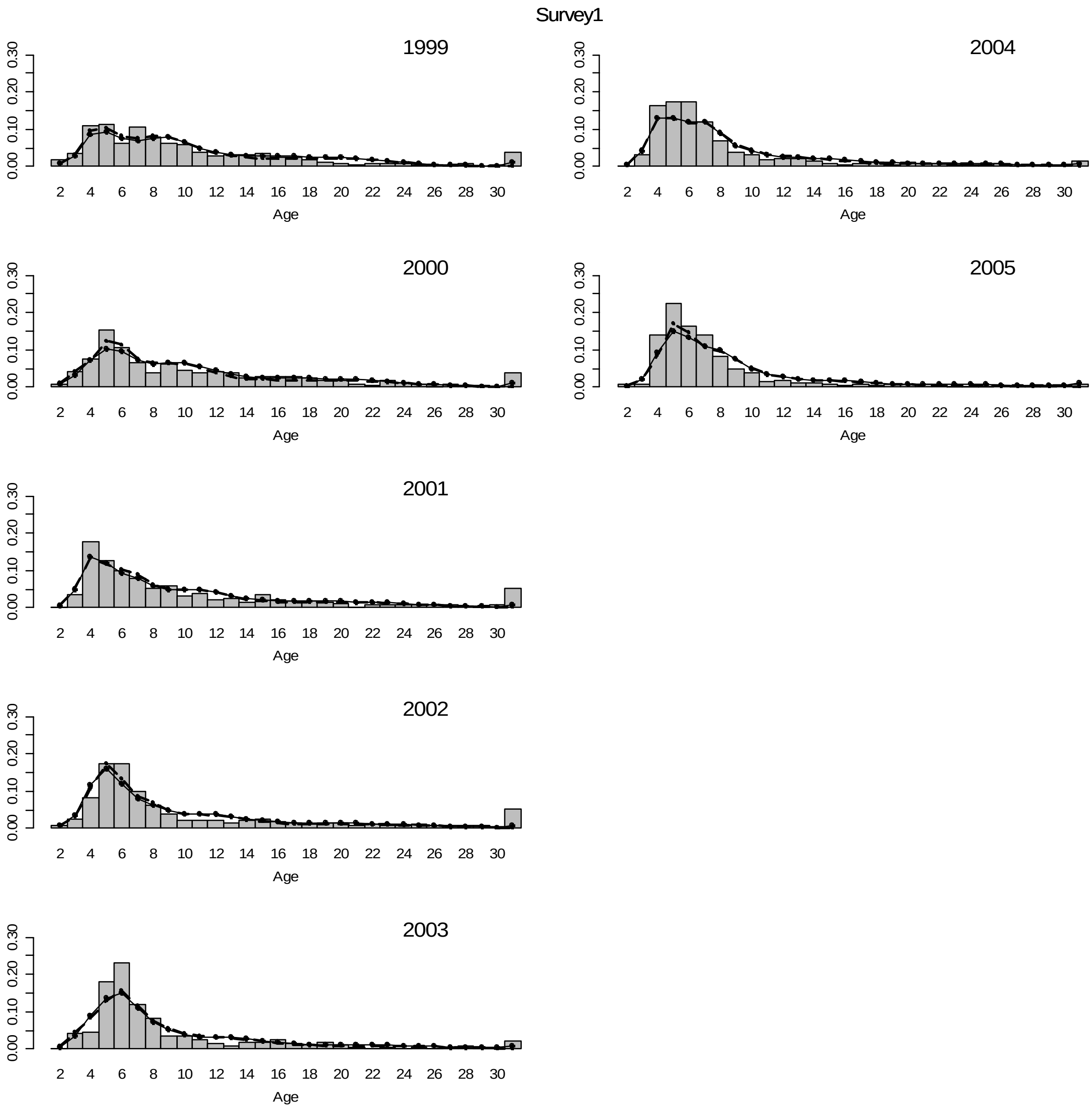


Figure 3.12a.—(continued).

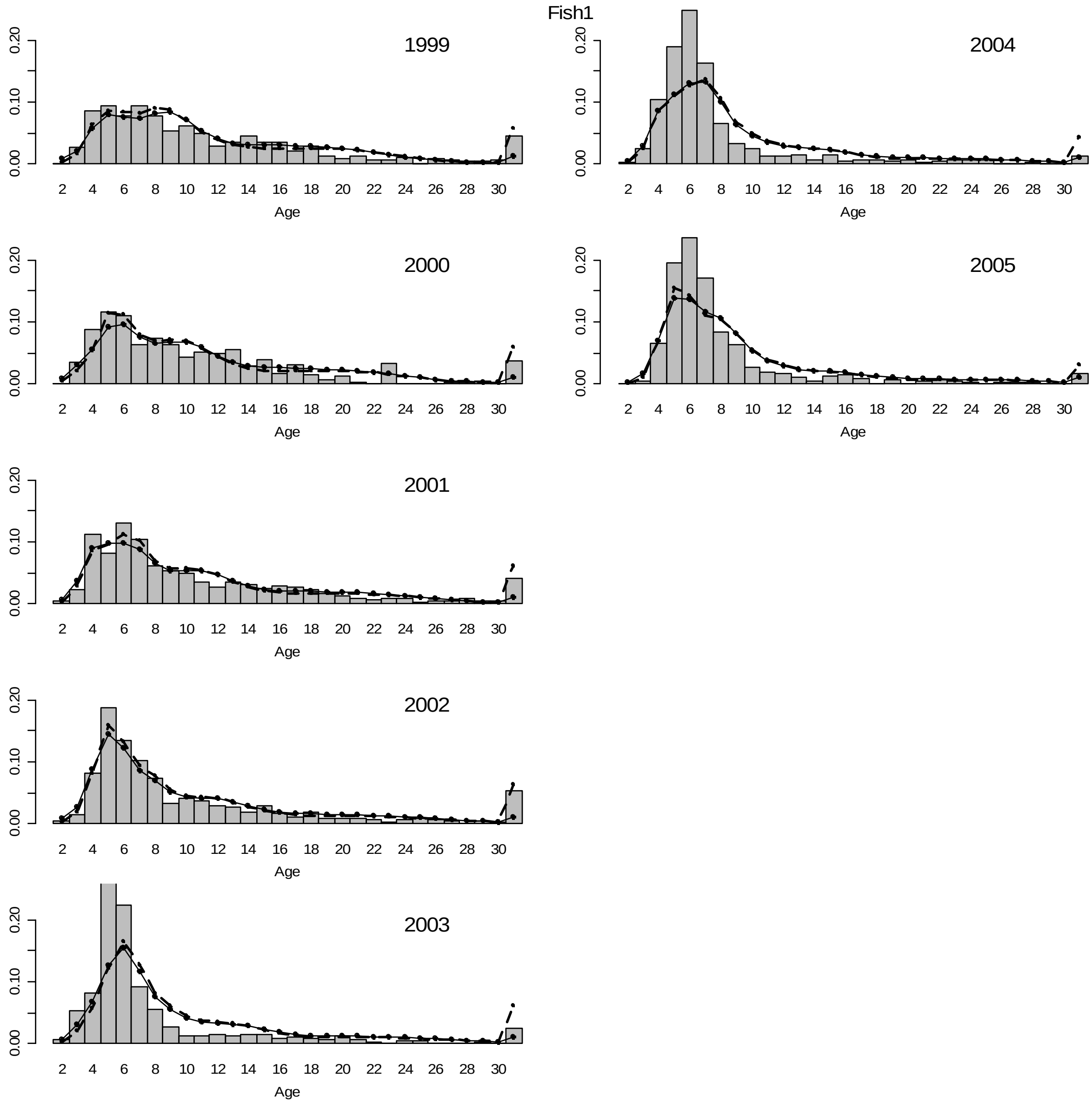


Figure 3.12b: Domestic longline fishery age compositions. Bars are observed values, Model 1 predictions are the dashed line, Model 3 predictions are the solid line.

