Chapter 3: Assessment of the Sablefish stock in Alaska

by

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Executive Summary

Summary of major changes

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

Input data: We added relative abundance and length data from the 2009 longline survey, relative abundance and length data from the 2008 longline and trawl fisheries, and age data from the 2008 longline survey and longline fishery were added to the assessment model. A NMFS GOA trawl survey was conducted in 2009 and its biomass estimate and associated lengths were also added.

Model changes: We are recommending no model changes for 2010. A modeling workshop to begin implementing CIE recommendations and evaluate industry concerns is planned for winter 2010. Our initial responses to the CIE review are in Appendix 3C.

Assessment results: The fishery abundance index was up 5% from 2007 to 2008 (the 2009 data are not available yet). The survey abundance index increased 2% from 2008 to 2009 following a 16% decrease from 2006 to 2008. Relative abundance in 2009 is level with 2000, and is near the all-time low for the domestic longline survey. The GOA 2009 trawl survey estimate fell 2% from 2007, and is at its lowest since 1999. Spawning biomass is projected to be lower from 2010 to 2013, and then stabilize.

Sablefish are managed under Tier 3 of NPFMC harvest rules. Reference points are calculated using recruitments from 1979-2007. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 112,726 t (combined across the EBS, AI, and GOA), 0.095, and 0.114, respectively. Projected spawning biomass (combined areas) for 2010 is 99,897 t (89% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.084 which translates into a 2010 ABC (combined areas) of 15,230 t. The OFL fishing mortality rate is 0.100 which translates into a 2010 OFL (combined areas) of 18,030 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

We recommend a 2010 ABC of 15,230 t. The maximum permissible yield for 2010 from an adjusted $F_{40\%}$ strategy is 15,230 t. The maximum permissible yield for 2010 is a 5% decrease from the 2009 ABC of 16,080 t. This decrease is supported by three low years in the domestic longline survey abundance estimate and two subsequent low trawl survey abundance estimates. There is also little evidence of any large incoming recruitment classes. Spawning biomass is projected to decline through 2013, and then is expected to increase assuming average recruitment is achieved. Because of the lack of recent strong year classes, the maximum permissible ABC is projected to be 13,658 t in 2011 and 12,592 in 2012 (using estimated catches, instead of maximum permissible, see Table 3.10).

Projected 2010 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 30% of unfished biomass in 2001 to a projected 35% in 2010. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 12% of the 2010 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now 92% mature and should comprise 23% of the spawning biomass in 2010.

In December 1999, the Council first apportioned 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 apportion the 2010 ABC and OFL.

Apportionments are based on survey and fishery information	2009 ABC Percent	2009 Survey RPW	2008 Fishery RPW	2010 ABC Percent	2009 ABC	2010 ABC	Change
Total					16,080	**15,230**	-5%
Bering Sea	17%	19%	21%	18%	2,720	**2,790**	3%
Aleutians	14%	13%	14%	14%	2,200	**2,070**	-6%
Gulf of Alaska	69%	68%	65%	68%	11,160	**10,370**	-7%
Western	15%	18%	15%	16%	1,640	**1,660**	1%
Central	45%	44%	39%	44%	4,990	**4,510**	-10%
W. Yakutat	15%	13%	17%	14%	1,630	**1,480**	-9%
E. Yakutat / Southeast	26%	25%	29%	26%	2,890	**2,720**	-6%

After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the ABC for West Yakutat is 1,620 t and for East Yakutat/Southeast is 2,580 t. This adjustment projected to 2011 is 1,450 t for W. Yakutat and 2,320 t for E. Yakutat.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2010	1,620 t	2,580 t
	2011	1,450 t	2,320 t

Responses to the joint BSAI/GOA Plan team comments

"The teams had the following comments on sperm whale depredation correction factors and killer whale depredation factors: 1-Analyze current sperm whale depredation data and see if there is a statistical effect; 2-Analyze including survey and fishery data together to evaluate what the relative impact is; 3-Evaluate difference between depredation in survey and fishery to investigate trends. There was a suggestion that a model-based random effects approach may be useful to evaluate whale depredation. This would likely increase the uncertainty in the index"

An analysis is underway to evaluate the effect of sperm whale depredation on the survey. The analysis is using the methodology outlined in Sigler et al. (2007) for the years 1998-2009 and will provide a statistical estimation of depredation rates. This work has not been completed, but we expect results to be available in time for the 2010 stock assessment cycle. Little depredation information is available for the fishery. Observers document killer whale depredation, but sperm whale depredation is not documented. In logbooks, whale sightings were collected only in 2007 and 2008. No significant differences were found in logbook catch rates when sets where killer whales were observed were removed from the fishery catch rate analysis (see ***Longline fishery catch rate analysis*** section). Therefore, it is difficult to evaluate differences between the fishery and survey for both killer and sperm whale depredation. We continue to explore methods to better quantify sperm whale depredation in the survey and hope to investigate the effect of killer whale depredation on abundance estimation in the coming year.

Responses to SSC comments specific to the sablefish assessment

The December 2008 SSC minutes included the following comments:

"The SSC agrees that at the current time the IFQ CPUE data does not significantly influence the 2009 stock assessment results. However, over time as this index continues to deviate from the trend of other data sources, inclusion of this data may become more influential. The SSC asks the author to continue to examine the influence of the IFQ CPUE index on model results and consider the implications of removing it from the assessment."

The CIE panel suggested that we continue to use the fishery index in the model (see Appendix 3C). We believe that in its current form, it may not be informative about relative abundance. However, we agree with the panel that if the data are modeled more appropriately (considering spatial dynamics, vessel effects, and targeting), we may find that the data can be more informative for future assessments. We will be pursuing this in a workshop in 2010.

"The SSC encourages the authors to conduct a retrospective analysis of the predicted biomass distribution resulting from the weighting scheme relative to observed biomass distributions. If time permits, the SSC encourages the author to examine the predicted regional biomass distribution derived from knowledge of age specific sablefish migration. The SSC also encourages the author to continue to explore the impact of sperm whale depredation."

We did conduct additional retrospective analyses for the CIE review and found that the retrospective pattern was apparent under all data weighting schemes to some extent. The only configuration discovered to remove it was to fix catchability and selectivity parameters, which is not something we are considering. In the last several years, the retrospective pattern has diminished (see ***Retrospective Analysis***) which suggests that perhaps the pattern was data induced, and the model has now "caught up" with the trend.

Plan team summaries

Area	Year	Biomass (4+)	OFL	ABC	TAC	Catch
GOA	2008	167,000	15,040	12,730	12,730	12,326
	2009	149,000	13,190	11,160	11,160	10,364
	2010	140,000	12,270	10,370		
	2011	129,000	11,008	9,300		
BS	2008	41,000	3,380	2,860	2,860	891
	2009	39,000	3,210	2,720	2,720	813
	2010	38,000	3,310	2,790		
	2011	36,000	2,969	2,502		
AI	2008	34,000	2,890	2,440	2,440	1,119
	2009	28,000	2,600	2,200	2,200	961
	2010	27,000	2,450	2,070		
	2011	25,000	2,198	1,856		

Year	2009				2010		2011	
Region	OFL	ABC	TAC	Catch*	OFL	ABC	OFL	ABC
BS	3,210	2,720	2,720	813	3,310	2,790	2,969	2,502
AI	2,600	2,200	2,200	961	2,450	2,070	2,198	1,856
GOA	13,190	11,160	11,160	10,364	12,270	10,370	11,008	9,300
W	--	1,640	1,640	1,288	--	1,660	--	1,489
C	--	4,990	4,990	4,698	--	4,510	--	4,044
WYAK	--	1,630	1,630	1,626	--	1,480	--	1,327
SEO	--	2,890	2,890	2,752	--	2,720	--	2,439
Total	19,000	16,080	16,080	12,138	18,030	15,230	16,175	13,658

*Current as of October 10, 2009 (http://www.fakr.noaa.gov).

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 (Krieger 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. The Bering Sea shelf is utilized significantly in some years and little used during other years (Shotwell 2007).

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, 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 (AI) region.

Early life history: Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (Mason et al. 1983, 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 in Alaska based on otolith analysis is March 30 (Sigler et al. 2001). Along the Canadian coast (Mason et al. 1983) and off Southeast Alaska (Jennifer Stahl, ADF&G, personal communication) sablefish spawn from January-April with a peak in February. Farther down the coast off of central California sablefish spawn earlier, from October-February (Hunter et al. 1989). Sablefish in spawning condition were also noted as far west as Kamchatka in November and December (Orlov and Biryukov 2005). The size of sablefish at 50% maturity off California and Canada is 58-60 cm for females, corresponding to an age of approximately 5 years (Mason et al. 1983, Hunter et al. 1989). In Alaska, 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 to deeper water, typically reaching their adult habitat, the upper continental slope at 4 to 5 years. This corresponds to the age range when sablefish start becoming reproductively viable (Mason et al. 1983). Younger fish (age 3-4) inhabit shallower waters on the shelf, while older fish migrate down to the slope. Fish also tend to move counterclockwise through the Gulf of Alaska with age (e.g., Maloney and Sigler 2008, Heifetz and Fujioka 1991).

Fishery

Early U.S. fishery, 1957 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 t 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 t 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 t 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.

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 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 in 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 t from 1964 to 1972, compared to the North Pacific trawl fishery, which averaged 4,600 t. In the Gulf of Alaska, sablefish were caught as bycatch in 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 pots (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 1-2 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. From 1995 to 2002 the season ran from approximately March 15-November 15. Starting in 2003 the season was extended by moving the start date to approximately March 1. 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 fell again in 2000 to approximately 42% of the 1988 peak. Catches since 2000 have increased modestly, largely due to a strong 1997 year class.

IFQ management has increased fishery catch rates and decreased the harvest of immature fish (Sigler and Lunsford 2001). Catching efficiency (the average catch rate per hook for sablefish) increased 1.8 times with the change from an open-access to an IFQ fishery. The improved catching efficiency of the IFQ fishery reduced the variable costs incurred in attaining 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 is primarily 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 of Alaska 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 2008) was:

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Vessels	700	646	504	544	528	511	503	491	438	438	399	409	395	388

To calculate the total number of hooks deployed in the Federal fishery, we use observer catch and effort data and extrapolate this information to the total catch in the fishery, including unobserved sets. Averages per year are presented for years 1990-1994 and 1995-2000. The number of hooks deployed appears to be most variable in the Bering Sea because the observed effort in this area is minimal. The extrapolated number 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
2006	5.1	9.6	11.2	13.3	13.4	52.6
2007	6.8	7.7	10.5	13.2	11.9	50.2
2008	4.8	5.9	8.8	12.7	9.8	42.0

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

Depredation by killer whales and sperm whales is not uncommon in the Alaska sablefish IFQ fishery (Sigler et al. 2007). Killer whale depredation occurs in the Bering Sea, Aleutian Islands, and Western Gulf of Alaska. Sperm whale depredation occurs in the Central and Eastern Gulf of Alaska.

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 up to 34% of the catch in the Aleutians. In 2008, pot fishing continued to increase in the BS (80% of fixed gear catch), whereas in the Aleutian Islands pot fishing decreased from 54% to 22% of the fixed gear catch. A small amount of pot fishery data is available from observer and logbook data and is now included in the fishery catch rate section.

Catch

Annual catches in Alaska averaged about 1,700 t 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 t, 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 t 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 t in 1988, fell to about 12,000 t in the late 1990's, and have been near 14,000 t recently. The proportion of catch due to pot fisheries in the Bering Sea and the Aleutian Islands increased starting in 2000 (Table 3.1b) and is discussed further below.

Bycatch and discards

Sablefish discards have decreased in recent years. From 1994 to 2003 discards averaged 1,357 t for the GOA and BSAI combined (Table 3.2 Hanselman et al. 2008). The highest amount, 13,601 t was in 2003, of which 1,130 t occurred in the GOA and 231 t occurred in the BSAI. Discards decreased after 2003, down to an average in 2004-08 of 612 t, of which 523 t occurred in the GOA and 89 t occurred in the BSAI. The discards from trawl fisheries decreased from a 1994-2003 average of 825 t to an average of 208 t for 2004-2008, while hook and line fisheries decreased slightly from 525 t down to 383 t (Table 3.2).

Table of the average catch (t) of the most abundant species caught in the 2003-2009 sablefish fishery are shown below. Grenadiers are by far the most abundant bycatch in the sablefish fishery. Commercially valuable species taken in the sablefish fishery include thornyhead rockfish, shortraker rockfish, rougheye rockfish, and Pacific cod.

	Hook and Line			Other Gear			All Gear		
Species	Discard	Retained	Total	Discard	Retained	Total	Discard	Retained	Total[1]
Grenadiers	-	-	8,834	-	-	104	-	-	8,938
Thornyhead rockfish	46	377	423	2	14	16	49	391	440
Arrowtooth flounder	321	87	408	110	18	128	431	105	536
Other skates	202	8	209	1	1	2	203	8	211
Shortraker rockfish	79	119	199	4	3	6	83	122	205
Longnose skate	167	6	173	1	1	2	168	7	175
Spiny dogfish	170	0	170	0	0	0	170	0	170
Rougheye rockfish	40	89	128	3	1	4	42	89	132
Pacific cod	32	74	106	1	6	8	33	81	114
Greenland turbot	40	53	93	20	5	25	60	58	118
Other	92	32	124	24	22	46	117	53	170
Total All Species	1,420	11,707	21,961	184	1,260	1,548	1,605	12,967	23,510

[1] Data from Terry Hiatt (AKFIN database), only includes catch where sablefish were defined as the target.

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 became 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. This exception was eliminated in 2008. 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.

A summary of sablefish management measures and a time series of catch, ABC and TAC is shown below.

Year	ABC	TAC	Catch(t)	Management measure
1980		18,000	10,444	Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish
1981		19,349	12,604	
1982		17,300	12,048	
1983		14,480	11,715	
1984		14,820	14,109	
1985		13,480	14,465	Amendment 14 of the GOA FMP allocated sablefish quota by gear type: 80% to fixed gear and 20% to trawl gear in WGOA and CGOA and 95% fixed to 5% trawl in the EGOA.
1986		21,450	28,892	Pots banned in Eastern GOA
1987		27,700	35,163	Pots banned in Central GOA
1988		36,400	38,406	
1989		32,200	34,829	Pots banned in Western GOA
1990		33,200	32,115	Amendment 15 of the BSAI FMP allocated sablefish quota by gear type: 50% to fixed gear in and 50% to trawl in the EBS, and 75% fixed to 25% trawl in the Aleutian Islands
1991		28,800	27,073	
1992		25,200	24,932	Pot fishing banned in Bering Sea (57 FR 37906)
1993		25,000	25,433	
1994		28,840	23,760	
1995		25,300	20,954	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. In 1997, maximum retainable allowances for sablefish were revised in the Gulf of Alaska
1996		19,380	17,577	Pot fishing ban repealed in Bering Sea except from June 1-30
1997	19,600	17,200	14,922	Maximum retainable allowances for sablefish were revised in the Gulf of Alaska. The percentage depends on the basis species.
1998	16,800	16,800	14,108	
1999	15,900	15,900	13,575	
2000	17,300	17,300	15,919	
2001	16,900	16,900	14,097	
2002	17,300	17,300	14,789	
2003	18,400	20,900	16,371	
2004	23,000	23,000	17,720	
2005	21,000	21,000	16,619	
2006	21,000	21,000	15,417	
2007	20,100	20,100	15,011	
2008	18,030	18,030	14,335	Pot fishing ban repealed in Bering Sea for June 1-30 (74 FR 28733)
2009	16,080	16,080	--	

Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1960-2009
Japanese longline fishery	Catch-per-unit-effort (CPUE)	1964-1981
U.S. longline fishery	CPUE, length	1990-2008
	Age	1999-2008
U.S. trawl fisheries	Length	1990,1991,1999, 2005-2008
Japan-U.S. cooperative longline survey	CPUE, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	CPUE, length	1990-2009
	Age	1996-2008
NMFS GOA trawl survey	Abundance index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009
	Lengths	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009

Fishery

Length, catch, and effort data were historically collected from the Japanese and U.S. longline and trawl fisheries, and are now collected from U.S. longline, trawl, and pot fisheries (Table 3.3). The Japanese data were collected by fishermen trained by Japanese scientists (L. L. Low, Alaska Fisheries Science Center, pers. commun., 25 August 1999). The U.S. fishery length and age 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 only a small 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 (Sigler et al. 2002).

The catches used in this assessment (Table 3.1) include catches from minor State-managed 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, Alaska Regional Office, pers. comm., 12 July 1999), the source of the catch data used in this assessment. Minor State fisheries catches averaged 180 t 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 sizes for the years 2000-2004 were low 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. 2006 and 2007 sample sizes were lower, but had 700-800 lengths so we continue to use these data. Again in 2008 we had larger length sample for the trawl fishery (>2000).

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 are collected by observers and by vessel captains in voluntary and required logbooks. Fishery data from the Observer Program are available since 1990. Vessels between 60 and 125 feet carry an observer 30% of the time and vessels over 125 feet carry an observer 100% of the time. Since 1999, logbooks have been required for vessels over 60 feet. 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. Since 2005 vessels less than 60 feet have accounted for approximately 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 are 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 estimate the actual set weight by multiplying the IFQ landing report weight by the proportion of the trip weight that was caught in the set, from logbook reported weights. 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. These catch rates are 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 analyses. All sets that experienced killer whale depredation are excluded from the observer fishery catch rate analysis since any depredation would bias CPUE downward. From 1990-2008 an average of 22% of observed sets in the Bering Sea were affected by whale depredation. However, the total number of observed sablefish sets in the Bering Sea ranges from only 1 to 37. In 2008 killer whale depredation of observed sets remained similar to past years in all areas except in west Yakutat, where 10 sets were depredated, though there commonly are none. However, all of these sets were during the same trip.

Whale presence or depredation was not recorded in logbooks prior to 2007 and therefore was not corrected for in the catch rate analyses. In 2007 and 2008 only, whale sightings were noted in some logbooks, but depredation of catch was not recorded. Killer whales were sighted during 107 sets in 2007 and 65 in 2008, mostly in the central and western Gulf of Alaska, but were also observed in all other areas except west Yakutat. Because we excluded killer whale depredated sets in observer data, we also excluded these sets from the logbook data. Excluding these sets had no significant effect on catch rates (e.g., in 2007: t-test, $p = 0.41$, $\alpha = 0.05$). Sperm whales were often observed during sets in the GOA, however sperm whale presence does not imply depredation and when depredation occurs it is often minimal and difficult to quantify in comparison to killer whale depredation (Sigler et al. 2007). Therefore, sperm whale depredated sets are not excluded from observer data, logbook data, or longline survey data.

Additionally, some logs are excluded because of other issues. Sets were excluded whenever data were missing for a set and a catch rate could not be calculated or assigned to a season, area, or a year. Some sets use 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.

Longline sample sizes: Observer data used in this analysis represent on average 14% of the annual IFQ hook and line catch. The percent of the IFQ catch observed was lowest in the East Yakutat/SE (5%), highest in West Yakutat and Aleutian Islands (~22%), and moderate in the Bering Sea, Central Gulf, and Western Gulf (10-14%). Although the percent of catch observed is not highest in the Central Gulf, the number of sets and vessels observed is greatest in this area and lowest in the Bering Sea (Table 3.5). In the Bering Sea fewer than 10 sets were observed from 2002-2005; however, since 2006 more sets have been observed. Observer coverage in the Aleutian Islands was consistent in all years except 2005 when only 23 sets from six vessels were observed. Low sample sizes in the Bering Sea are likely a result of poor observer coverage for sablefish directed trips, and because pot fishing accounts for such a large proportion of the catch in these areas and is not included in this analysis. Additionally, killer whales impact sablefish catch rates in these areas. For example, in 2008 14% of observed sets in the Bering Sea were affected by killer whale depredation and were eliminated from the analysis.

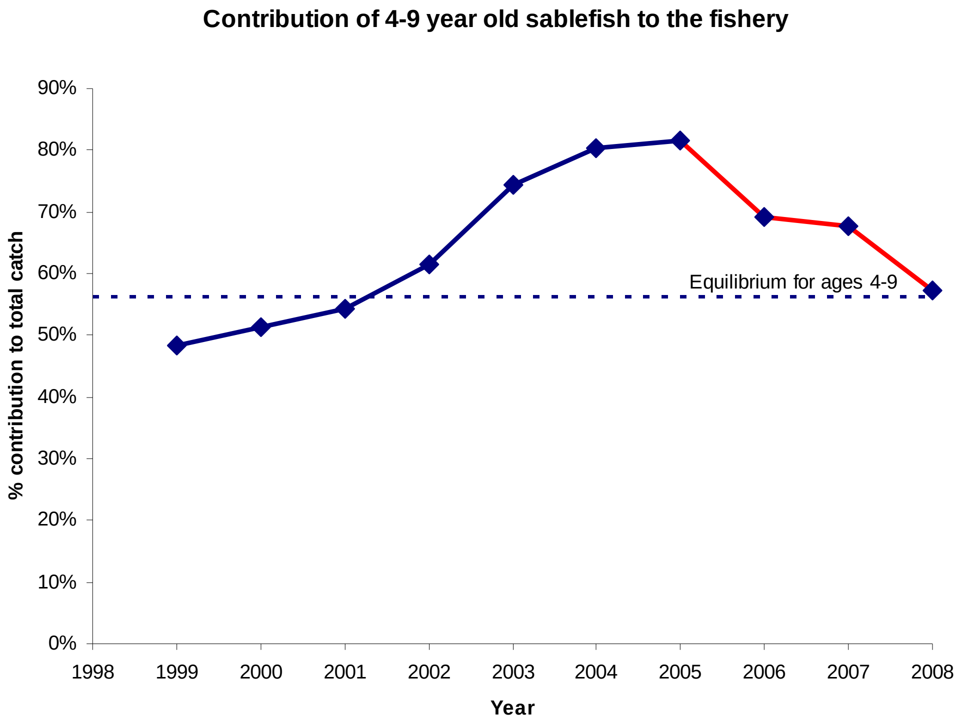
Logbook sample sizes are substantially higher than observer samples sizes, especially since 2004. Logbook samples increased sharply in 2004 in all areas primarily because the IPHC was used to edit and enter logbooks electronically. This increasing trend is likely due to the strong working relationship the IPHC has with fishermen, their diligence in collecting logbooks dockside, and because many vessels under 60 feet are now participating in the program voluntarily. Similar to the observer data, logbook data had fewer sets in the Bering Sea, but had high samples sizes throughout the Gulf.

Longline catch rates: 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 rate trends are generally similar for both the observer and logbook data, except in the Aleutian Islands and the Bering Sea where sample sizes are relatively small. Logbook and observer catch rates are most similar to each other in the Central Gulf, likely due to the high sample sizes in this area in both data sets. Although the general trends are very similar between the two sources, the specific trends in 2008 differed slightly in many areas. Since 2004, though, the logbook data is more substantial than the observer data and has lower CV's and SE's due to the large number of vessels, especially in west and east Yakutat (Table 3.5).

Sablefish abundance increased after a low in 1998-2000 in response to the above average 1997 and 2000 year classes. In the logbook and observer fishery data sets, catch rates then decreased starting in 2004 or 2005 in all areas except the Aleutian Islands and the Bering Sea. Since 2006 or 2007 the fishery CPUE's are increasing or stable in the GOA.

The age structure of the population may help explain why catch rates have started to decrease since 2005. Year classes typically show up in the fishery beginning at age 4. The influence of the 1997 and 2000 year classes to the fishery is evident as catch rates generally increased during the years 2001-2004 for both the observer and logbook data in all areas of the GOA (Figures 3.4 and 3.5). These years correspond to when the 1997 and 2000 year classes were major contributors to the fishery. The percent of catch attributed to

4-9 year old fish increased from 48% in 1999 to nearly 82% of the catch in 2005. By 2008, the catch of this age group has decreased to about what we would expect at equilibrium levels with this fishing mortality. These large pulses of recruits targeted by the fishery might explain some of the incongruence between the survey and the fishery.

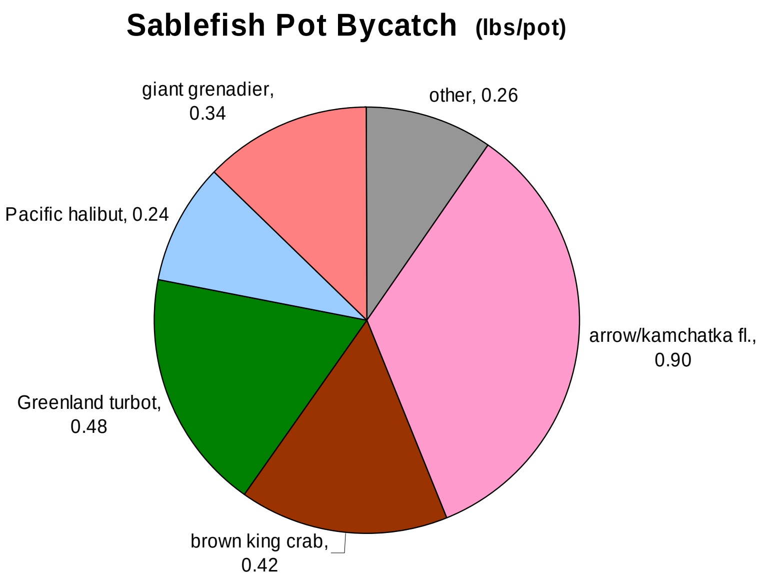


Longline spatial and temporal patterns: Changes in spatial or temporal patterns of the fishery may cause fishery catch rates to be unrepresentative of abundance. For example, fishers sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 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. 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. The highest catch rates are also in the spring, moderate in the summer, and lowest in the fall. 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 do 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

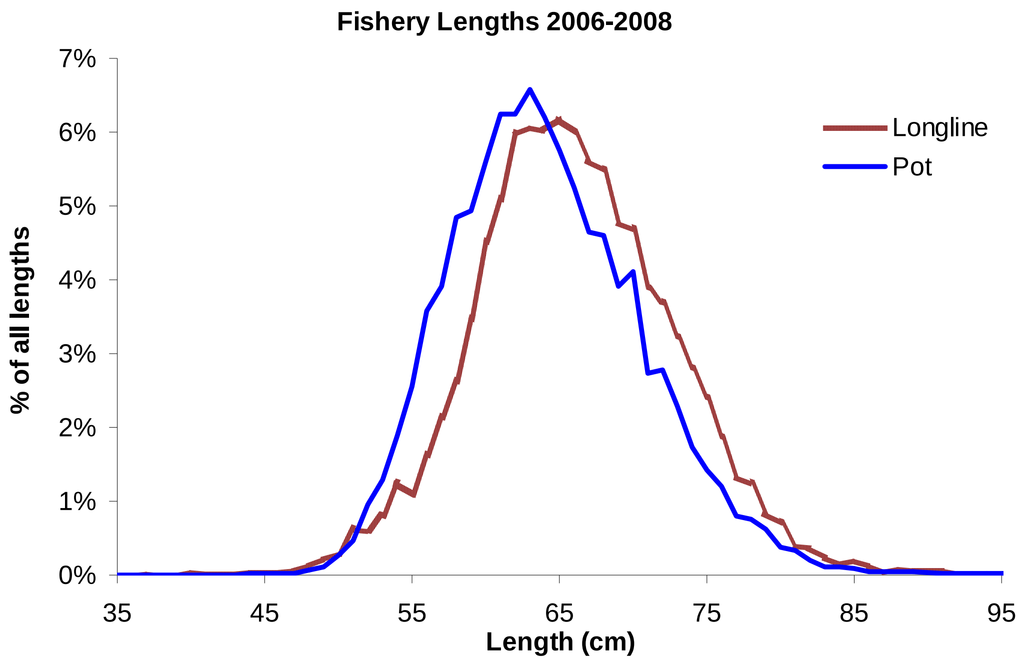
Pot catch rates: There is more uncertainty in catch rates from 1999-2004 because there were few observed vessels during this period. From 2005-2008 the average catch rate was 22.5 lbs/pot in the Aleutian Islands and the Bering Sea. However, because there were still relatively few vessels observed in 2005-2008 there was high variability in the average catch rates. Because of the high variability, catch rates within areas were not significantly different between any years in both the observer and logbook data. For both the Bering Sea and Aleutian Islands, no trend in catch rates is discernable.

The composition of bycatch species caught in observed pots in the Bering Sea and Aleutian Islands is comprised of mostly of flatfish, giant grenadier, and brown king crab. From 2002-2008, sablefish have comprised on average 76% of the catch in weight. The average catch during this period for the five most common species caught is illustrated in the figure below. Because pot data is limited, annual fluctuations in catch of bycatch species may not be dependable. For this reason, the average catch (2002-2008) is presented instead of a time series.



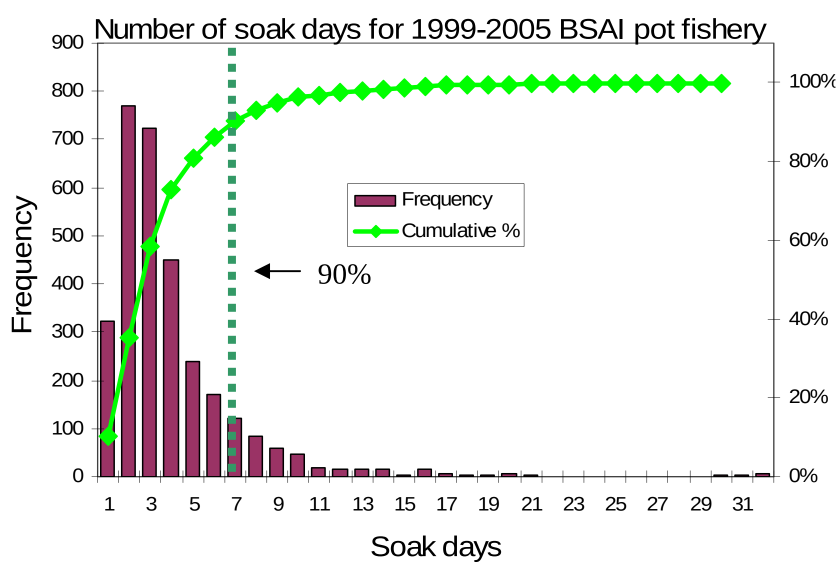
Pot spatial and temporal patterns: Seasonal changes in effort were examined in the 2007 SAFE report, but no distinct trends were found.

Pot length frequencies: We compared the length frequencies recorded by observers from the 2006-2008 longline and pot fisheries. The average length of sablefish in the Aleutian Islands and in the Bering Sea was smaller for sablefish caught by pot gear (63.8 cm) than longline gear (66.0 cm), but the distributions indicate that both fisheries focus primarily on adults. Pot and longline gear is set at similar depths in the Aleutians and Bering Sea and catch males and females at the same rates (average % females in BS/AI was 58% for both gear types). 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.