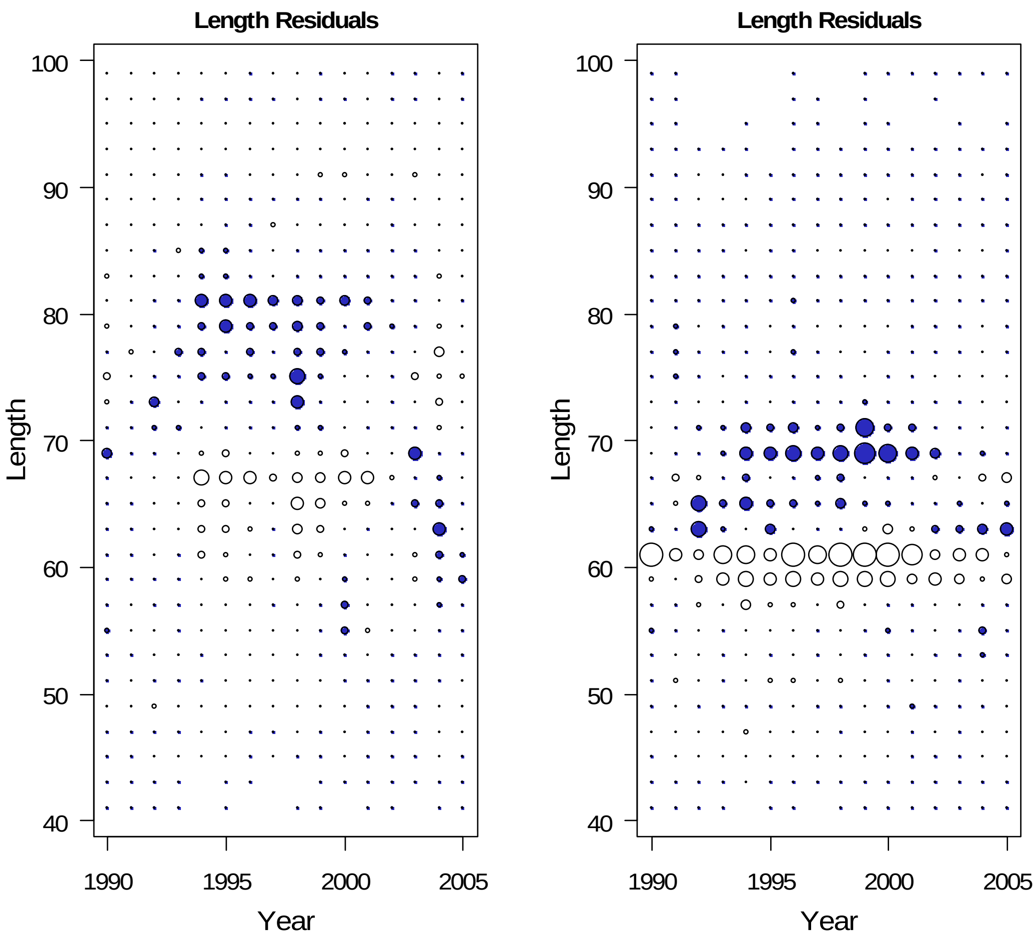


Figure 3.13: Residuals from the U.S. longline fishery length compositions for Model 3. Dark bubbles are positive residuals, while open bubbles are negative residuals.

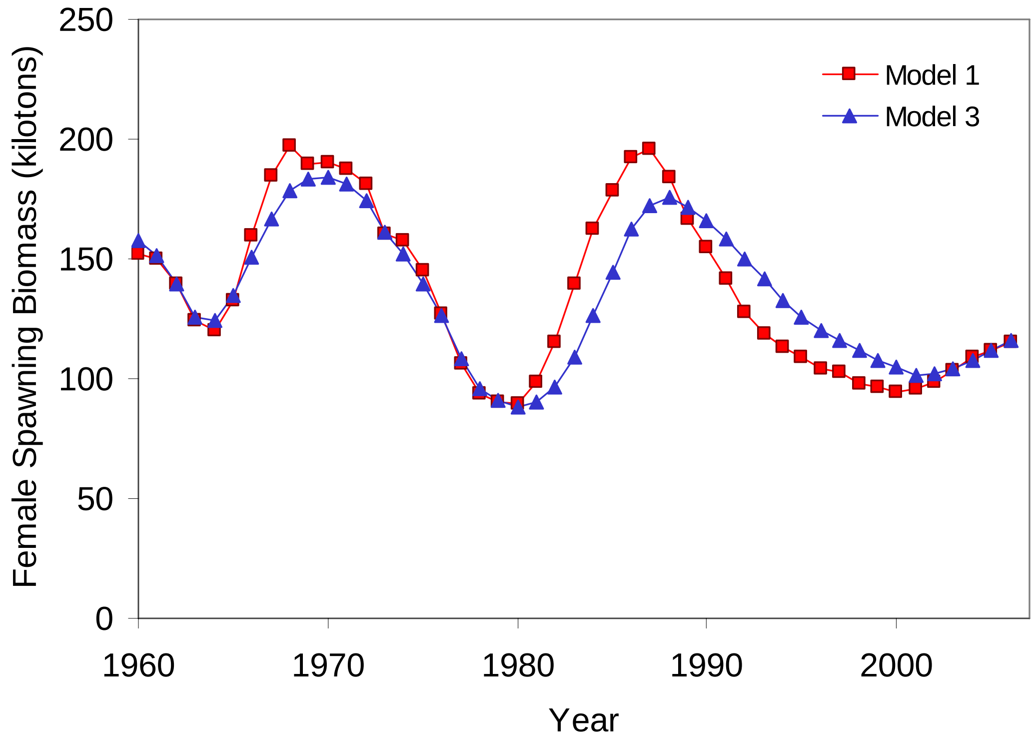


Figure 3.14a.--Estimated sablefish female spawning biomass (thousands mt) versus year by assessment model year. The recommended model is Model 3. Model 1 is the 2006 version of the 2005 model but approximately corrected to reflect female spawning biomass.

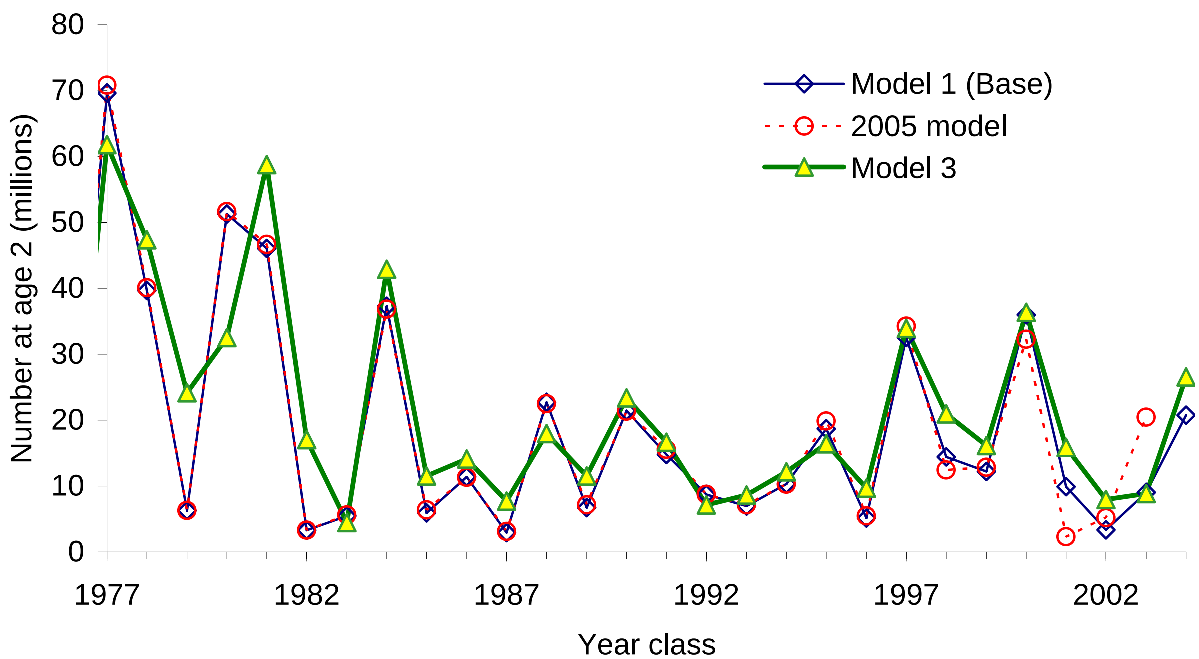


Figure 3.14b.--Estimated recruitment (number at age 2, millions) versus year for the 2005 and 2006 assessment models (Models 1 and 3).