Sablefish diets in pots: The North Pacific Fishery Management Council requested that the AFSC Auke Bay Laboratory scientists investigate a number of issues related to management of the sablefish pot fishery in the Bering Sea and the Aleutian Islands. One concern was the possibility of cannibalism by larger sablefish while in pots. Because few small sablefish are found in pots, there was concern that small sablefish were entering the pots and being cannibalized by larger sablefish. No sablefish were found in the stomachs of large pot-caught sablefish. Most stomachs were empty (72%); the most common item found was squid (13%) (see the 2008 SAFE).

Pot soak times: In 2006, some questions were raised about storing pots at sea, escape rings, and biodegradable panels. While we have not analyzed the consequences of these potential regulatory issues, in 2006 we examined the soak times of the observed pot sets. These are plotted below:



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

Pot sample sizes: Sablefish pot fishing has increased dramatically in the Aleutian Islands and the Bering Sea since 1999. However, in 2008, pot gear accounted for 80% of the Bering Sea fixed gear IFQ catch, but only 22% of the catch in the Aleutian Islands. This was a decrease in the Aleutian Islands from a high of 56% in 2007. Fishery catch and effort data for pot gear are available from observer data since 1999; however, due to confidentiality agreements, we cannot present these data due to low sample sizes. Pot fishery data are also available from logbooks since 2004; however, these data are also sparse. The number of sets and pots fished in observer data and logbooks increased dramatically in 2005 and remained high through 2008. Over all years, the average number of pots used per set was 78.

Longline surveys

AFSC Longline Surveys

Overview: 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 3B.

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 we began aging samples in the year they were collected. Otolith collections were length-stratified from 1979-94 and random thereafter.

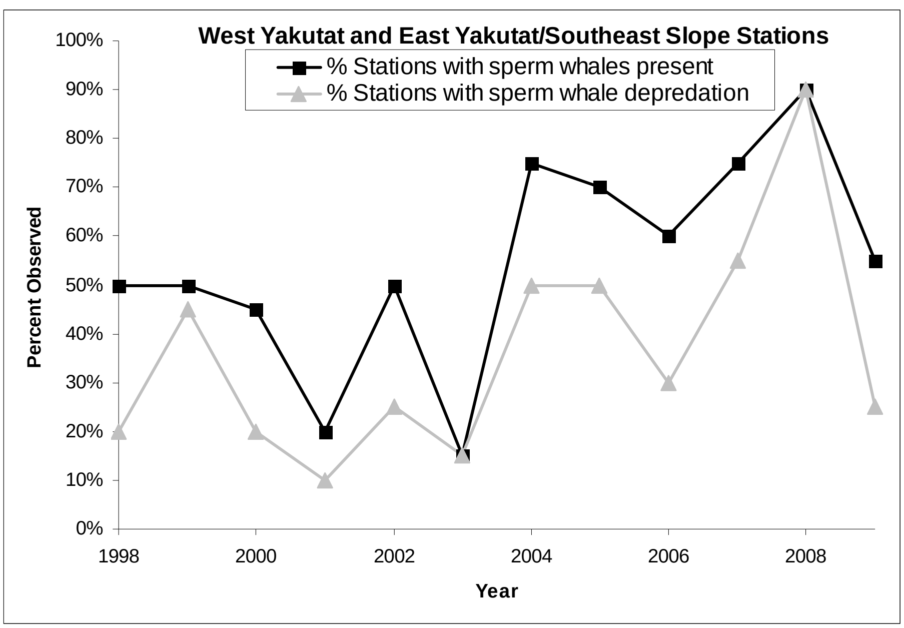
Standardization: Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased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

Whale Depredation: 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, 1987 (T. Sasaki, pers. commun., 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 1990 (Table 3.6). In 2009, however, killer whales depredated on ten out of the sixteen Bering Sea stations. It is unknown why depredation was so prevalent in 2009 but there were significant impacts on the catch. For example, in 2007 9,253 sablefish were caught at sixteen stations in the Bering Sea. In 2009, only 2,814 sablefish were caught at those same sixteen stations. Since 1990, portions of the gear affected by killer whale depredation during domestic longline surveys have been excluded from the analysis of the survey data. Following this methodology for 2009 led to suspiciously severe decrease in abundance indices (~75% reduction in RPN). A significant component of this reduction was attributed to killer whales depredating on stations that on average produce high catch rates. Of the six stations that were not depredated, five of those typically produce below average catches in the Bering Sea.

Several adjustment methods to correct for whale depredated stations in the Bering Sea in 2009 were explored. Incorporating a weighted moving average of all stations in the last three years or applying a linear model with year and station effects were explored. Results from these exploratory analyses still yielded suspiciously low abundance indices. The alternative we have chosen is to use the same methodology to estimate the 2009 Bering Sea indices as the methodology we apply when the Bering Sea is not sampled; multiplying the last year the Bering Sea was sampled (2007) by the ratio of change from the Gulf of Alaska (2007 to 2009). The rationale for this is the Gulf of Alaska is adequately sampled and is representative of the sablefish population in Alaska. Therefore, 2009 abundance indices (RPN, RPW) for the Bering Sea presented in this assessment are computed estimates rather than sampled estimates typical of odd years in the Bering Sea. Continued analysis regarding killer whale depredation and its effects on abundance indices is warranted and we hope to explore modeling approaches that will take advantage of the full data set to interpolate depredated stations.

Sperm whale depredation may affect longline catches in the Gulf of Alaska. Data on sperm whale depredation have been collected since the 1998 longline survey (Table 3.6). Apparent sperm whale depredation is defined as sperm whales being present with the occurrence of damaged sablefish. Sperm whales are most commonly observed in the central and eastern Gulf of Alaska (98% of sightings); the majority of interactions occur in the West Yakutat and East Yakutat/Southeast areas. Sperm whale presence and evidence of depredation has been variable since 1998. A plot of the percentage of sampling days that sperm whales were present and depredating in the West Yakutat and East Yakutat/Southeast slope stations combined is below:



Occurrence of depredation has ranged from 10% of sampling days that sperm whales were present in 2001 to 90% in 2008. Sperm whales have often been present but not depredating on the gear, except in 2003 and 2008 when depredation occurred every time sperm whales were observed. 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 whale depredation. This work was redone in 2006 using additional data from 2002-2004 which were analyzed by fitting the data to a general linear model (Sigler et al. 2007). Neither sperm whale presence (p = 0.71) nor 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). This analysis is currently being updated through 2009 but results are not available at this time. A previous study using data collected by fisheries observers in Alaskan waters also found no significant effect on catch (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 sets with sperm whales absent (3% reduction, 95% CI of (0.4 – 5.5%), t-test, p = 0.02, Straley et al. 2005).

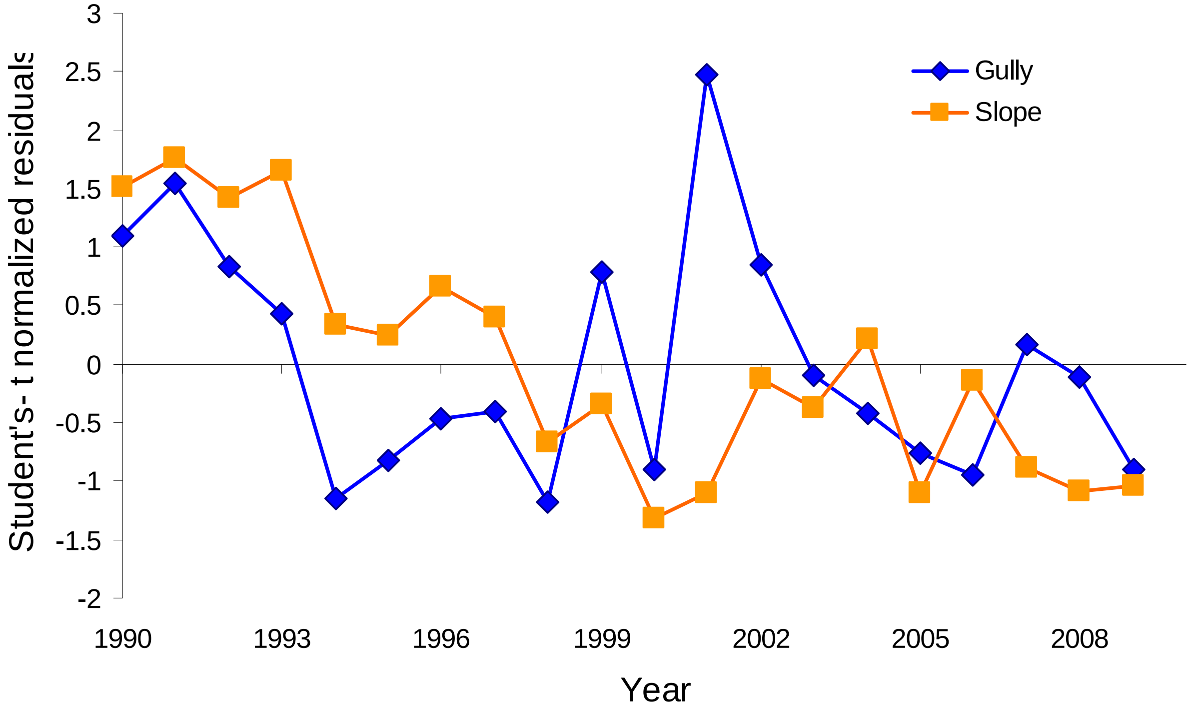
The longline survey catch rates were not adjusted for sperm whale depredation because we do not know when measureable depredation began during the survey time series, and because studies of depredation on the longline survey showed no significant effect (Sigler et al. 2007). Current abundance is unbiased 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 occurred throughout the survey time series, then current biomass will be overestimated. We will continue to monitor sperm whale depredation of survey and fishery catches for changes in the level of depredation.

Gully Stations: In addition to the continental slope stations sampled during the survey, twenty-seven stations are sampled in gullies at the rate of one to two stations per day. The sampled gullies are Shelikof Trough, Amatuli Gully, W-grounds, Yakutat Valley, Spencer Gully, Ommaney Trench, Dixon Entrance, and one station on the continental shelf off Baranof Island. The majority of these stations are located in deep gully entrances to the continental shelf in depths from 150-300 m in areas where the commercial fishery targets sablefish. No gullies are currently sampled in the Western Gulf of Alaska, Aleutian Islands, or Bering Sea.

Previous analyses have shown that on average gully stations catch fewer larger fish than adjacent slope stations and length distributions are generally different (Rutecki et al. 1997; Zenger et al. 1994). Compared with the adjacent regions of the slope, sablefish catch rates for gully stations have been mixed with no significant trend (Zenger et al. 1994). Important characteristics of gully catches are they may indicate recruitment signals before slope areas because of their shallow depth and tendencies to catch smaller fish. And, they may represent alternative habitat characteristics which may be more desirable than adjacent slope areas under certain conditions.

Catch rates from these stations have not been included in the historical abundance index calculations because of their locations relative to the more preferred slope habitat of sablefish and in particular because of their shallow depths. These areas do support significant numbers of sablefish, however, and are important areas sampled by the survey. We compared the RPNs of gully stations to the RPNs of slope stations in the GOA to see if catches were comparable, or more importantly, if they portrayed different trends than the RPNs used in this assessment.

Gully RPNs were highly correlated ($r = 0.881$) with slope RPNs in the East Yakutat/Southeast Outside area but poorly correlated in the West Yakutat ($r = 0.453$) and Central Gulf regions ($r = 0.145$). To compare trends, we computed Student's-*t* normalized residuals for all GOA gullies and slope stations and plotted them for the time series.



Overall, gully catches in the GOA were poorly correlated with slope catches ($r = 0.311$). There also is no evidence of major differences in trends. In regards to gully catches being a recruitment indicator, the increase in the gully RPNs in 1999 and 2001-2002 may be in response to the above average 1997 and 2000 year classes. Both the 2001 and 2002 RPNs for the gully stations are higher than the peak in 1999, which supports the current model estimate that the 2000 year class was larger than 1997. Therefore, it is possible that the gully stations may both show large year classes earlier, but be a better gauge of their strength than the full slope survey. In the future, we will continue to explore sablefish catch rates in gullies and explore their usefulness in indicating recruitment; they may also be useful for quantifying depredation, since sperm whales have rarely depredated on gully stations.

Interactions between the fishery and survey are described in Appendix 3A.

IPHC Longline Surveys

The International Pacific Halibut Commission (IPHC) conducts a longline survey each year to assess Pacific halibut. This survey differs from the AFSC longline survey in gear configuration and sampling design, but catches substantial numbers of sablefish. More information on this survey can be found in Soderlund et al. (2009). A major difference between the two surveys is that the IPHC survey samples the shelf consistently from 1-500 meters, whereas the AFSC survey samples the slope and select gullies from 200 to 1000 meters. Because the majority of effort occurs on the shelf in shallower depths, the IPHC survey may catch smaller and younger sablefish than the AFSC survey; however, lengths of sablefish are not taken on the IPHC survey.

For comparison to the AFSC survey, IPHC RPNs were calculated similar to the AFSC survey, the only difference being the depth stratum increments. First an average CPUE was calculated by depth stratum for each region. The CPUE was then multiplied by the area size of that stratum. A region RPN was calculated by summing the RPNs for all strata in the region. Area sizes used to calculate biomass in the RACE trawl surveys were utilized for IPHC RPN calculations.

The first figure below compares the RPNs for the two time series for all areas combined. The two series track well, but the IPHC survey RPN has more variability. This makes sense because it surveys shallower water where younger sablefish reside. Since the abundance of younger sablefish will be more variable as year classes pass through, the survey should more closely resemble the NMFS GOA trawl survey index described below (Figure 3.3). Differences in scale can be attributed to CPUE calculation methods (i.e,, the AFSC CPUE is fish/skate (45 hooks), and the IPHC CPUE is fish/hook).

Because of their differences in variability we computed Student's t normalized residuals and plotted them for the time series (2^{nd} figure below). The trends compared this way tracked very closely ($r = 0.61$) and suggested a similar recent decreasing trend and terminus. Trends by region were also similar but more variable for most areas. We will continue to examine trends in each region and at each depth interval for evidence of recruiting year classes and for comparison to the AFSC longline survey. There is some effort in depths shallower than 200 meters on the AFSC survey, and we will compute RPNs for these depths for future comparisons with the IPHC RPNs.

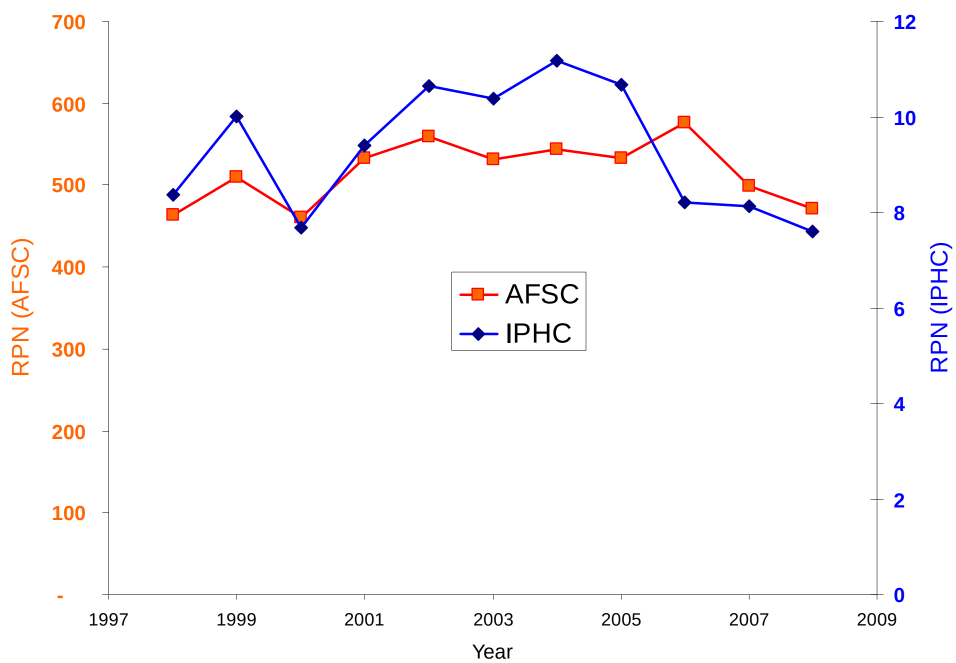


Figure. Comparison of RPNs computed for the IPHC and AFSC longline surveys.

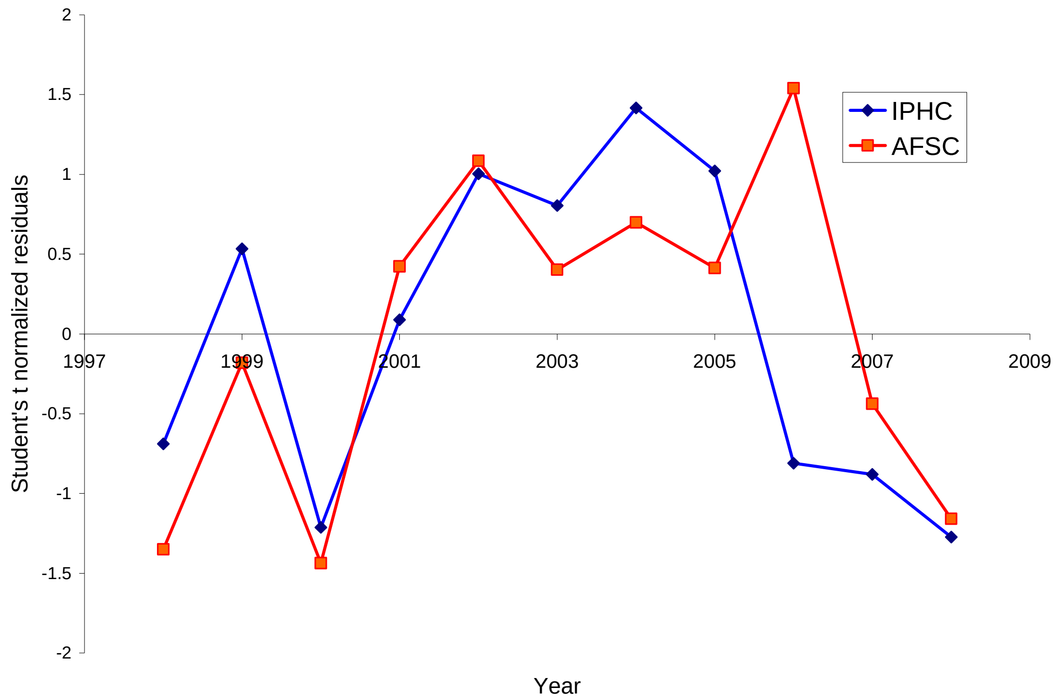


Figure. Student's t normalized residuals of the IPHC and AFSC RPN indices for sablefish.

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted biennially or triennially since 1980 in the Aleutian Islands, and 1984 in the Gulf of Alaska. Trawl surveys of the Eastern Bering Sea slope were conducted biennially from 1979-1991 and standardized for 2002, 2004, and 2008. 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 the data could give mixed signals on year class strength. At this time we are using only the Gulf of Alaska trawl survey biomass estimates (<500 m depth, Figure 3.3) and length data (<500 m depth, Figures 3.14, 3.15) as an index for the whole population. The largest proportion of sablefish biomass is in the Gulf of Alaska so it should be indicative of the overall population. Biomass estimates used in the assessment for 1984-2009 are shown in Table 3.4. The GOA trawl survey index is at a low level in 2009, similar to 2007 and 1999.

Aleutian Islands and Bering Sea Slope survey biomass estimates are not used in the assessment model but are tracked in the following figure:

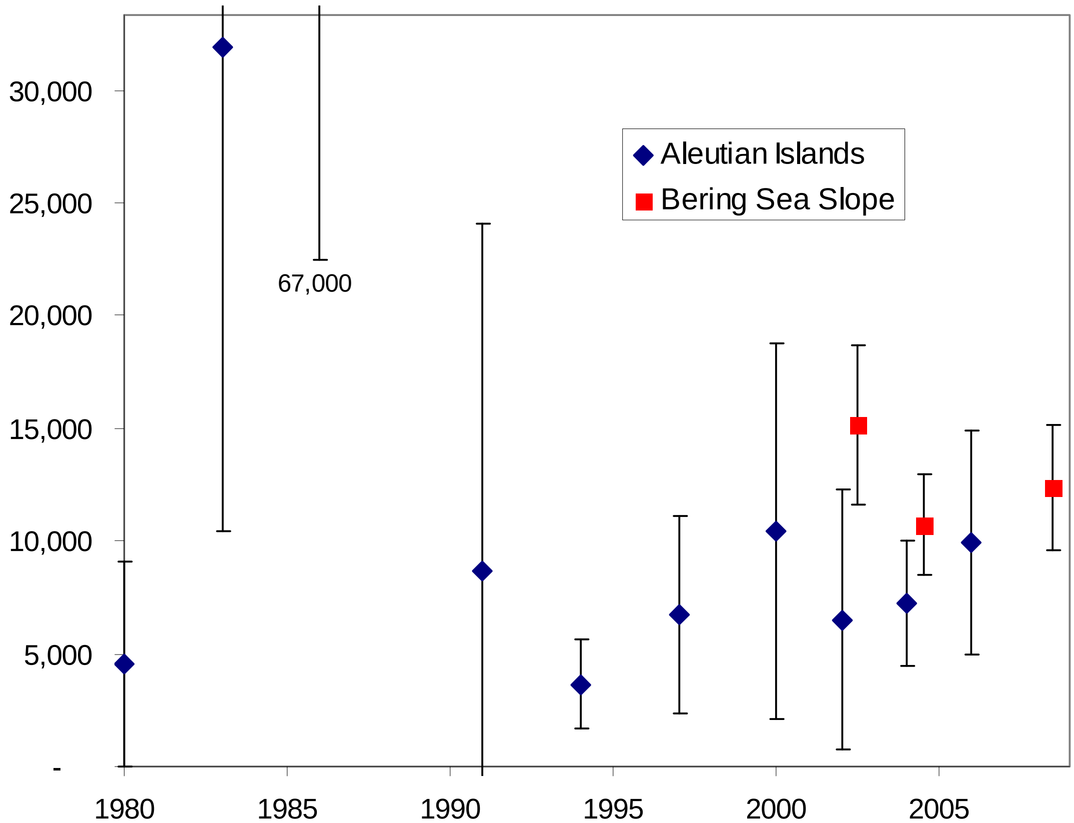


Figure. Aleutian Islands and Bering Sea Slope biomass estimates from NMFS trawl surveys. Bering Sea Slope years are jittered forward 6 months so they do not overlap with Aleutian Islands estimates and y-axis is restricted from showing highest biomass (67,000 t) so recent data is more visible.

Trawl survey catches are tabled in Appendix 3B.

Other surveys

The Alaska Department of Fish and Game conducts mark-recapture and a longline survey in Northern Southeast Alaska Inside (NSEI) waters. This population is considered be a different population, but some migration into and out of Inside waters has been confirmed with tagging studies. This population has been low to moderate recently, with longline survey data confirming the lows in 1999/2000 (see figure below), but showing a mild increase through 2008 (Dressel 2009). However, the most recent abundance estimates from a mark-recapture program, shows a sizeable decline from 2007 to 2008 after increases from 2005-2007 (Dressel per. comm. 2009).

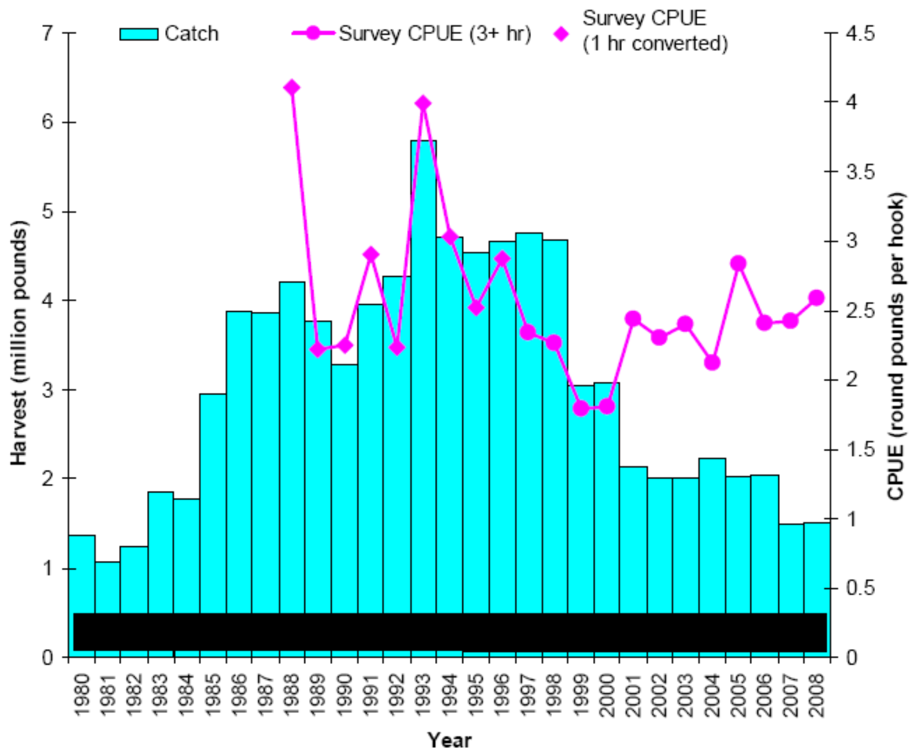


Figure. Northern Southeast Inside sablefish long line survey catch per unit effort in round pounds per hook and harvest over time (from Dressel per. comm. 2009).

The Department of Fish and Oceans of Canada (DFO) conducts a trap survey, conducts tagging studies, and tracks fishery catch rates in British Columbia, Canada. In a recent report (TSC 2008) they summarized the following:

"Catch rates from the fall standardized survey have declined by about 62% since a recent high in 2003. The 2007 stratified random survey declined about 30% from 2006 to 2007. Trap fishery catch rates in 2006 and 2007 are at about the level observed during the mid-2000 to mid-2002 period and much lower than those observed in the early 1990s. Catch rates from a survey in mainland B.C. inlets, where there is no directed sablefish fishing, have declined about 50% since a recent high in 2002."

These large reported declines in abundance south of Alaska concern us, and points to the need to better understand the contribution to Alaska sablefish productivity from B.C. sablefish. Some ideas we have proposed are to conduct an area-wide study of sablefish tag recoveries, and to model the population to include B.C. sablefish.

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 exceptionally large 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 1970's year classes accounted for the sharp increase in overall abundance during the early 1980's. During the late 1980's 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 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 1997 year class first became important in the survey in the western areas at age 4 (2001 plot), and shows up in the Central Gulf throughout 2002-3 and then the Eastern Gulf in 2004 (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 2000) 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 index, 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. The recent stabilization and increase in the survey index was likely caused by the 1997 and 2000 year classes entering the fishery. However, surveys in 2008 and 2009 have shown this area to be at it lowest levels during the domestic survey. The overall long-term decline in abundance for this area, which is considered a part of the main spawning area (central and eastern Gulf of Alaska), will be monitored closely.

Relative abundance trends – short-term

Assessment results: The fishery abundance index was up 5% from 2007 to 2008 (the 2009 data are not available yet). The survey abundance index increased 2% from 2008 to 2009 following a 16% decrease from 2006 to 2008. Relative abundance in 2009 is level with 2000, and is near the all-time low for the domestic longline survey. The GOA 2009 trawl survey estimate fell 2% from 2007, and is at its lowest since 1999.

Analytic approach

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). The current model configuration follows a more complex version of the Gulf of Alaska Pacific ocean perch model (Hanselman et al. 2005a) with split sexes to attempt to more realistically represent the underlying population dynamics of sablefish. The current configuration was accepted by the Groundfish Plan Team and NPFMC in 2008 (Hanselman et al. 2008). 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

The following table lists the parameters estimated independently:

Parameter name	Value	Value	Source
Time period	1981-1993	1996-2004	
Natural mortality	0.1	0.1	Johnson and Quinn (1988)
Female maturity-at-age	$m_a = 1/(1+e^{-0.84(a-6.60)})$		Sasaki (1985)
Length-at-age - females	$\bar{L}_a = 75.6(1-e^{-0.208(a+3.63)})$	$\bar{L}_a = 80.2(1-e^{-0.222(a+1.95)})$	Hanselman et al. (2007)
Length-at-age - males	$\bar{L}_a = 65.3(1-e^{-0.227(a+4.09)})$	$\bar{L}_a = 67.8(1-e^{-0.290(a+2.27)})$	Hanselman et al. (2007)
Weight-at-age - females	$\ln \hat{W}_a = \ln(5.47) + 3.02 \ln(1-e^{-0.238(a+1.39)})$		Hanselman et al. (2007)
Weight-at-age - males	$\ln \hat{W}_a = \ln(3.16) + 2.96 \ln(1-e^{-0.356(a+1.13)})$		Hanselman et al. (2007)
Age-age conversion	N/A	N/A	Heifetz et al. (1999)
Recruitment variability ($\square_r$)	1.2	1.2	Sigler et al. (2002)

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 are currently estimated to reach average maximum lengths and weights of 68 cm and 3.4 kg for males and 8 cm and 6.2 kg for females.

Data previously used in the model to populate the age-length conversion matrices were biased by length-stratified sampling and poor geographic coverage. By using these data and constructing age-length conversion matrices without smoothing, model results may have been biased. Because observed lengths at age were collected systematically by length, not randomly, they yielded a higher percentage of large fish at age. For the 2007 assessment we estimated new growth relationships because many more age data were available. We divided the data into two time periods based on the change in sampling design that occurred in 1995. It appears that sablefish maximum length and weight has increased slightly over time. New age-length conversion matrices were constructed using these curves with normal error fit to the standard deviations of the collected lengths at age (Figure 3.8). These new matrices provided for a superior fit to the data. Therefore, we use a bias-corrected and updated growth curve for the older data (1981-1993) and a new growth curve describing recent randomly collected data (1996-2004). This analysis was accepted by the Plan Team in November 2007 and is presented in its entirety in Hanselman et al. (2007).

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 are mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.5 for females and 5 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 - 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). Prior to the 2006 assessment, average male and female maturity was used to compute spawning biomass. Beginning with the 2006 assessment, female-only maturity has been used to compute spawning biomass. Female maturity-at-age from Sasaki (1985) is described by the logistic fit of $m_a = 1/(1+e^{-0.84(a-6.60)})$. Recently collected field and histological descriptions of maturity are being analyzed and will be incorporated into the maturity-at-age data 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 in 2006 we returned to fixing the parameter at 0.10.