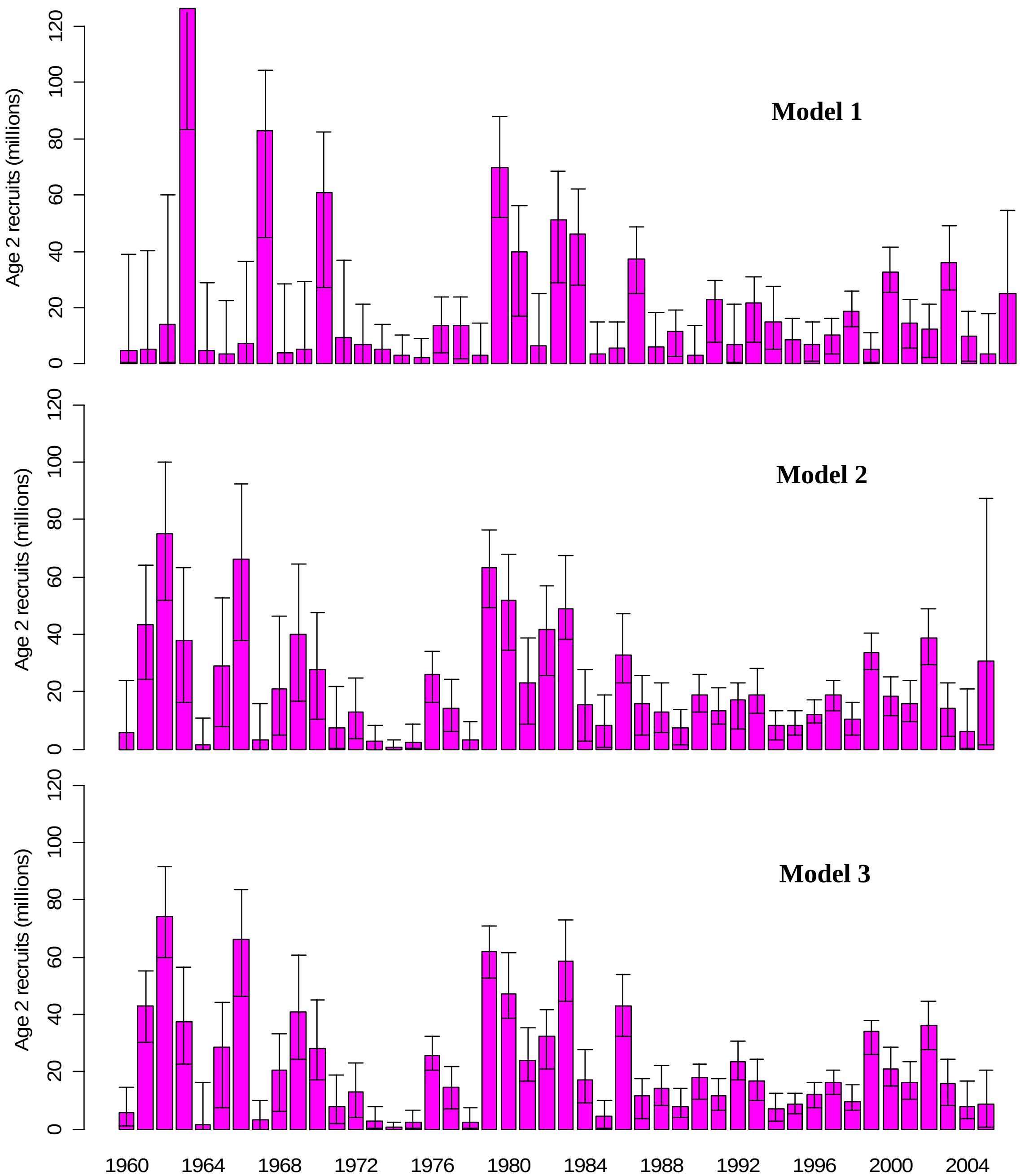


Figure 3.15.—Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on 5,000,000 MCMC runs. Year on bottom is year when fish recruited as age 2 sablefish, so year class is 2 years prior.

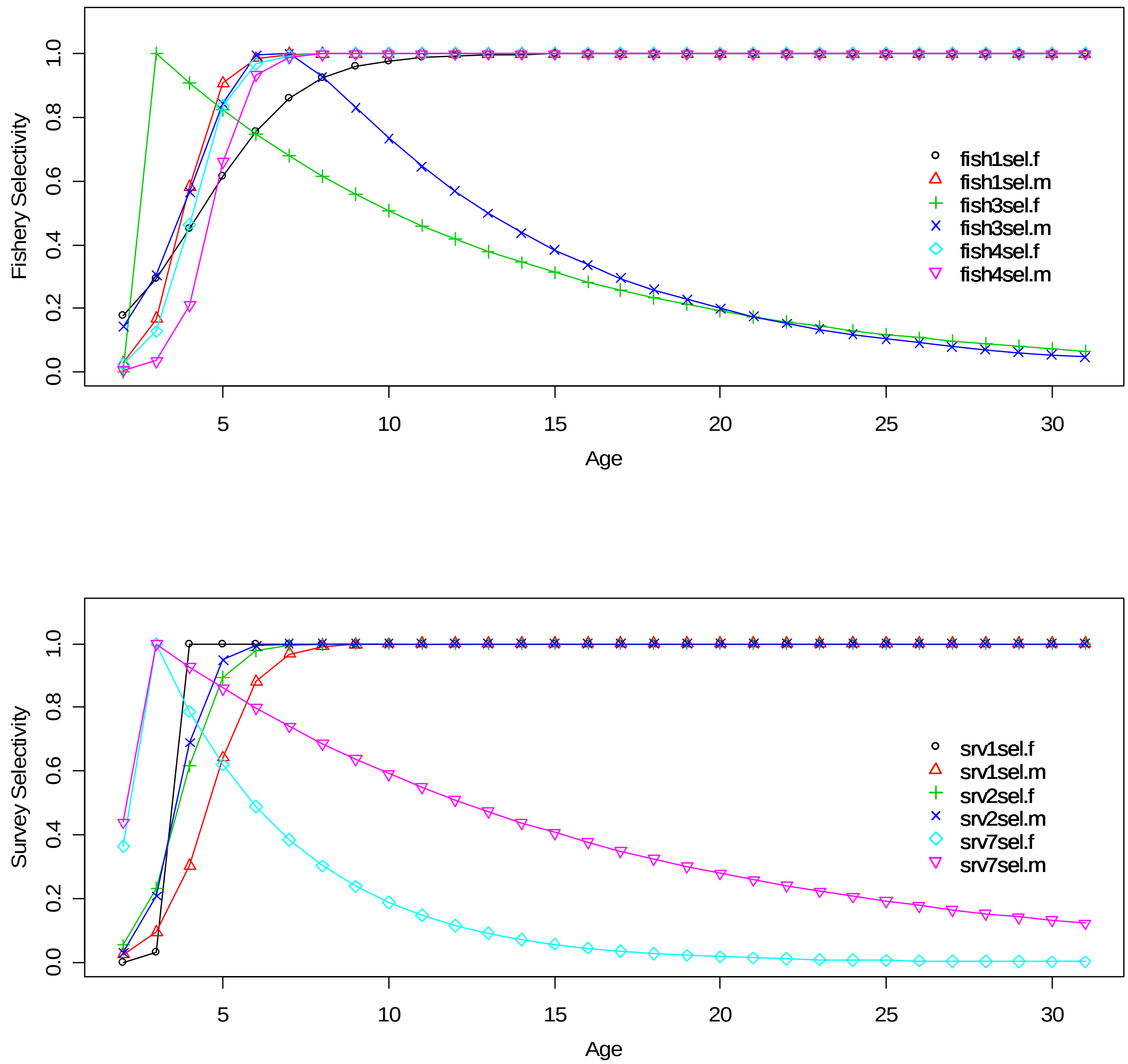


Figure 3.16.--Sablefish selectivities from Model 3. Top panel is fishery selectivities where fish1=Dom LL fishery-derby, fish3=Japanese LL survey, fish4=Dom LL fishery IFQ. Bottom panel is survey selectivities, srv1= Dom. LL survey, srv2 = Japanese LL survey, srv7 = NMFS GOA trawl survey. Sexes are represented by .f=female and .m=male.

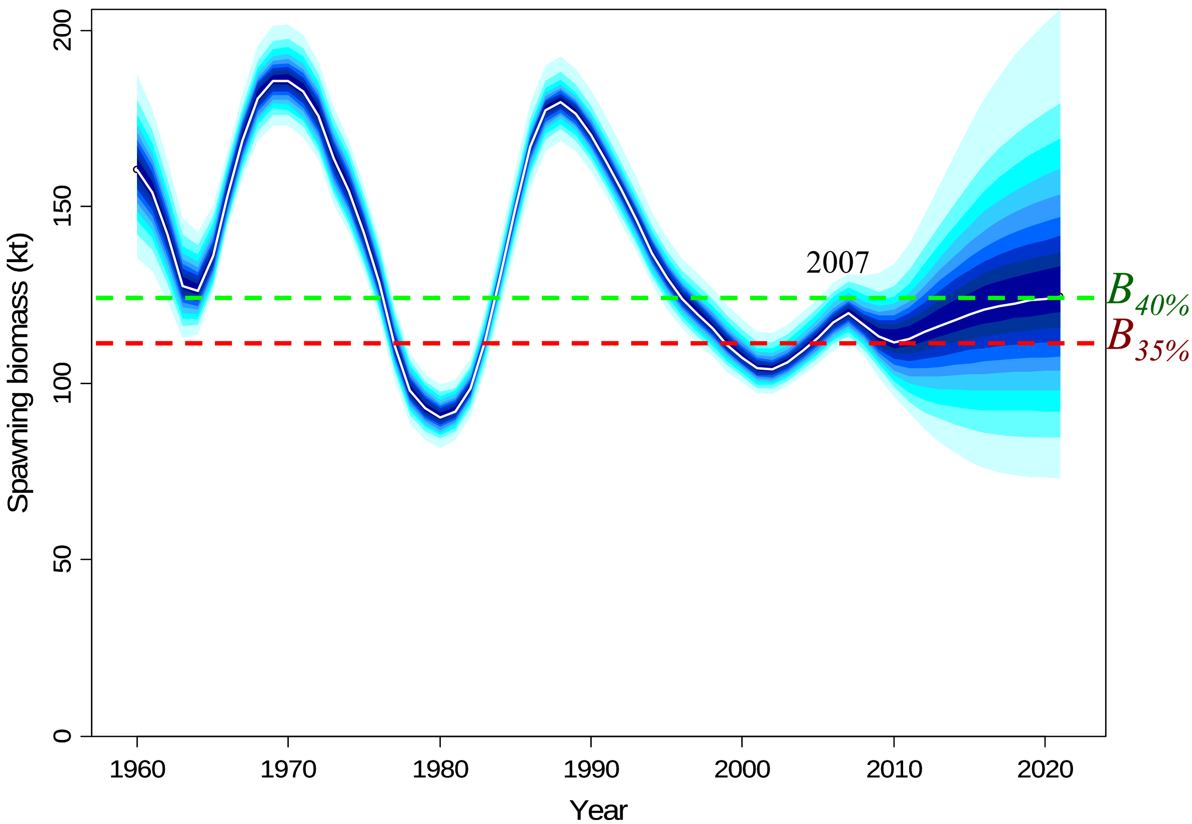


Figure 3.17.--Estimates of female spawning biomass (thousands mt) and their uncertainty. White line is the median and shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 5,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval.

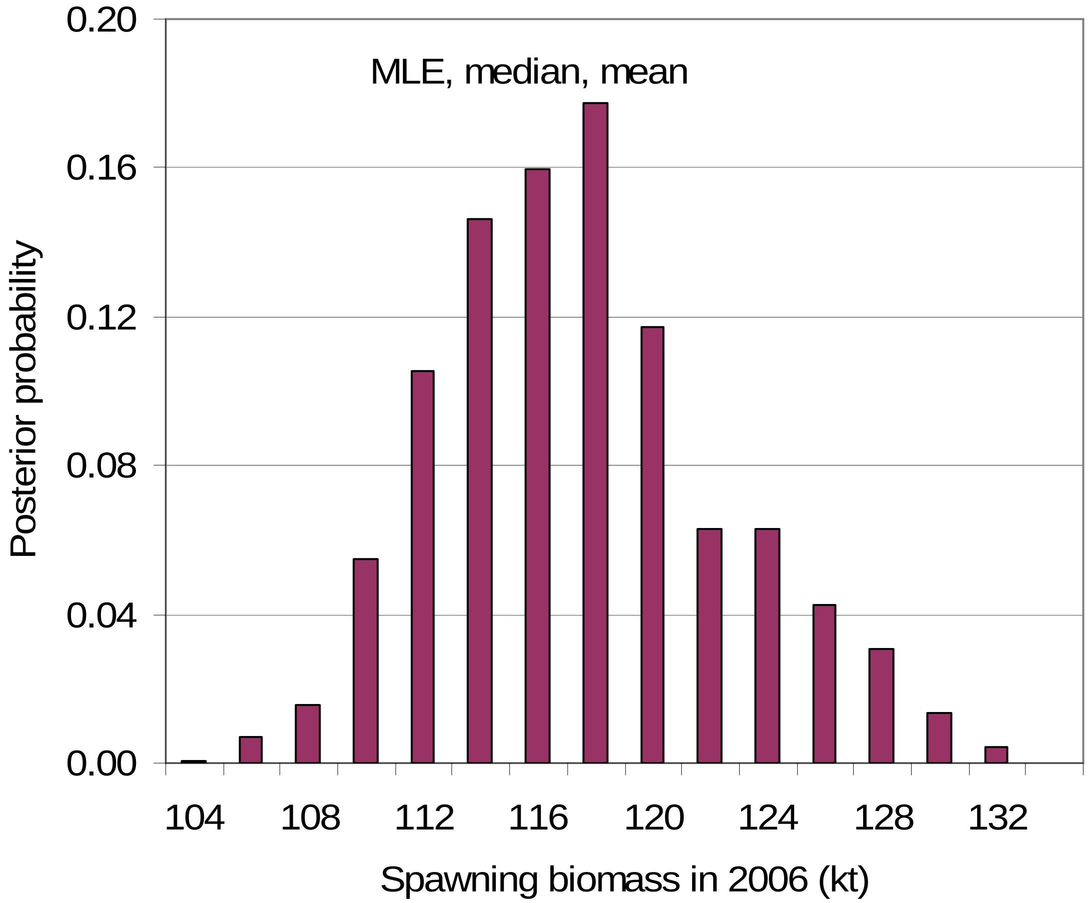


Figure 3.18.--Posterior probability distribution for spawning biomass (thousands mt) in 2006.