Parameters estimated conditionally

Below is a summary of the parameter totals estimated conditionally in the recommended model:

Parameter name	Symbol	Number
Catchability	q	6
Log-mean-recruitment	μ_r	1
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_y	77
Average fishing mortality	μ_f	2
Fishing mortality deviations	ϕ_y	100
Fishery selectivity	fs_a	8
Survey selectivity	ss_a	7
Total		204

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, U.S. longline derby fishery, U.S. longline IFQ 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. For assessments through 2006, we used their results to create a prior distribution which linked catchability estimates for the two surveys. For 2007, we estimated new catchability prior distributions based on the ratio of the various abundance indices to a combined Alaskan trawl index. This resulted in similar mean estimates of catchability to those previously used, but allowed us to estimate a prior variance to be used in the model. This also facilitates linking the relative catchabilities between indices. These priors were used in the recommended model for 2008. This analysis was presented at the September 2007 Plan Team and is presented in its entirety in Hanselman et al. (2007). Lognormal prior distributions were used with the parameters shown below and in Figure 3.9:

Index	U.S. LL Survey	Jap. LL Survey	Fisheries	GOA Trawl
Mean	7.857	4.693	4.967	0.692
CV	33%	24%	33%	30%

Recruitment is not estimated with a stock-recruit relationship, but is estimated with a level of average recruitment with deviations from average recruitment for the years 1933-2008.

Fishing mortality is estimated with two average fishing mortality parameters for the two fisheries (fixed gear and trawl) and deviations from the average for years 1960-2009 for each fishery.

Selectivity is represented using a function and is separately estimated by sex for the longline survey, fixed-gear fishery, and the trawl survey. Selectivity for the longline surveys and fixed-gear fishery is restricted to be asymptotic by using the logistic function. Selectivity for the trawl fishery and trawl survey are dome-shaped (right descending limb) and estimated with a two-parameter gamma-function and a power function respectively (see Box 1 for equations). This right-descending limb is allowed because we do not expect that the trawl survey and fishery will catch older aged fish as frequently because they fish shallower than the fixed-gear fishery. Selectivity for the fixed-gear fishery is estimated separately for the “derby” fishery prior to 1995 and the IFQ fishery from 1995 thereafter. Fishers may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the 1985-1994 “derby” fishery, when fishers reportedly often fished in less productive depths due to crowding. In choosing their ground, they presumably target bigger, older fish, and depths that produce the most abundant catches.

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. The Bayesian analysis has been modified in various ways since the 1999 assessment. In this assessment, the Bayesian analysis considers additional uncertainty in the remaining model parameters, but not natural mortality. The multidimensional posterior distribution is mapped by Bayesian integration methods. The posterior distribution was computed based on 10 million Markov Chain Monte Carlo (MCMC) simulations drawn from the posterior distribution and thinned to 5,000 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. This was determined to be sufficient through simple chain plots, and comparing the means and standard deviations of the first half of the chain with the second half.

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 as random draws from a lognormal distribution with the mean and standard deviation of the 1979-2007 recruitment, in addition to the uncertainty propagated during the MCMC simulations.

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 $B_{35\%}$ 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.

Box 1	Model Description
Y	Year, $y=1, 2,\dots T$
T	Terminal year of the model
A	Model age class, $a = a_0, a_0+1, \dots, a_+$
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	Proportion of females mature at age a
μ_r	Average log-recruitment
μ_f	Average log-fishing mortality
$\phi_{y,g}$	Annual fishing mortality deviation
τ_y	Annual recruitment deviation ~ $(0, \sigma_r)$
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, age class a and gear g ($= s_a^g \mu_f e^{\phi_{y,g}}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=\sum_g F_{y,a,g} + M$)
R_y	Recruitment in year y
B_y	Spawning biomass in year y
$s_{a,s}^g$	Selectivity at age a for gear type g and sex s
$A_{50\%}, d_{50\%}$	Age at 50% selection for ascending limb, age at 50% deselection for descending limb
δ	Slope/shape parameters for different logistic curves
$\mathbf{A}$	Ageing-error matrix dimensioned $a_+ \times a_+$
$\mathbf{A}^l$	Age to length conversion 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 and 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 and 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, standard deviation for 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	
$s_{a,s}^{g}=\left(1+e^{(-\delta_{g,s}(a-a_{50\%,g,s}))}\right)^{-1}$	Logistic selectivity
$s_{a,s}^{g}=\dfrac{a^{\delta_{g,s}}}{\max\left(s_{a,s}^{g}\right)}$	Inverse power family
$s_{a,s}^{g}=\left(\dfrac{a}{a_{\max}}\right)^{a_{\max,g,s}/p}e^{(a_{\max,g,s}-a)/p}$ $p=0.5\left[\sqrt{a_{\max,g,s}{}^2+4\delta_{g,s}{}^2}-a_{\max,g,s}\right]$	Reparameterized gamma distribution
$s_{a,s}^{g}=\left(1-\varphi_s^g\right)^{-1}\left(\dfrac{\left(1-\varphi_s^g\right)}{\varphi_s^g}\right)^{\varphi_s^g}\dfrac{\left(e^{(\delta_{g,s}\varphi_s^g(a_{50\%,g,s}-a))}\right)}{\left(1+e^{(\delta_{g,s}(a_{50\%,g,s}-a))}\right)}$	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*
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\dfrac{s_{a,s}^{g}}{\max\left(s_{a,s}^{g}\right)}w_{a,s}$	Survey biomass index (RPW)
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\dfrac{s_{a,s}^{g}}{\max\left(s_{a,s}^{g}\right)}$	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
$L_{age} = \lambda_{age} \sum_{i=1}^{n_g} -\psi_y^g \sum_{a_0}^{a_+} \left(P_{i,a}^g + v\right) \ln\left(\hat{P}_{i,a}^g + v\right)$	Age composition likelihood
$L_{length} = \lambda_{length} \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l}^g + v\right) \ln\left(\hat{P}_{i,l}^g + v\right)$	Length composition likelihood (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

Model evaluation

For this assessment, we present last year's model updated for 2009 with no model changes. We intend to revisit modeling options at an upcoming sablefish workshop. A comparison to the model likelihood components and key parameter estimates from 2008 are shown in Box 2.

Box 2: Model comparison of the 2008 and 2009 models by contribution to the objective function (negative log-likelihood values) and key parameters.

Model Likelihood Components (Data)	CV/Sample Size (ψ)	**2008**	**2009**
Catch	CV = 3%	3	4
Domestic LL survey RPW	CV = 5%	44	46
Domestic LL survey RPN	CV = 5%	23	24
Japanese LL survey RPW	CV = 5%	30	31
Japanese LL survey RPN	CV = 5%	27	26
Domestic LL fishery RPW	CV = 5%	16	17
Japanese LL fishery RPW	CV = 5%	21	21
NMFS GOA trawl survey	CV = 8-15%	51	53
Domestic LL survey ages	ψ = 250	217	224
Domestic LL fishery ages	ψ = 50	38	41
Domestic LL survey lengths	ψ = 49	117	123
Japanese LL survey ages	ψ = 250	217	216
Japanese LL survey lengths	ψ = 49	107	106
NMFS trawl survey lengths	ψ = 35-65	90	83
Domestic LL fishery lengths	ψ = 49	76	80
Domestic trawl fishery lengths	ψ = 10	21	23
Data *L*		1098	1118
Total objective function value		1123	1141
Key parameters			
Number of parameters		**201**	**204**
B_{2009} *(Female spawning biomass)*		104	103
$B_{40\%}$ *(Female spawning biomass)*		120	115
B_{1960} *(Female spawning biomass)*		152	146
$B_{0\%}$ *(Female spawning biomass)*		300	288
SPR% current		36%	35%
$F_{40\%}$		0.095	0.095
$F_{40\%}$ *(adjusted)*		0.085	0.084
ABC		16.1	15.2
$q_{Domestic\ LL\ survey}$		7.73	7.8
$q_{Japanese\ LL\ survey}$		6.0	6.0
$q_{IFQ\text{-}LL\ fishery}$		4.1	4.2
$q_{Trawl\ Survey}$		1.4	1.0
$a_{50\%}$ *(domestic LL survey)*		3.9	3.8
Domestic $a_{50\%\ selectivity}$		4.1	4.1
□$_r$ *(average recruitment)*		18.4	18.0
□$_r$ *(recruitment variability)*		1.20	1.20

Model results

Definitions

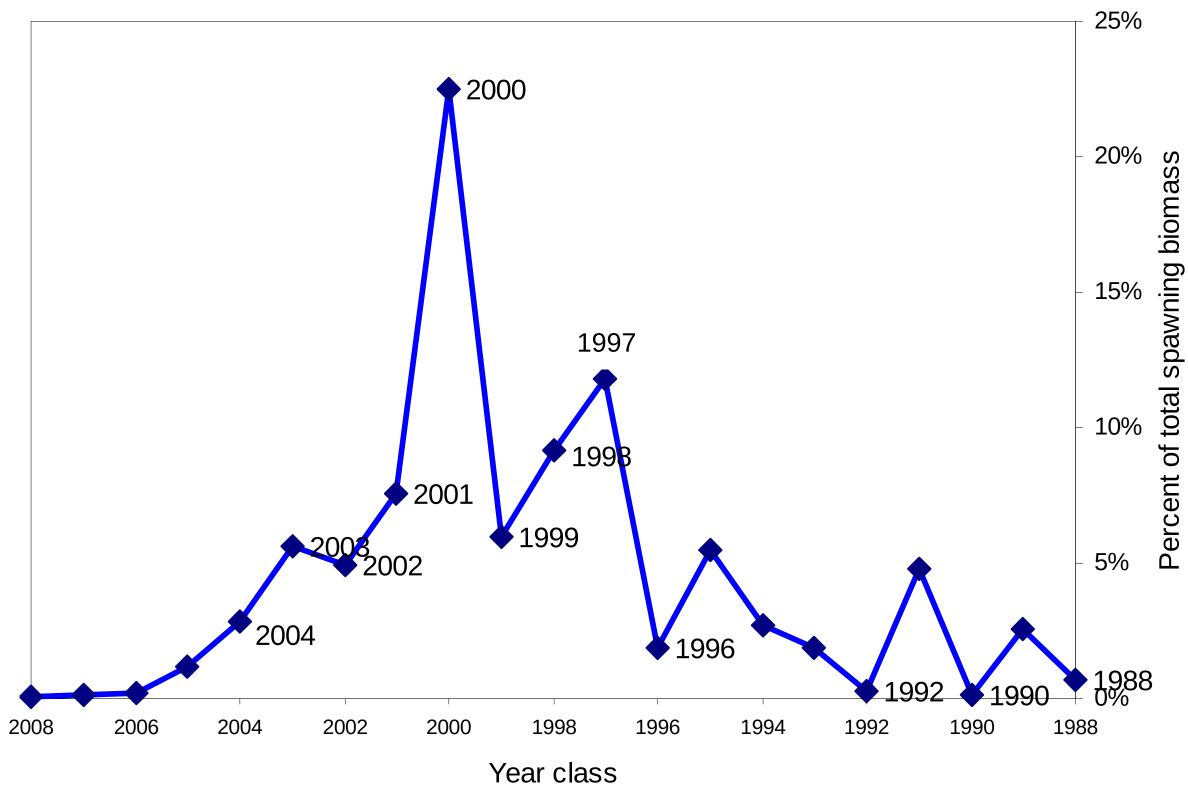
Spawning biomass is the biomass estimate of mature females. Total biomass is the estimate of all sablefish age two and greater. Recruitment is measured as number of age two sablefish. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

Abundance trends

Sablefish abundance increased during the mid-1960's (Table 3.9, Figure 3.10) due to strong year classes in the early 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 53,080 t in 1972. The population recovered due to a series of strong year classes from the late 1970's (Fig 3.18); spawning abundance peaked again in 1987. The population then decreased because these strong year classes expired. The model suggested an increasing trend in spawning biomass since the all-time low in 2001, but is exhibiting a steady decrease in total biomass since 2003 (Figure 3.10).

Projected 2010 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 30% of unfished biomass in 2001 to a projected 35% in 2010. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 12% of the 2010 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now 92% mature and should comprise 23% of the spawning biomass in 2010.

The following figure shows the contribution of the last twenty year classes to projected spawning biomass for 2010.



Recruitment trends

Annual estimated recruitment varies widely (Figure 3.18b). The two recent strong year classes in 1997 and 2000 were pervasive among all data sources. After 2000, few strong year classes are apparent. Few small fish were caught in the 2005 through 2009 trawl surveys (Figures 3.12-13). The 2001 year class appeared to be an above-average year class in the Aleutian Islands/Western Gulf in the 2005-2007 longline survey age compositions. However, the 2001 year class appeared moderate in the Central Gulf in the 2006-2007 survey age composition (Figure 3.7) and is still low in the overall age compositions (Figure 3.18). The 2002 year class appears weak in the 2005 and 2006 longline survey age composition, but showed up somewhat in the Central Gulf in the 2007 age compositions and again in the 2008 Eastern Gulf age compositions. The 2003 year class appears to be average sized in the Western area. However, several more years of data are needed to assess the strength of such a recent year class. The RPN by age class is quite low in the 2008 age compostion (Figure 3.7), but shows an interesting flattening of the middle age distribution. In the Central Gulf, the 1998-2003 year classes all have almost identical RPNs. One possible explanation is the targeting discussed earlier is removing the peaks caused by large year classes like 2000.

During review in 2006, it was suggested that the distribution of recruitment is skewed, and that a new criterion for what recruitments are strong and weak should be determined. Since 2007, year classes were classified as weak if they were in the bottom 25% of recruitment values, strong if they were in the top 25% of recruitment values, and average if they were in the middle 50% of recruitment values. The following table using values estimated recruitment values shows that 12 out of the last 14 year classes (1993-2006) were average or below average except for the 1997 and 2000 year classes.

Strong	1960	1963	1964	1971	1977	1978	1980	1981	1984	1989	1991	1997	2000
Average	1972	1973	1974	1975	1976	1979	1982	1983	1985	1986	1987	1988	
	1990	1992	1993	1994	1995	1996	1998	2001	2002	2003	2004	2005	
Weak	1958	1959	1961	1962	1965	1966	1967	1968	1969	1970	1999	2006	

Average recruitment during 1979-2007 is 18.0 million 2-year-old sablefish per year, which is similar to the average recruitment for the 1958-2007 year classes. Estimates of recruitment strength during the 1960's are uncertain because they depend on less data and because the abundance index is based only on the fishery catch rate, which may be a biased measure of abundance.

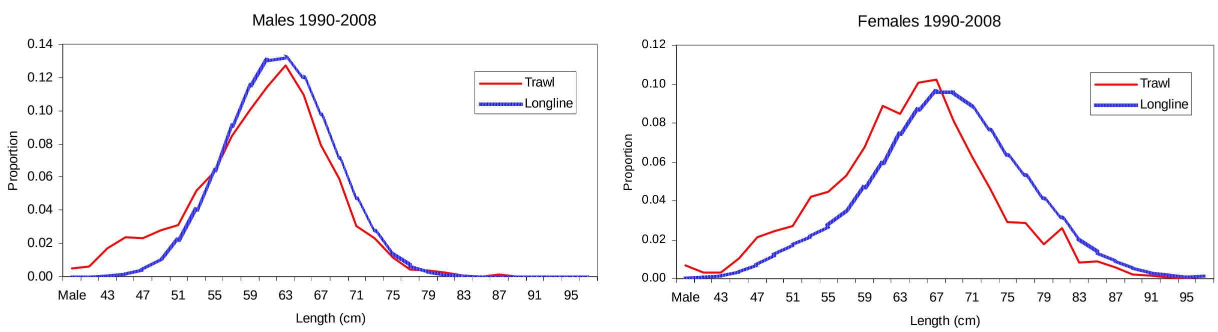
Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1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

Sablefish recruitment varies greatly from year to year (Figure 3.18), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success also is related to recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1960-1961 and 1977 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). Larger than average year classes were produced again in 1997-2000, when the population was at a recent low point. 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.