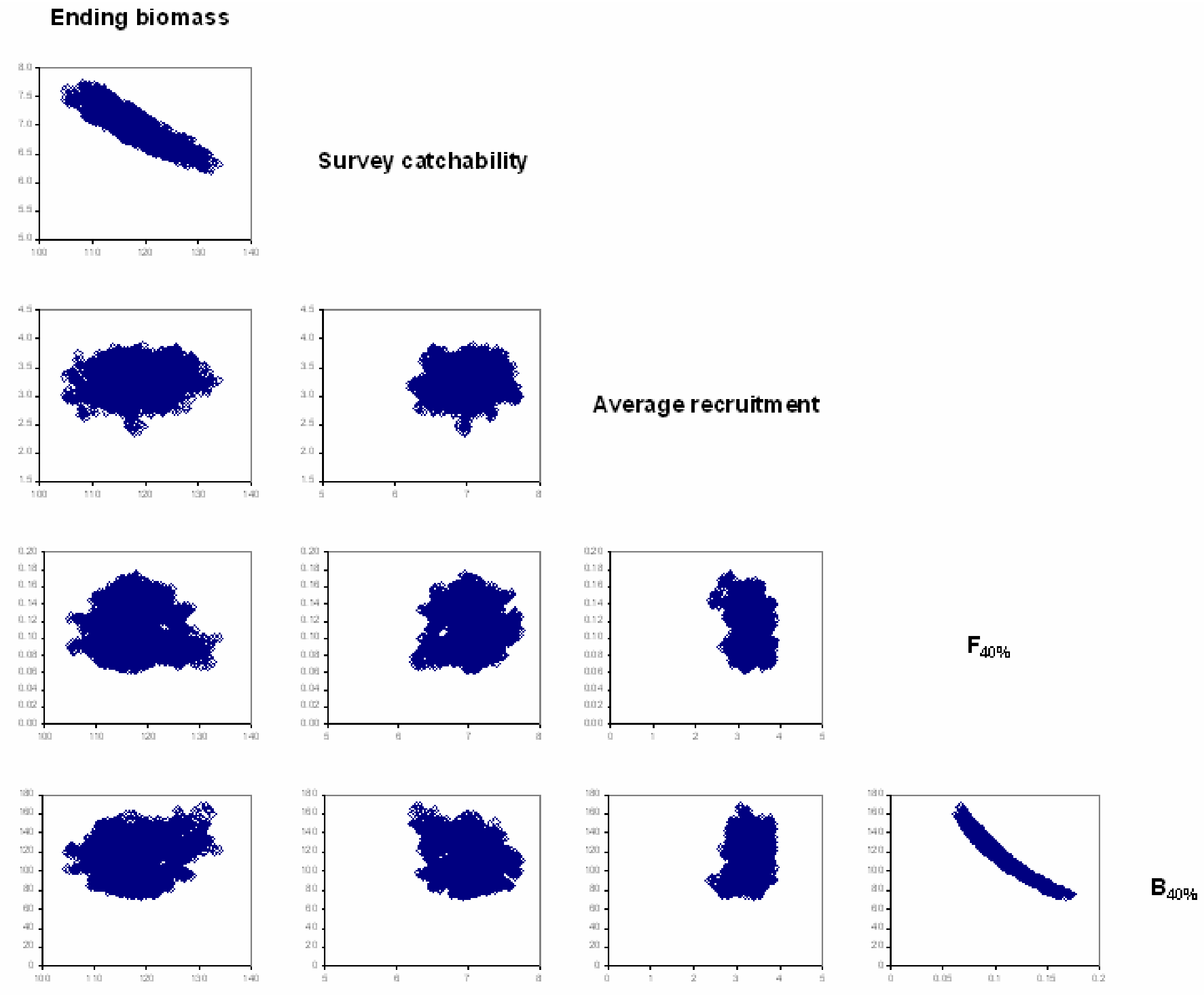
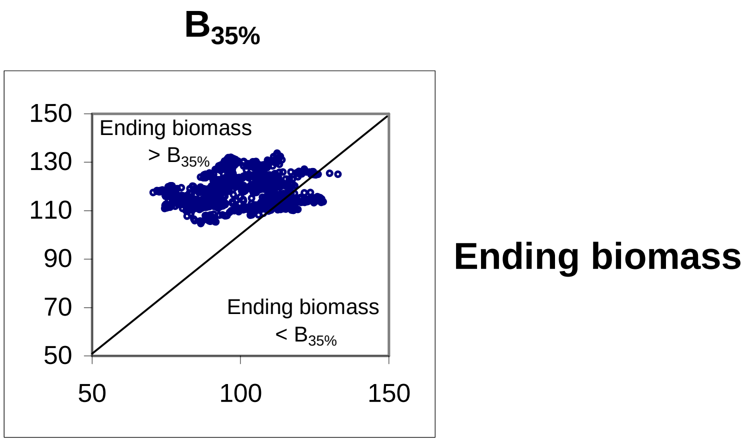


Figure 3.19. Pairwise scatterplots of key parameter MCMC runs.

a.



b.

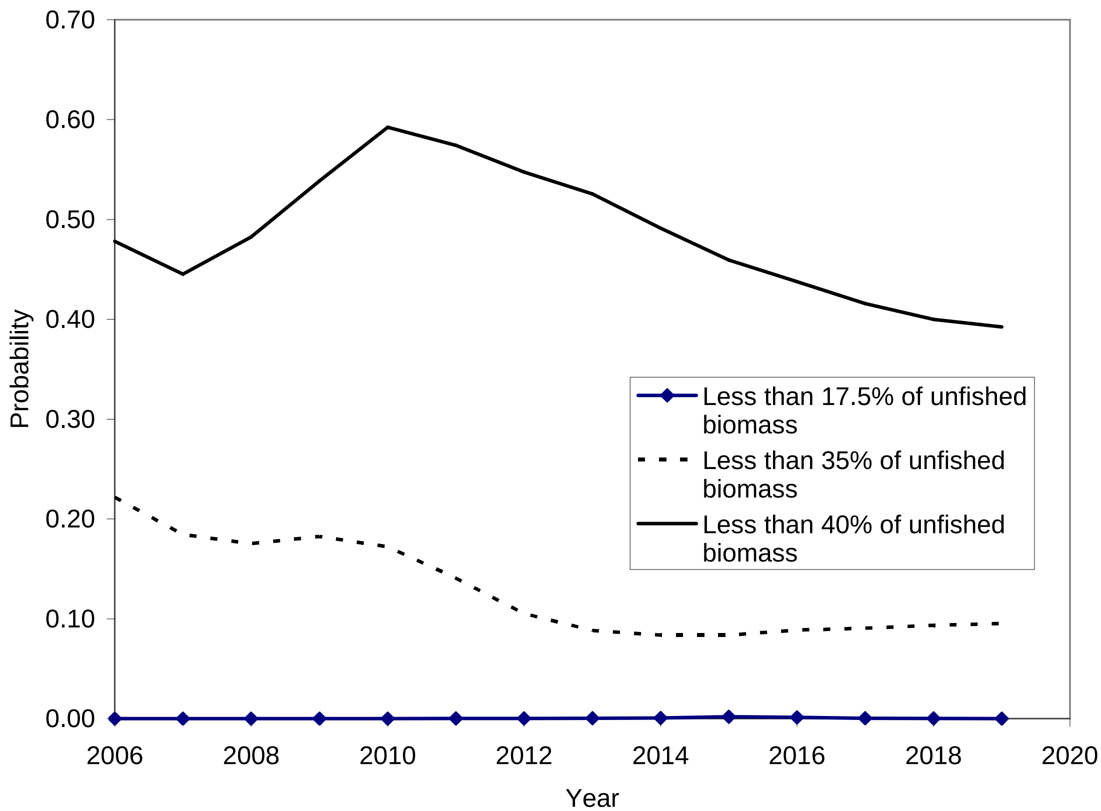


Figure 3.20a.—Ending biomass was compared to $B_{35\%}$ for each MCMC run and the probability that ending biomass falls below $B_{35\%}$ was estimated (0.19). 3.20b. Probability that projected spawning biomass will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