Selectivities

Selectivity is asymptotic for the longline survey and fisheries and dome-shaped (or descending right limb) for the trawl survey and trawl fishery (Figure 3.19). The age-of-50% selection is 3.9 years for females in the longline survey and 4.1 years for the females in the IFQ longline fishery. Males were selected at an older age than females in both the derby and IFQ fisheries. Females are selected at an older age in the IFQ fishery than in the derby fishery (Figure 3.19a). Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishers were pushed to fish shallower water that young fish inhabit (Sigler and Lunsford 2001). Relative to the longline survey, 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 in shallower waters (< 300 m) where young sablefish reside. The trawl fishery selectivity is the same for males and females (Figure 3.19a). The simpler selectivity curves for the trawl survey are nearly identical to previous estimates, but the curves for the trawl fishery differ and appear more biologically reasonable (Figure 3.19). These patterns are consistent with the idea that sablefish recruit to the fishery at 3-5 years of age and then gradually become less available to the trawl fishery as they move offshore into deeper waters. The trawl survey selectivity has a reasonably smooth descending shape that probably describes trawl selectivity to 500 m in the Gulf of Alaska (Figure 3.19b).



Fishing mortality and management path

Fishing mortality was estimated to be high in the 1970s, relatively low in the early 1980s and then increased and held relatively steady in the 1990s and 2000s (Figure 3.20). 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. Previously we used the management path as suggested by Goodman et al. (2002), but several reviews have suggested a similar phase-plane plot that shows our harvest control rules. In this “management path” we plot estimated fishing mortality relative to the (current) limit value and the estimated spawning biomass relative to target spawning biomass ($B_{40\%}$). Figure 3.21 shows that recent management has generally constrained fishing mortality below the limit rate, but has not been able to keep the stock above the $B_{40\%}$ target.

Uncertainty

We compared a selection of parameter estimates from the Markov-Chain Monte Carlo simulations with the maximum-likelihood estimates, and compared each method's associated level of uncertainty (see following table). The three catchability estimates were estimated similarly in terms of mean and median by the two methods, where the MCMC results had much higher standard deviations. $F_{40\%}$ was estimated lower by the maximum likelihood and shows some skewness as indicated by the difference between the MCMC mean and median. Under both methods the variance is relatively high. Ending female spawning biomass and the last large recruitment (2000) are both estimated precisely and similarly by both methods.

Table of key parameter estimates and their uncertainty.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ (Hessian)	σ (MCMC)	BCI-Lower	BCI-Upper
$q_{domesticLL}$	7.77	7.76	7.77	0.02	0.17	7.43	8.09
q_{coopLL}	5.96	5.96	5.96	0.02	0.14	5.70	6.25
q_{trawl}	1.04	0.99	0.98	0.32	0.09	0.84	1.18
$F_{40\%}$	0.095	0.109	0.104	0.024	0.034	0.063	0.182
2010 SSB (kt)	103.0	104.6	104.5	4.1	2.9	99.2	110.6
2000 Year Class	36.2	40.7	42.0	4.5	6.1	27.0	50.0

Retrospective analysis

Retrospective analysis is the examination of the consistency among successive estimates of the same parameters obtained as new data are added to a model. Retrospective analysis has been applied most commonly to age-structured assessments. Retrospective biases can arise for many reasons, ranging from bias in the data (e.g., catch misreporting, non-random sampling) to different types of model misspecification such as wrong values of natural mortality, or temporal trends in values set to be invariant. Classical retrospective analysis involves starting from some time period earlier in the model and successively adding data and testing if there is a consistent bias in the outputs (NRC 1998).

For this assessment, we show the retrospective trend in spawning biomass and total biomass for six years (2004-2009). This analysis is simply removing all new data that have been added for each consecutive year for the preferred model. Each year of the assessment generally adds one year of longline fishery lengths, trawl fishery lengths, longline survey lengths, longline and fishery ages (from one year prior), fishery abundance index, and longline survey index. Every other year, a trawl survey estimate and corresponding length composition are added.

Over the last six years, there had been a downward drift in recent spawning biomass estimates for the current time period (Figure 3.22). The historic part of the spawning biomass time series remains relatively constant with the addition of new data, which is reassuring. This drift in spawning biomass estimates in general retains the same trend, but moves downward. In addition to reflecting incoming data that suggests lower biomass and recruitment, there may be some model bias affecting the estimates. A common way to incur this type of bias might be a natural mortality estimate that is too high.

Total biomass shows a slightly different pattern, where not only do the estimates become lower, but the recent trend exhibited by the three most recent "assessments" shows a reversal and now is descending (Figure 3.22). This reversal is unlikely a model bias, but a reflection of new data influencing the current estimates of stock size.

Interestingly, in the last several assessment cycles, this retrospective pattern seems to have ceased (Figure 3.23). Recently, the estimates of the trajectories for the last three years (2007-2009) are almost identical. This may be a case of the model catching up to the data. This is also evident in that the last two years, the assessment projection for the following year has been accurate, while previously it had been overestimating.

Experimentation in 2008, and at the request of the CIE review panel in 2009 involved attempting various parameter configurations to remove the retrospective bias. These trials revealed ways to nearly remove this retrospective bias. Three scenarios that greatly alleviated the bias and some explanation were:

1) Fixing catchability parameters at the most recent model's estimates removed all retrospective bias. While this removes the retrospective bias, it is likely that it is merely masking another process that is causing these parameters to drift. Fixing these parameters can also be risky because the catchability parameters are relatively unknown, particularly for longline surveys.
2) If catchability is not actually changing over time, but the estimates are, it may be caused by some other parameter being misspecified that catchabilities are confounded with. Catchability is always confounded with natural mortality, fishing mortality and selectivity. In a second scenario, we also estimated natural mortality. This removed nearly all the retrospective bias. The estimates of natural mortality drifted instead of catchability, ranging from values of 0.117 from the present model to 0.107 to the earliest retrospective model. In addition, fixing natural mortality at a higher value (0.11) also decreased some of the retrospective trend.
3) Since changing estimated natural mortality seemed to alleviate some bias, we also thought it might be reasonable to see if a higher fishing mortality might perform similarly. In this scenario, we increased catch estimates since 1990 by the difference in one year's retrospective trend's biomass estimate (2008 to 2007). Not surprisingly, this had almost the same effect as allowing natural mortality to increase.

From this relatively brief exploration of the retrospective bias, several potential causes were postulated. Each recent year the model has recommended a level of catch below $F_{40\%}$ (because the stock is below $B_{40\%}$), that level has not been fully attained, yet in general the indices are coming in lower than the year before. Therefore, when the model was recalculated in the following year, under the current assumptions regarding natural mortality, it estimates that catchability must have been higher to obtain the higher abundance indices preceding it. This is how the model accounts for the decline in the survey abundance indices even though there was less catch than the prescribed quota. On the other hand, if natural mortality is higher or rising, or if catch is unaccounted for, then this would account for an additional amount of mortality that might cause the index to decrease. Indeed, when more mortality is accounted for, the catchability coefficients remain the same.

Of course, these ideas cannot be justified without some attempt to explain what this could mean biologically. Catchability could actually be increasing as bottom temperature increases (a scent plume travels further in warm water). Natural mortality could be increasing from either predation by whales and fish, or increased competition for prey by rising populations of rockfish. It is possible that depredation by whales is increasing in magnitude over time in both the survey and fishery. This is an unattributed source of mortality that could have this effect on the model, both through interference with survey numbers and estimated total catch.

Revealing retrospective trends can show potential biases in the model, but may not prove what their source is. Other times a retrospective trend is merely a matter of the model having too much inertia in the age-structure and other historic data to respond to the most recent data. We will monitor and explore these patterns in the future.

Projections and harvest alternatives

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

Natural mortality (M)	0.10
Tier	3b
Equilibrium unfished spawning biomass	281,816
Reference point spawning biomass, $B_{40\%}$	112,726
Reference point spawning biomass, $B_{35\%}$	98,636
Spawning biomass	99,897
2009 total (age 4+) biomass	221,000
Maximum permissible fishing level	
$F_{40\%}$	0.095
$F_{40\%}$ adjusted	0.084
$F_{40\%}$ adjusted Yield	**15,230**
Overfishing level	
$F_{35\%}$	0.114
$F_{35\%}$ adjusted	0.100
$F_{35\%}$ adjusted Yield	18,030
Authors' recommendation	
F	0.084
ABC	**15,230**

We recommend a 2010 ABC of 15,230 t. The maximum permissible yield for 2010 from an adjusted F40% strategy is 15,230 t. The maximum permissible yield for 2010 is a 5% decrease from the 2009 ABC of 16,080 t. This decrease is supported by three low years in the domestic longline survey abundance estimate and two subsequent low trawl survey abundance estimates. There is also little evidence of any large incoming recruitment classes. Spawning biomass is projected to decline through 2013, and then is expected to increase assuming average recruitment is achieved. Because of the lack of recent strong year classes, the maximum permissible ABC is projected to be 13,658 t in 2011 and 12,592 in 2012 (using estimated catches, instead of maximum permissible, see Table 3.10).

Reference fishing mortality rate

Sablefish are managed under Tier 3 of NPFMC harvest rules which specifies that the fishing rate be adjusted downward when biomass is below the target reference biomass. Compared to a constant fishing rate strategy, the adjustable rate strategy was shown in simulations by Sigler and Fujioka (1993) to significantly reduce the risk of overfishing of sablefish, while attaining nearly the same yield with lower fishing effort. Fujioka et al (1997) showed analytically the same advantages of an adjustable fishing rate compared to a constant fishing rate strategy. Reference points are calculated using recruitments from 1979-2007. The updated point estimates of B40%, F40%, and F35% from this assessment are 112,726 t (combined across the EBS, AI, and GOA), 0.095, and 0.114, respectively. Projected spawning biomass (combined areas) for 2010 is 99,897 t (89% of B40%), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of FABC under Tier 3b is 0.084 which translates into a 2010 ABC (combined areas) of 15,230 t. The OFL fishing mortality rate is 0.100 which translates into a 2010 OFL (combined areas) of 18,030 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

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 2009 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2009 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 2010, 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 catch in 2009 to the ABC recommended in the assessment for 2009. (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 ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then maximum permissible thereafter. Projections incorporating estimated catches 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 2005-2009 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 1) above its MSY level in 2009 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, 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 2022 under this scenario, then the stock is not approaching an overfished condition.)

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 pre-specified catches to increase accuracy of short-term projections in fisheries (such as sablefish) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for 2010 and 2011. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then set catch at maximum permissible thereafter.

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2008) is 14,335 t. This is less than the 2008 OFL of 21,310 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2009:
a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2009 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 3.10). If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 3.10, the stock is not overfished and is not approaching an overfished condition.

Bayesian analysis

The estimates of ending spawning biomass are well-defined by the available data. Most of the probability lies between 95,000 and 105,000 t (Figure 3.24). The probability changes smoothly and with a relatively normal distribution.

Scatter plots of selected pairs of model parameters were produced to evaluate the shape of the posterior distribution (Figure 3.25). The plots indicate that the parameters are reasonably well defined by the data. As expected, catchabilities and ending spawning biomass are confounded. The catchability of the longline survey is most confounded with ending spawning biomass because it has the most influence in the model in recent abundance predictions.

We estimated the posterior probability that projected abundance will fall, or stay below thresholds of 17.5% (MSST), and 35% (MSY), and 40% (B_{target}) of the unfished spawning biomass based on the posterior probability estimates. Abundance was projected for 14 years. For management, it is important to know the risk of falling under these thresholds. Spawning biomass was compared to key biological reference points for each MCMC run (thinned and burnt-in) and the probability that spawning biomass falls below these reference points was estimated. The probability that next year's spawning biomass was below $B_{35\%}$ was 0.33. During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of falling below $B_{35\%}$ is 0.99, and the probability of staying below $B_{40\%}$ is near 100% (Figure 3.26).

Alternate Projection

During the 2007 rockfish CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. For this assessment we show a projection that considers uncertainty from the whole model by running projections within the model. This projection propagates uncertainty throughout the entire assessment procedure and is based on 10,000,000 MCMC (burnt-in and thinned) using the standard Tier 3 harvest rules. The projection shows wide credible intervals on future spawning biomass (Figure 3.27). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1979-2007 recruitments, and this projection predicts that the median spawning biomass will dip below $B_{35\%}$ by 2011, and then return to $B_{40\%}$ if average recruitment is attained.

Acceptable biological catch

We recommend a 2010 ABC of 15,230 t. The maximum permissible yield for 2010 from an adjusted F40% strategy is 15,230 t. The maximum permissible yield for 2010 is a 5% decrease from the 2009 ABC of 16,080 t. This decrease is supported by three low years in the domestic longline survey abundance estimate and two subsequent low trawl survey abundance estimates. There is also little evidence of any large incoming recruitment classes. Spawning biomass is projected to decline through 2013, and then is expected to increase assuming average recruitment is achieved. Because of the lack of recent strong year classes, the maximum permissible ABC is projected to be 13,658 t in 2011 and 12,592 in 2012 (using estimated catches, instead of maximum permissible, see Table 3.10).

Projected 2010 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 30% of unfished biomass in 2001 to a projected 35% in 2010. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 12% of the 2010 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now 92% mature and should comprise 23% of the spawning biomass in 2010.

The following table shows the maximum permissible ABC, and ABCs recommended by the stock assessment authors, Plan Teams, SSC, and NPFMC, by fishing year 1997-2008.

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
2007	20,100	20,100	20,100	20,100	20,100
2008	18,030	18,030	18,030	18,030	18,030
2009	16,080	16,080	16,080	16,080	16,080

Area apportionment 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 apportionment. 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 apportioned using an exponential weighting of regional RPWs. 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 set the exponential factor at ½, so that, except for the first year, 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 regional 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 apportionments of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an apportionment based on survey and fishery data. We continue to use survey and fishery data to apportion the 2010 ABC. The fishery and survey information were combined to apportion ABC using the following method. The RPWs 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 has typically been twice that of the survey data, so the survey data was weighted twice as much as the fishery data. Recent improvements in sample size of observer and logbook collections have reduced the variance on the fishery sources.

Apportionments are based on survey and fishery information	**2009 ABC Percent**	**2009 Survey RPW**	**2008 Fishery RPW**	**2010 ABC Percent**	**2009 ABC**	**2010 ABC**	**Change**
Total					16,080	**15,230**	-5%
Bering Sea	17%	19%	21%	18%	2,720	**2,790**	3%
Aleutians	14%	13%	14%	14%	2,200	**2,070**	-6%
Gulf of Alaska	69%	68%	65%	68%	11,160	**10,370**	-7%
Western	15%	18%	15%	16%	1,640	**1,660**	1%
Central	45%	44%	39%	44%	4,990	**4,510**	-10%
W. Yakutat	15%	13%	17%	14%	1,630	**1,480**	-9%
E. Yakutat / Southeast	26%	25%	29%	26%	2,890	**2,720**	-6%

After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the ABC for West Yakutat is 1,620 t and for East Yakutat/Southeast is 2,580 t. This adjustment projected to 2011 is 1,450 t for W. Yakutat and 2,320 t for E. Yakutat.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2010	1,620 t	2,580 t
	2011	1,450 t	2,320 t

This year's apportionment reflects a decrease in the longline survey index in the Central Gulf, while the survey index showed small increases in the rest of the areas. The Bering Sea had a substantial increase in fishery RPW in 2008 (Figure 3.28a). The only area to have sizeable increases in both fishery and survey RPWs was the Western Gulf. The standard weighted average approach described above, which includes values from 2004-2009 for survey RPWs and 2003-2008 for fishery RPWs, greatly alleviates the effect of an individual year's change in RPW (Figure 3.28b). The Bering Sea continues to increase its share of the apportionment mainly due to its rapid increase in fishery RPW, and the Central Gulf had a slight downward shift due to recent decreases in survey RPWs. However, the current apportionment is characteristic of most prior years except for 2005 (Figure 3.28c).

Overfishing level (OFL)

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b results in a value of 18,030 t for the combined stock. The OFL is apportioned by region, Bering Sea (3,310 t), Aleutian Islands (2,450 t), and Gulf of Alaska (12,270 t), by the same method as the ABC apportionment.

Ecosystem considerations

Preliminary results of first-order trophic interactions for sablefish have recently been provided from the ECOPATH model. While prominence of some interactions may be the result of insufficient data, estimation of prey interactions of adult sablefish in the Gulf of Alaska appear reasonable. Sampling coverage appeared the broadest geographically in 2005 in the Gulf so we show that data as an example (Figure 3.29). In 2005, more than half of the sablefish diet consisted of offal, squid, pandalid shrimp, and walleye pollock. Further analysis of prey data may help form hypotheses to explain increases and decreases in sablefish abundance.

Significant predator interactions on sablefish may be more difficult to predict accurately. Sablefish may not be sufficiently abundant to be prominent or consistent enough in predator diets to discern the major predators given the current level of sampling potential predators. Most diet information is from the trawl survey which does not fully sample the sablefish population. Sufficient sampling of potential predators of adult sablefish, such as sharks and whales, may not be feasible. We will closely monitor developments in these models and their corresponding data for interesting trends and hypotheses.

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

Ecosystem effects on the stock

Prey population trends: Young-of-the-year sablefish prey mostly on euphausiids (Sigler et al. 2001) and copepods (Grover and Olla 1990), while juvenile and adult sablefish are opportunistic feeders. Larval sablefish abundance has been linked to copepod abundance and young-of-the-year abundance may be similarly affected by euphausiid abundance because of their apparent dependence on a single species (McFarlane and Beamish 1992). The dependence of larval and young-of-the-year sablefish on a single prey species may be the cause of the observed wide variation in annual sablefish recruitment. No time series is available for copepod and euphausiid abundance, so predictions of sablefish abundance based on this predator-prey relationship are not possible.

Juvenile and adult sablefish feed opportunistically, so 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 being invertebrates (Yang and Nelson 2000). Of the fish found in the diets of adult sablefish, pollock were the most abundant 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. In southeast Alaska, juvenile sablefish also consume juvenile salmon at least during the summer months (Sturdevant et al. 2009). 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 (Tanasichuk 1997). Off Vancouver Island, herring and other fish were increasingly important as sablefish size increased; however, the most important prey item was euphausiids. It is unlikely that juvenile and adult sablefish 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 juvenile 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). Although juvenile sablefish may not be a prominent prey item because of their relatively low and sporadic abundance compared to other prey items, they share residence on the continental shelf with arrowtooth flounder, halibut, Pacific cod, bigmouth sculpin, big skate, and Bering skate, which are the main piscivorous groundfishes in the Gulf of Alaska (Yang et al. 2006). It seems possible that predation of sablefish by other fish is significant to the success of sablefish recruitment even though they are not a common prey item.

Sperm whales are likely a major predator of adult sablefish. Fish are an important part of sperm whale diet in some parts of the world, including the northeastern Pacific Ocean (Kawakami 1980). Fish have appeared in the diets of sperm whales in the eastern Aleutians and Gulf of Alaska. Although fish species were not identified in sperm whale diets in Alaska, sablefish were found in 8.3% of sperm whale stomachs off of 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. 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, while not at all in others (Shotwell 2007). 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; these prey are prominent in the diet of many other groundfish species as well. This diet overlap may cause competition for resources between small sablefish and other groundfish species.

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.

Anthropogenic changes in the physical environment: 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 primarily based on the criterion that sablefish are currently above Minimum Stock Size Threshold (MSST), however caution is warranted as the Center of Independent Experts review of the EIS stated *"The use of stock abundance relative to MSST to assess the possible influence of habitat degradation on fish stocks was not considered to be appropriate for several reasons"* (Drinkwater 2004). Stoner et al. (2005) noted "*Comparisons of trawled and untrawled locations in the Gulf of Alaska and the Bering Sea reveal that densities and biomass of sponges, anemones, bryozoans, gastropod shells, soft corals, and other biota providing structure for small fishes decrease with fishing activity. It follows that loss of structured habitat in low-relief shelf environment can have both direct and indirect impacts on the function of habitat for demersal fishes, particularly during their first year of life*".

Juvenile sablefish are substantially dependent on benthic prey (18% of diet by weight) which may be adversely affected by fishing. Little is known about effects of fishing on that habitat as well as the habitat requirements for growth to maturity. Although sablefish do not appear substantially dependent on physical structure, reduction of living structure is predicted in much of the area where juvenile sablefish reside. Effects of habitat reduction on the continental shelf may indirectly reduce juvenile survivorship by reducing prey availability or by altering the relative abilities of competing species to feed and avoid predation. The increased abundance of arrowtooth flounder, a resident of the continental shelf, is a substantial change in the ecosystem that may have anthropogenic causes. These issues may be relevant to sablefish recruitment in areas of the Bering Sea and Gulf of Alaska where intensive bottom trawl fishing coincides with areas where juvenile sablefish have been found. Umeda et al. (1983) noted an abundance of juvenile sablefish from the 1977 year class in the Bering Sea that is subject to intense bottom fishing.

Effects of the sablefish 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 17% 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.

Table of 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	2003-2005 average	2006	2007	2008	2009	Average	Average catch (t)
Birds	12.0%	19.0%	25.5%	22.7%	16.8%	17.3%	1.81
Brittle stars	0.5%	0.2%	0.7%	0.2%	5.2%	0.5%	0.15
Corals Bryozoans	1.2%	3.0%	0.4%	3.0%	6.1%	2.0%	0.96
Eelpouts	1.0%	2.1%	1.3%	9.7%	2.5%	2.2%	2.4
Grenadier	64.0%	80.6%	18.8%	46.0%	68.8%	65.6%	4,484.16
Large Sculpins	0.1%	0.1%	0.1%	0.0%	0.3%	0.1%	7.76
Octopus	0.6%	0.1%	0.5%	0.2%	0.2%	0.4%	2.19
Sea anemone	0.1%	0.3%	2.4%	0.6%	1.2%	0.7%	0.99
Sea star	0.0%	0.2%	1.1%	0.1%	0.2%	0.2%	6.81
Shark, Other	7.2%	1.2%	3.5%	15.3%	0.0%	3.8%	4.64
Shark, pacific sleeper	3.1%	4.4%	0.9%	2.0%	1.6%	2.9%	14.39
Shark, salmon	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.17
Shark, spiny dogfish	18.7%	12.4%	19.6%	16.8%	23.5%	17.6%	145
Skate, Big	0.2%	0.7%	0.1%	0.2%	0.1%	0.3%	3.15
Skate, Longnose	3.9%	3.8%	1.5%	3.0%	2.3%	3.1%	16.11
Skate, Other	0.5%	0.9%	0.7%	0.4%	0.6%	0.6%	123.72
Snails	1.6%	4.4%	4.8%	3.3%	8.8%	3.2%	6.06
Sponge	0.3%	0.4%	0.1%	9.3%	0.8%	1.3%	2.75

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 apportioned 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% from the derby fishery (1990-1994) to the IFQ fishery (1995-1998) (Sigler and Lunsford 2000).

Fishery-specific effects on EFH non-living substrate:

The primary fishery for sablefish is with longline gear. While it is possible that longlines could move small boulders it is unlikely fishing would persist where this would often occur. Relative to the effect on living structures and relative to the effect by bottom tending mobile gear, a significant effect of longlines on bedrock, cobbles, or sand is not easily envisioned.

Data gaps and research priorities

There is little information on early life history of sablefish and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the sablefish population. Improved fishery observer 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.

Future sablefish research is going to focus on several directions:

1) We wish to hold a sablefish data/modeling workshop in winter 2010 to discuss:
    a. Use of RPNs and RPWs from the same survey
    b. Utility of GLMs for analyzing fishery catch rates and survey data
    c. Use of length and age data from the same survey and year
    d. Inclusion of trawl survey age data
    e. Inclusion of longline survey gully ages and abundance data
    f. Use of unsexed Japanese longline and trawl length data
    g. Use of environmental data to aid in determining recruitment
    h. Inclusion of different sources of sex-ratio data
    i. Migration rate data
    j. Appropriateness of current variance assumptions about data components
2) 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.
3) Improve knowledge of sperm whale depredation during the longline survey and its effect on survey catch rates.
4) A sablefish maturity study has been initiated and will provide updated maturity estimates from visual and histological methods.

Summary

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

Natural mortality (M)	0.10
Tier	3b
Equilibrium unfished spawning biomass	281,816
Reference point spawning biomass, B40%	112,726
Reference point spawning biomass, B35%	98,636
Spawning biomass	99,897
2009 total (age 4+) biomass	221,000
Maximum permissible fishing level	
F40%	0.095
F40% adjusted	0.084
F40% adjusted Yield	**15,230**
Overfishing level	
F35%	0.114
F35% adjusted	0.100
F35% adjusted Yield	18,030
Authors' recommendation	
F	0.084
ABC	**15,230**

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Tables

Table 3.1a. Alaska sablefish catch (t). 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/ SEO.	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

Table 3.1a. Alaska sablefish catch (t). 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/ SEO.	Un-known	Fixed	Trawl
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	16,371	927	1,009	2,118	7,088	5,228	1,880	3,347	0	14,286	2,085
2004	17,720	1,038	955	2,170	7,457	6,099	2,299	3,800	0	16,063	1,656
2005	16,619	1,064	1,481	1,929	6,701	5,443	1,869	3,575	0	15,063	1,556
2006	15,417	1,036	1,132	2,140	5,908	5,201	1,905	3,296	0	14,177	1,240
2007	15,011	1,173	1,149	2,064	5,609	5,016	1,772	3,243	0	13,776	1,235
2008	14,335	1,119	891	1,666	5,302	5,358	2,057	3,301	0	13,211	1,124

Table 3.1b. Retained Alaska sablefish catch (t) 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	213	35	761	1,009
2004	384	32	539	955
2005	688	115	679	1,481
2006	458	60	614	1,132
2007	632	40	476	1,149
2008	177	76	638	891
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	295	226	406	927
2004	432	293	312	1,038
2005	590	273	202	1,064
2006	584	84	368	1,036
2007	879	92	203	1,173
2008	748	183	187	1,119

Table 3.2. Discarded catches of sablefish (amount [t], percent of total catch, total catch [t]) by gear (H&L=hook & line, Pot, Trwl=trawl), FMP area for 1994-2008. Average values are shown for 1994-2003. Annual values for 1994-2003 are shown in previous sablefish SAFE chapters.

		BSAI			GOA			Combined		
YEAR	Gear	Discard	% Discard	Catch	Discard	% Discard	Catch	Discard	% Discard	Catch
1994 -	H&L	122	10%	1,281	403	3%	13,358	525	4%	14,639
2003	Pot	7	2%	508				7	2%	508
Average	Trwl	52	17%	314	773	35%	2,232	825	32%	2,546
	Total	181	9%	2,103	1,177	8%	15,590	1,357	8%	17,693
2003	H&L	127	11%	1,167	436	4%	12,553	562	4%	13,720
	Pot	7	2%	508	-	0%	-	7	2%	508
	Trwl	96	37%	261	695	38%	1,824	791	38%	2,085
	Total	231	12%	1,937	1,130	8%	14,376	1,361	8%	16,313
2004	H&L	29	3%	852	461	3%	14,346	489	3%	15,197
	Pot	18	2%	817	-	0%	-	18	2%	817
	Trwl	86	27%	325	206	16%	1,332	292	18%	1,656
	Total	133	7%	1,993	667	4%	15,677	800	5%	17,670
2005	H&L	28	3%	880	255	2%	12,860	283	2%	13,741
	Pot	33	3%	1,277	-	0%	-	33	3%	1,277
	Trwl	32	8%	388	181	16%	1,169	213	14%	1,556
	Total	93	4%	2,545	436	3%	14,029	529	3%	16,574
2006	H&L	46	5%	983	286	2%	12,123	332	3%	13,106
	Pot	6	1%	1,042	-	0%	-	6	1%	1,042
	Trwl	10	7%	144	269	25%	1,096	280	23%	1,240
	Total	62	3%	2,169	556	4%	13,219	618	4%	15,388
2007	H&L	16	2%	679	244	2%	11,586	260	2%	12,265
	Pot	46	3%	1,511	-	0%	-	46	3%	1,511
	Trwl	9	7%	132	175	16%	1,102	183	15%	1,235
	Total	70	3%	2,322	418	3%	12,688	489	3%	15,011
2008	H&L	84	10%	825	467	4%	11,457	551	5%	12,282
	Pot	3	0%	926	-	0%	-	3	0%	926
	Trwl	1	0%	259	72	8%	865	73	7%	1,124
	Total	88	4%	2,010	539	4%	12,323	627	4%	14,333
2004 -	H&L	40	5%	844	343	3%	12,475	383	3%	13,318
2008	Pot	21	2%	1,115	-		-	21	2%	1,115
Average	Trwl	28	11%	250	181	16%	1,113	208	15%	1,362
	Total	89	4%	2,208	523	4%	13,587	612	4%	15,795

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			40,949				
1981						34,699		1,146		
1982						65,092				
1983						66,517		889		
1984	8,590					100,029				
1985						125,129		1,294		
1986						128,718				
1987	3,574					102,639		1,057		
1988						114,239				
1989						115,067		655		
1990	2,778			1,229	33,822	78,794	101,530			
1991				721	29,615	69,653	95,364	902		
1992				0	21,000	79,210	104,786			
1993	3,911			468	23,884	80,596	94,699	1,178		
1994				89	13,614	74,153	70,431			
1995				87	18,174		80,826			
1996	2,890			239	15,213		72,247		1,175	
1997				0	20,311		82,783		1,211	
1998				35	8,900		57,773		1,183	
1999	2,789			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	2,913			503	37,386		77,678		1,198	1,128
2004				694	31,746		82,767		1,185	1,029
2005	2,884			2,306	33,914		74,433		1,187	1,040
2006				721	30,594		78,625		1,178	1,154
2007	2,190			860	28,650		73,480		1,174	1,115
2008				2,018	23,893		71,661		1,182	1,146
2009	2,189						67,978			

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 CPUE in numbers weighted by respective strata areas. Relative population weight equals CPUE 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, 2005, and 2007 and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004, 2006, 2008, and 2009. NMFS trawl survey estimates are from the Gulf of Alaska at depths <500 m.

	RELATIVE POPULATION NUMBER		RELATIVE POPULATION WEIGHT/BIOMASS				
Year	Coop. longline survey	Dom. longline survey	Jap. longline fishery	Coop. longline survey	Dom. longline survey	U.S. fishery	NMFS Trawl survey
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			294
1985	903			2,569			
1986	838			2,456			
1987	667			2,068			271
1988	707			2,088			
1989	661			2,178			
1990	450	649		1,454	2,141	1,201	214
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	250
1994	366	489		1,288	1,882	822	
1995		501			1,803	1,243	
1996		520			2,017	1,201	145
1997		491			1,764	1,341	
1998		466			1,662	1,130	
1999		511			1,740	1,316	104
2000		461			1,597	1,139	
2001		533			1,798	1,110	238
2002		559			1,916	1,152	
2003		532			1,759	1,218	189
2004		544			1,738	1,357	
2005		533			1,695	1,304	179
2006		576			1,848	1,206	
2007		500			1,584	1,270	111
2008		472			1,550	1,364	
2009		482			1,580		107

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.