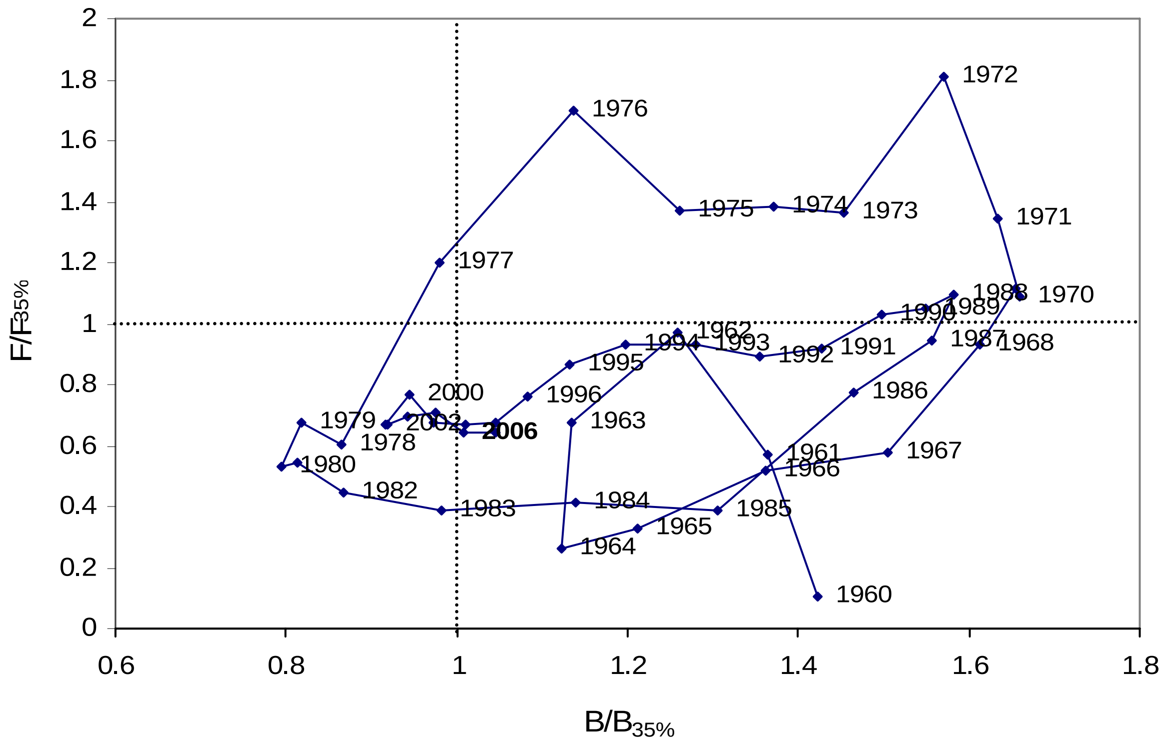


Figure 3.21 -- Management path for Alaskan sablefish plotting the ratio of current fishing mortality and fishing mortality limit versus the ratio of spawning biomass and the current limit spawning biomass over time.

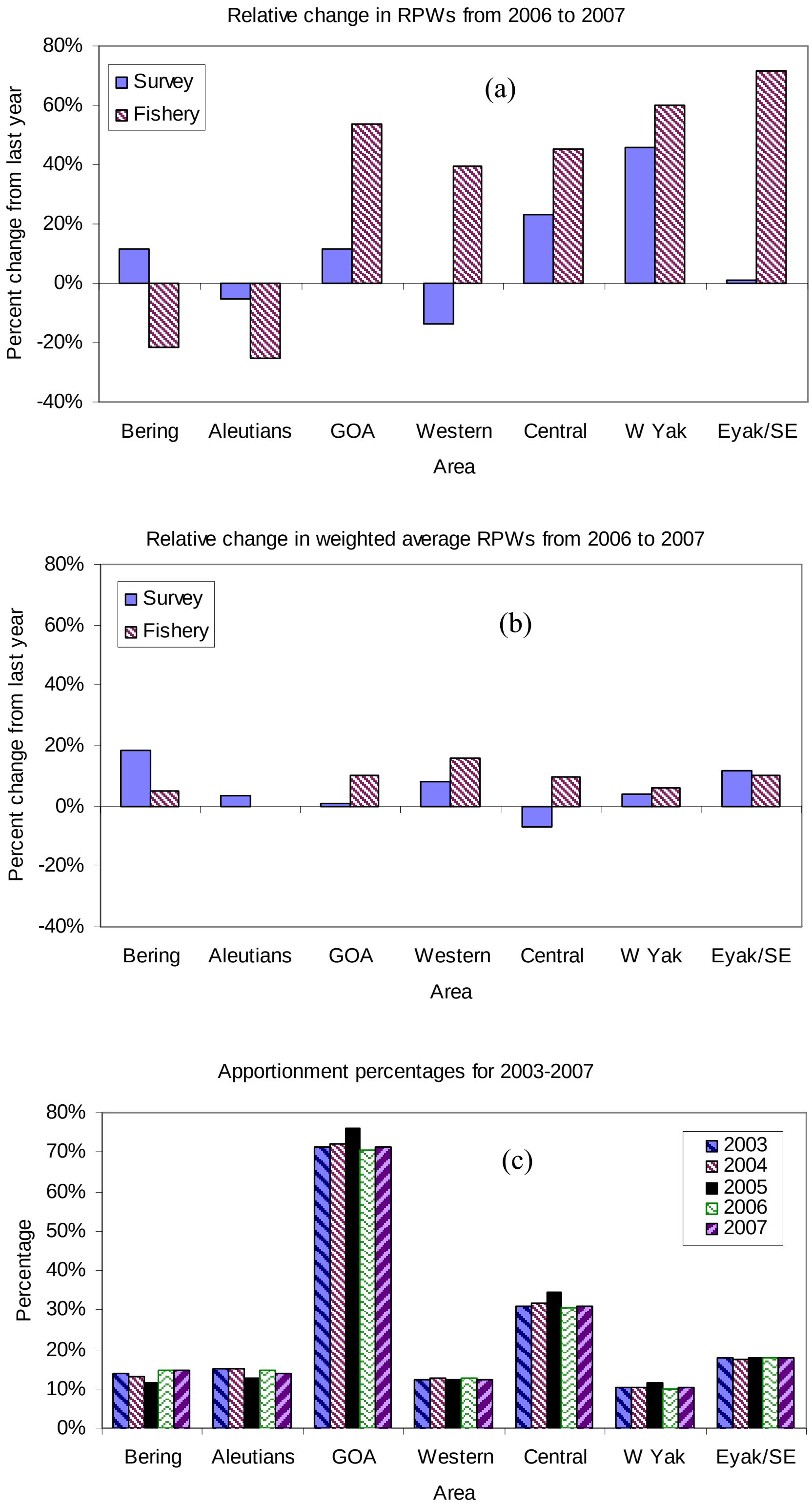
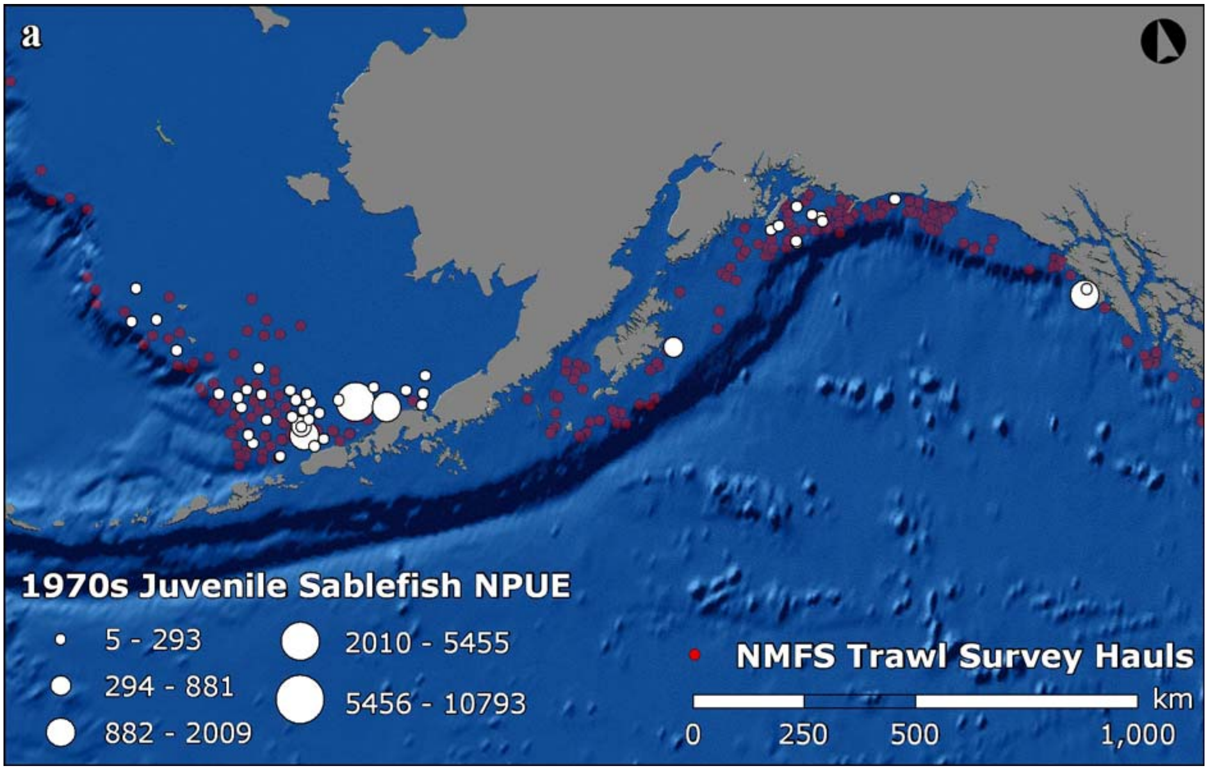


Figure 3.22 -- (a) The percentage change of each Relative Population Weight (RPW) index by area from 2005 assessment to 2006 assessment. (b) The percentage change of the weighted average of each RPW index by area. (c) The apportionment percentages by area of ABCs for 2003-2007.



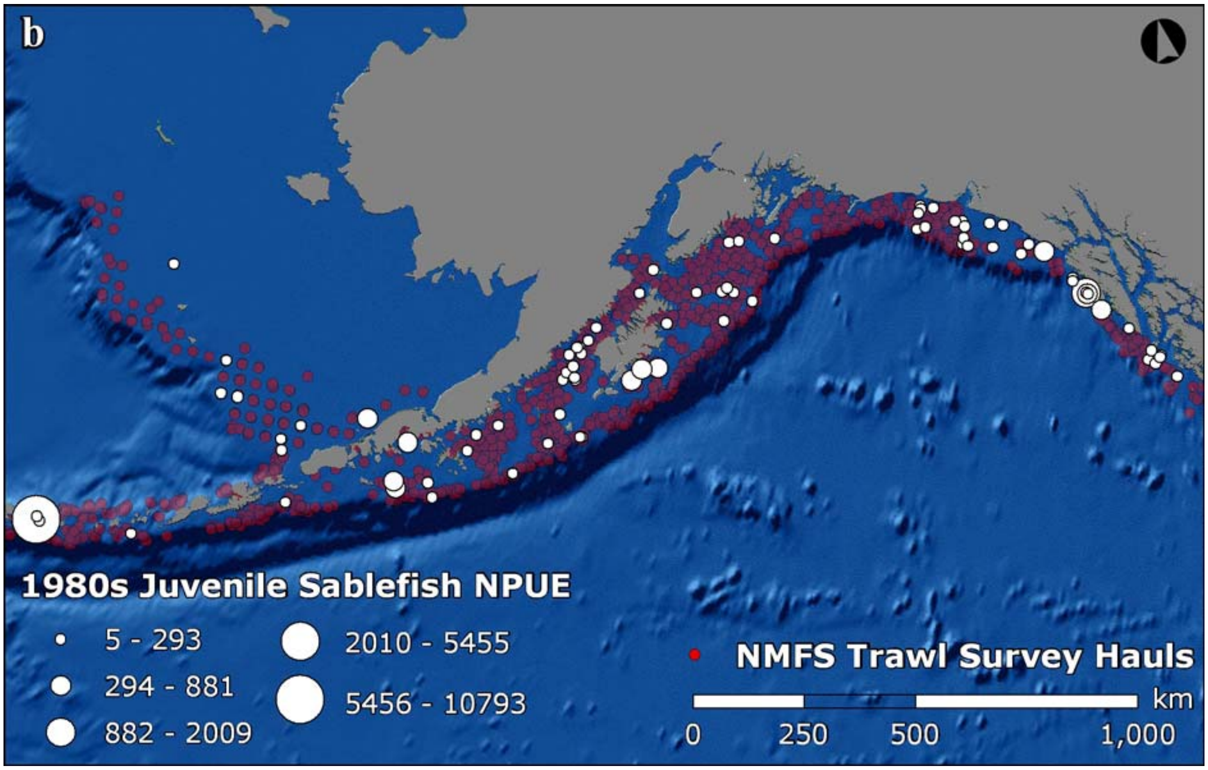
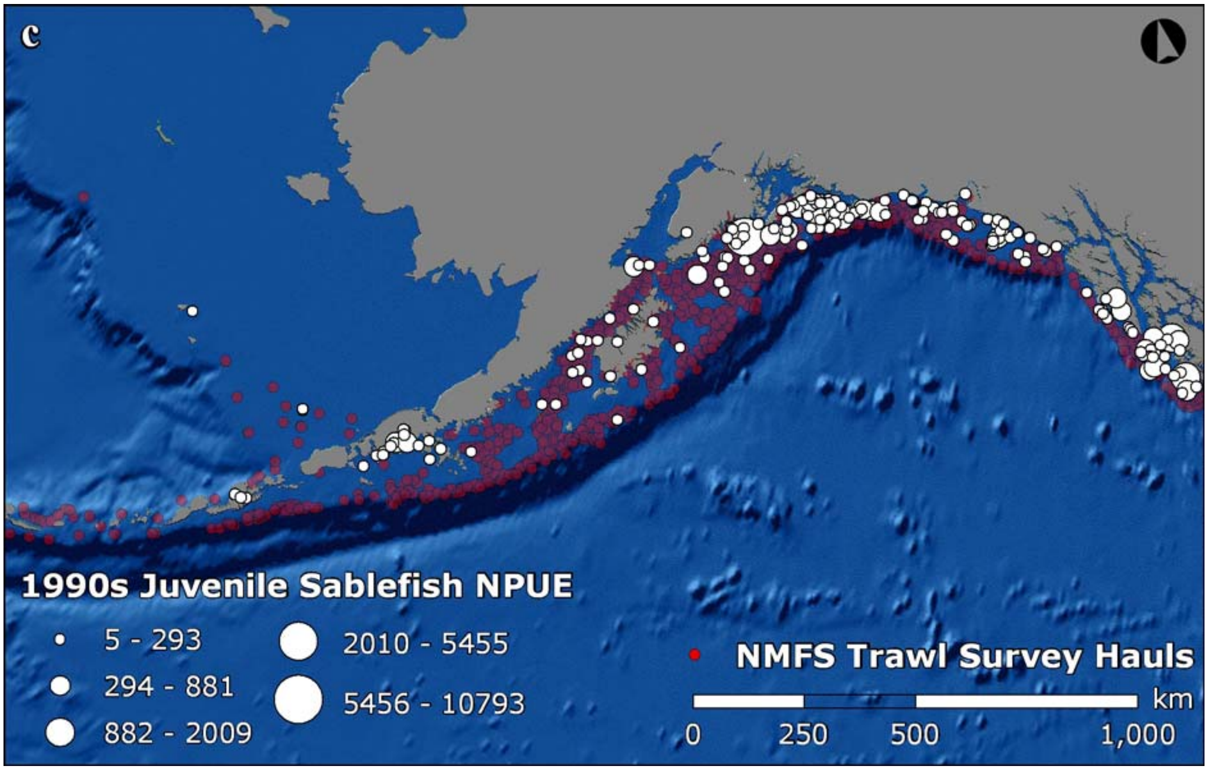


Figure 3.23 -- Distribution of juvenile sablefish taken in the NMFS standard bottom trawl surveys. Values are based on percent of juveniles (40cm or less) in length sample multiplied by numbers of sablefish per unit effort (NPUE) for each trawl haul. Data is shown by decade (a) 1970s, (b) 1980s, (c) 1990s and (d) 2000s and only hauls that caught sablefish are included (red dots).



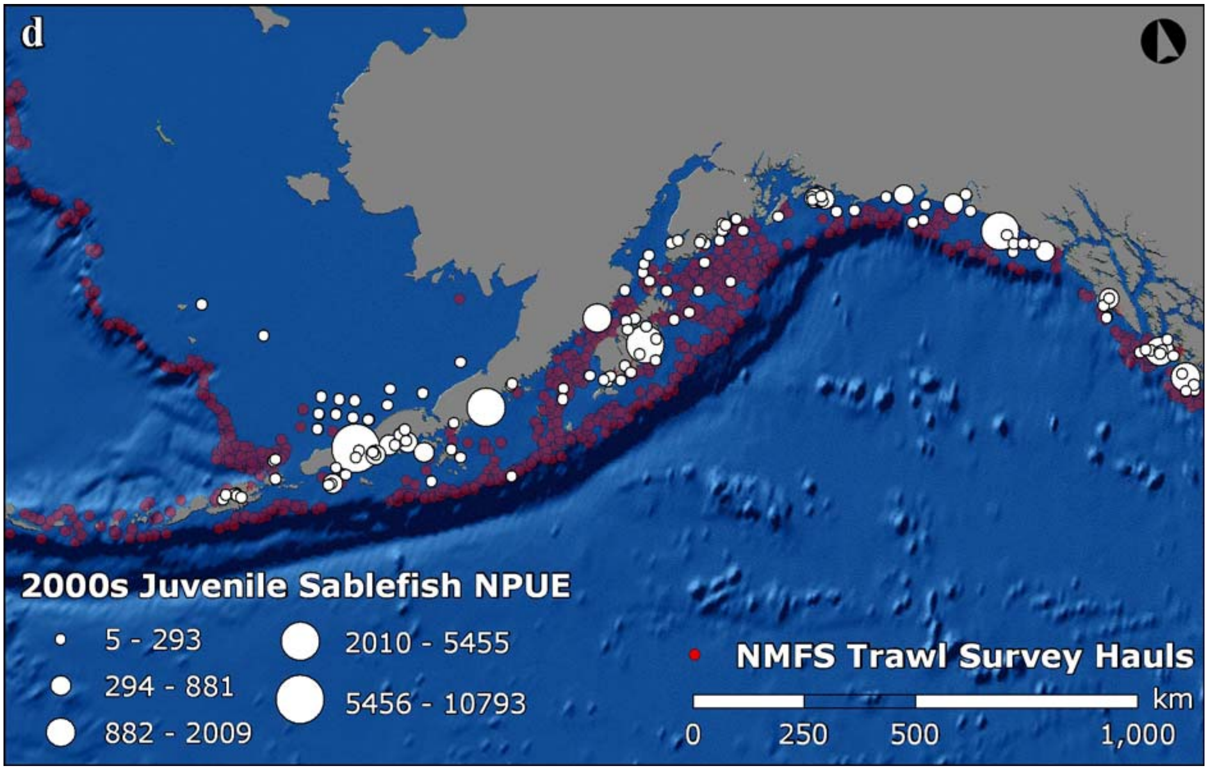


Figure 3.23 – (continued).

Appendix 3A.--Sablefish longline survey - fishery interactions

NMFS has requested the assistance of the fishing fleet to avoid the annual sablefish longline survey since the inception of sablefish IFQ management in 1995. We requested that fishermen stay at least five nautical miles away from each survey station for 7 days before and 3 days after the planned sampling date (3 days allow for survey delays). Beginning in 1998, we also revised the longline survey schedule to avoid the July 1 rockfish trawl fishery opening as well as other short, but less intense fisheries.

History of interactions

Publicity, the revised longline survey schedule, and fishermen cooperation generally have been effective at reducing trawl fishery interactions. 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.

Since 2000, the number of vessels fishing near survey stations has remained relatively low. In 2006, siz longline vessels and two trawl vessels were found fishing near stations. During the past several surveys, many fishing vessels were contacted by the survey vessel and in most cases fishermen were aware of the survey or willing to help out by fishing other grounds.

LONGLINE SURVEY - FISHERY INTERACTIONS

	Longline		Trawl		Pot		Total	
Year	Stations	Vessels	Stations	Vessels	Stations	Vessels	Stations	Vessels
1995	8	7	9	15	0	0	17	22
1996	11	18	15	17	0	0	26	35
1997	8	8	8	7	0	0	16	15
1998	10	9	0	0	0	0	10	9
1999	4	4	2	6	0	0	6	10
2000	10	10	0	0	0	0	10	10
2001	1	1	1	1	0	0	2	2
2002	3	3	0	0	0	0	3	3
2003	4	4	2	2	0	0	6	6
2004	5	5	0	0	1	1	6	6
2005	1	1	1	1	0	0	2	2
2006	6	6	1	2	0	0	7	8

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions decreased in 1999 and 2001-2005. 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. We are concerned about potential survey/fishery interactions with the trawl fleet when rockfish rationalization begins. This management action will likely lengthen the rockfish trawl fishery in the central Gulf area which will likely cause an overlap between the trawl fishery and longline survey operations.

Appendix 3B.--Research survey catches (kg) by survey.

Year	Echo integration trawl	Trawl	Japan US longline survey	Domestic longline survey	Total
1977		3,126			3,126
1978	23	14,302			14,325
1979		27,274	103,839		131,113
1980		69,738	114,055		183,793
1981	813	87,268	150,372		238,452
1982		107,898	239,696		347,595
1983	44	45,780	235,983		281,807
1984		127,432	284,431		411,864
1985		185,692	390,202		575,894
1986	80	123,419	395,851		519,350
1987		116,821	349,424		466,245
1988		14,570	389,382	302,670	706,622
1989		3,711	392,624	367,156	763,491
1990	94	25,835	272,274	366,236	664,439
1991		3,307	255,057	386,212	644,576
1992	168	10	281,380	392,607	674,165
1993	34	39,275	280,939	407,839	728,088
1994	65	852	270,793	395,443	667,153
1995				386,169	386,169
1996	0	12,686		430,447	439,165
1997	0	1,080		395,579	397,347
1998	5	25,528		324,957	336,096
1999	0	43,224		311,358	293,149
2000	0	2,316		289,966	271,654
2001	2	11,411		326,274	315,538
2002	154	2,607		309,098	295,617
2003	141	15,737		279,687	295,565
2004	53	1,826		287,732	289,611
2005	244	17,915		254,762	272,921
2006	19	1,816		286,518	288,353

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