Observer Fishery Data

Aleutian Islands-Observer						Bering Sea-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.53	0.05	0.10	193	8	1990	0.72	0.22	0.15	42	8
1991	0.50	0.03	0.07	246	8	1991	0.28	0.11	0.20	30	7
1992	0.40	0.06	0.15	131	8	1992	0.25	0.21	0.43	7	4
1993	0.28	0.04	0.14	308	12	1993	0.09	0.07	0.36	4	3
1994	0.29	0.05	0.18	138	13	1994	0.35	0.31	0.45	2	2
1995	0.30	0.04	0.14	208	14	1995	0.41	0.14	0.17	38	10
1996	0.23	0.03	0.12	204	17	1996	0.63	0.38	0.30	35	15
1997	0.35	0.07	0.20	117	9	1997				0	0
1998	0.29	0.05	0.17	75	12	1998	0.17	0.06	0.18	28	9
1999	0.38	0.07	0.17	305	14	1999	0.29	0.18	0.32	27	10
2000	0.29	0.03	0.11	313	15	2000	0.28	0.18	0.31	21	10
2001	0.26	0.04	0.15	162	9	2001	0.31	0.05	0.07	18	10
2002	0.32	0.03	0.11	245	10	2002	0.10	0.05	0.22	8	4
2003	0.26	0.04	0.17	170	10	2003	0.16	0.09	0.29	8	2
2004	0.21	0.04	0.21	138	7	2004	0.17	0.11	0.31	9	4
2005	0.15	0.05	0.34	23	6	2005	0.23	0.07	0.16	9	6
2006	0.23	0.04	0.16	205	11	2006	0.17	0.07	0.21	68	15
2007	0.35	0.10	0.29	198	7	2007	0.28	0.05	0.18	34	8
2008	0.37	0.04	0.10	247	6	2008	0.38	0.22	0.58	12	5

Western Gulf-Observer						Central Gulf-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.64	0.28	0.22	178	7	1990	0.54	0.08	0.07	653	32
1991	0.44	0.11	0.13	193	16	1991	0.62	0.11	0.09	303	24
1992	0.38	0.10	0.14	260	12	1992	0.59	0.11	0.09	335	19
1993	0.35	0.06	0.09	106	12	1993	0.60	0.08	0.07	647	32
1994	0.32	0.07	0.10	52	5	1994	0.65	0.12	0.09	238	15
1995	0.51	0.09	0.09	432	22	1995	0.90	0.14	0.08	457	41
1996	0.57	0.11	0.10	269	20	1996	1.04	0.14	0.07	441	45
1997	0.50	0.10	0.10	349	20	1997	1.07	0.17	0.08	377	41
1998	0.50	0.07	0.07	351	18	1998	0.90	0.11	0.06	345	32
1999	0.53	0.13	0.12	244	14	1999	0.87	0.17	0.10	269	28
2000	0.49	0.13	0.13	185	12	2000	0.93	0.10	0.06	319	30
2001	0.50	0.10	0.10	273	16	2001	0.70	0.08	0.06	347	31
2002	0.51	0.10	0.09	348	15	2002	0.84	0.13	0.08	374	29
2003	0.45	0.09	0.10	387	16	2003	0.99	0.14	0.07	363	34
2004	0.47	0.16	0.17	162	10	2004	1.08	0.19	0.09	327	29
2005	0.58	0.07	0.13	447	13	2005	0.89	0.06	0.07	518	32
2006	0.42	0.04	0.13	306	15	2006	0.82	0.06	0.08	361	33
2007	0.37	0.04	0.11	255	12	2007	0.93	0.06	0.07	289	30
2008	0.46	0.07	0.16	255	11	2008	0.84	0.07	0.08	207	27

Table 3.5 (cont.)

Observer Fishery Data											
West Yakutat-Observer						East Yakutat/SE-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.95	0.47	0.25	75	9	1990				0	0
1991	0.65	0.14	0.10	164	12	1991	0.52	0.37	0.71	17	2
1992	0.64	0.35	0.27	98	6	1992	0.87			20	1
1993	0.71	0.15	0.10	241	12	1993	1.02	0.19	0.19	26	2
1994	0.65	0.35	0.27	81	8	1994	0.36			5	1
1995	1.02	0.20	0.10	158	21	1995	1.45	0.20	0.14	101	19
1996	0.97	0.15	0.07	223	28	1996	1.20	0.11	0.09	137	24
1997	1.16	0.22	0.09	126	20	1997	1.10	0.14	0.13	84	17
1998	1.21	0.20	0.08	145	23	1998	1.27	0.12	0.10	140	25
1999	1.20	0.31	0.13	110	19	1999	0.94	0.12	0.13	85	11
2000	1.28	0.20	0.08	193	32	2000	0.84	0.13	0.16	81	14
2001	1.03	0.14	0.07	184	26	2001	0.84	0.08	0.09	110	14
2002	1.32	0.26	0.10	155	23	2002	1.20	0.23	0.19	121	14
2003	1.36	0.20	0.07	216	27	2003	1.29	0.13	0.10	113	19
2004	1.23	0.19	0.08	210	24	2004	1.08	0.10	0.09	135	17
2005	1.32	0.09	0.07	352	24	2005	1.18	0.13	0.11	181	16
2006	0.96	0.10	0.10	257	30	2006	0.93	0.11	0.11	104	18
2007	1.02	0.11	0.11	208	24	2007	0.92	0.15	0.17	85	16
2008	1.40	0.12	0.08	173	23	2008	1.06	0.13	0.12	103	17

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
2006	0.51	0.16	0.31	61	5
2007	0.38	0.22	0.58	61	3
2008	0.30	0.03	0.12	119	4

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
2006	0.38	0.07	0.18	106	9
2007	0.37	0.08	0.21	147	8
2008	0.52	0.20	0.39	94	7

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
2006	0.69	0.08	0.11	1067	38
2007	0.59	0.06	0.10	891	31
2008	0.71	0.06	0.08	516	29

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
2006	0.87	0.04	0.05	1358	80
2007	0.83	0.04	0.05	1190	69
2008	0.88	0.05	0.06	1039	68

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
2006	0.97	0.05	0.06	1306	84
2007	0.97	0.05	0.05	1322	89
2008	0.97	0.05	0.05	1118	74

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
2006	1.06	0.04	0.04	860	107
2007	1.13	0.04	0.04	972	122
2008	1.08	0.05	0.05	686	97

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
2007	305,786	0	7	na	na	na	136,368	0	5
2008	na	na	na	201,300	0	3	171,365	0	2
2009	302,999	0	10	na	na	na	194,172	0	2

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
2007	473,217	2	1	169,660	5	0	302,098	6	0
2008	510,094	3	0	133,608	8	0	236,236	10	0
2009	469,323	5	1	141,002	3	0	266,990	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.

Year class	Western	Central	Eastern
1977	na	4	4
1980-81	5	3	6
1984	5	9	12
1990	6	7	7
1995	4	6	7
1997	4	4	5
2000	4	4	5

Table 3.7b. Years that the above average 1995, 1997, and 2000 year classes became abundant by region RPN>10,000). “Western” includes the Bering Sea, Aleutian Islands, and western Gulf of Alaska. The 1995 year class now is considered average.

Year class	Western	Central	Eastern
1995	1998	2001	2002
1997	2000	2001	2002
2000	2004	2004	2005

Table 3.8. Sablefish fork length (cm), weight (kg), and proportion mature by age and sex (weights from 1996-2004 age-length data).

	Fork length (cm)		Weight (kg)		Fraction mature	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2	48.1	46.8	1.0	0.9	0.059	0.006
3	53.1	53.4	1.5	1.5	0.165	0.024
4	56.8	58.8	1.9	2.1	0.343	0.077
5	59.5	63.0	2.2	2.6	0.543	0.198
6	61.6	66.4	2.5	3.1	0.704	0.394
7	63.2	69.2	2.7	3.5	0.811	0.604
8	64.3	71.4	2.8	3.9	0.876	0.765
9	65.2	73.1	2.9	4.2	0.915	0.865
10	65.8	74.5	3.0	4.4	0.939	0.921
11	66.3	75.7	3.0	4.6	0.954	0.952
12	66.7	76.6	3.1	4.8	0.964	0.969
13	67.0	77.3	3.1	4.9	0.971	0.979
14	67.2	77.9	3.1	5.1	0.976	0.986
15	67.3	78.3	3.1	5.1	0.979	0.99
16	67.4	78.7	3.1	5.2	0.982	0.992
17	67.5	79.0	3.1	5.3	0.984	0.994
18	67.6	79.3	3.2	5.3	0.985	0.995
19	67.6	79.4	3.2	5.3	0.986	0.996
20	67.7	79.6	3.2	5.4	0.987	0.997
21	67.7	79.7	3.2	5.4	0.988	0.997
22	67.7	79.8	3.2	5.4	0.988	0.998
23	67.7	79.9	3.2	5.4	0.989	0.998
24	67.7	80.0	3.2	5.4	0.989	0.998
25	67.7	80.0	3.2	5.4	0.989	0.998
26	67.8	80.1	3.2	5.4	0.99	0.998
27	67.8	80.1	3.2	5.4	0.99	0.999
28	67.8	80.1	3.2	5.4	0.99	0.999
29	67.8	80.1	3.2	5.5	0.99	0.999
30	67.8	80.2	3.2	5.5	0.99	0.999
31	67.8	80.2	3.2	5.5	1	1

Table 3.9. Sablefish age 4+ biomass, spawning biomass plus upper and lower 95% credible intervals (LCI, UCI), and catch (thousands t), and number (millions) at age 2 by year. The 2009 catch is estimated.

Year	Age 4+ biomass (kt)	Spawning biomass (SSB,kt)	SSB (LCI)	SSB (UCI)	Number (millions) at age 2	Catch	Catch/Age4+ biomass
1960	377	151	129	180	1.5	3.1	0.008
1961	451	154	137	178	1.6	16.1	0.036
1962	433	161	145	183	86.9	26.4	0.061
1963	396	166	149	188	3.7	16.9	0.043
1964	501	176	158	198	4.5	7.3	0.015
1965	494	189	170	213	49.0	8.7	0.018
1966	478	203	184	227	60.8	15.6	0.033
1967	521	214	194	238	5.5	19.2	0.037
1968	581	221	201	245	24.3	31.0	0.053
1969	546	224	205	246	1.6	36.8	0.067
1970	528	224	206	245	0.5	37.8	0.072
1971	472	217	201	238	0.5	43.5	0.092
1972	405	201	186	220	5.6	53.0	0.131
1973	329	173	160	190	50.8	36.9	0.112
1974	280	150	138	166	0.7	34.6	0.124
1975	306	129	117	143	0.9	29.9	0.098
1976	268	113	103	126	21.2	31.7	0.118
1977	227	100	91	112	1.3	21.4	0.094
1978	227	93	85	103	2.2	10.4	0.046
1979	210	90	83	100	85.7	11.9	0.057
1980	192	88	81	97	31.1	10.4	0.054
1981	308	89	83	97	8.5	12.6	0.041
1982	348	95	89	102	56.8	12.0	0.034
1983	351	109	103	117	30.2	11.8	0.034
1984	424	128	122	137	22.9	14.1	0.033
1985	455	147	140	155	0.7	14.5	0.032
1986	471	164	156	173	27.0	28.9	0.061
1987	432	172	165	181	18.1	35.2	0.081
1988	423	170	163	179	1.7	38.4	0.091
1989	398	162	155	170	10.5	34.8	0.087
1990	350	152	145	160	8.5	32.1	0.092
1991	318	140	134	148	24.8	27.0	0.085
1992	288	129	123	136	0.9	24.9	0.086
1993	288	118	112	125	29.9	25.4	0.088
1994	254	108	102	114	1.3	23.8	0.094
1995	265	100	95	106	8.3	21.0	0.079
1996	238	95	91	101	10.0	17.6	0.074
1997	224	93	88	99	17.3	14.9	0.067
1998	215	91	87	97	5.2	14.1	0.066
1999	219	89	84	94	27.4	13.6	0.062
2000	206	87	82	92	18.4	15.9	0.077
2001	225	85	81	90	10.7	14.1	0.063
2002	235	85	81	91	36.2	14.8	0.063
2003	232	88	84	94	11.5	16.4	0.070
2004	267	91	87	97	7.6	17.7	0.066
2005	265	96	91	102	10.2	16.6	0.063
2006	255	101	96	107	7.8	15.4	0.061
2007	247	104	99	111	6.4	15.0	0.061
2008	235	105	100	111	3.5	14.3	0.061
2009	221	103	98	109	6.6	12.1	0.055

Table 3.10. Sablefish spawning biomass (kilotons), fishing mortality, and yield (kilotons) for seven harvest scenarios. Abundance projected using 1979-2007 recruitments. Sablefish are not classified as overfished because abundance currently exceeds $B_{35\%}$.

Year	Maximum permissible F	Author's F (prespecified catch 2010-10)*	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass (kt)							
2009	103.0	103.0	103.0	103.0	103.0	103.0	103.0
2010	99.9	99.9	99.9	99.9	99.9	99.9	99.9
2011	93.7	95.6	97.3	95.0	101.5	92.2	93.7
2012	88.1	89.7	94.2	90.1	102.7	85.7	88.1
2013	84.8	86.1	91.7	86.9	105.0	81.7	83.7
2014	84.7	85.8	90.9	86.7	110.1	81.1	82.7
2015	87.3	88.1	92.6	89.4	118.1	83.2	84.4
2016	91.2	91.9	96.1	93.6	128.1	86.6	87.5
2017	95.4	95.9	100.3	98.3	138.9	90.2	90.9
2018	99.3	99.7	107.4	102.9	149.7	93.5	94.0
2019	102.7	103.0	112.5	107.2	160.2	96.3	96.7
2020	105.7	105.9	115.9	111.1	170.2	98.7	99.0
2021	108.3	108.5	119.8	114.8	179.7	100.8	101.0
2022	110.6	110.8	125.3	118.2	188.7	102.6	102.8
Fishing mortality							
2009	0.062	0.062	0.062	0.062	0.062	0.062	0.062
2010	0.084	0.063	0.042	0.069	-	0.100	0.100
2011	0.078	0.080	0.041	0.069	-	0.092	0.092
2012	0.073	0.075	0.039	0.069	-	0.085	0.085
2013	0.070	0.071	0.038	0.069	-	0.081	0.081
2014	0.070	0.071	0.038	0.069	-	0.079	0.079
2015	0.071	0.071	0.039	0.069	-	0.080	0.080
2016	0.072	0.072	0.040	0.069	-	0.082	0.082
2017	0.074	0.074	0.042	0.069	-	0.084	0.084
2018	0.075	0.076	0.045	0.069	-	0.086	0.086
2019	0.077	0.077	0.048	0.069	-	0.088	0.088
2020	0.078	0.079	0.048	0.069	-	0.090	0.090
2021	0.080	0.080	0.048	0.069	-	0.091	0.091
2022	0.081	0.081	0.048	0.069	-	0.093	0.093
Yield (kt)							
2009	12.1	12.1	12.1	12.1	12.1	12.1	12.1
2010	15.2	15.2	7.8	12.7	-	18.0	15.2
2011	13.1	13.7	7.2	11.8	-	15.1	13.1
2012	12.2	12.6	7.1	11.7	-	13.7	14.4
2013	12.7	13.0	7.7	12.5	-	14.0	14.6
2014	13.6	13.9	8.5	13.2	-	15.0	15.5
2015	14.7	15.0	9.2	13.9	-	16.2	16.6
2016	15.9	16.0	10.0	14.6	-	17.5	17.7
2017	16.9	17.0	10.7	15.3	-	18.5	18.7
2018	17.7	17.8	11.3	15.8	-	19.4	19.5
2019	18.5	18.6	11.9	16.3	-	20.2	20.3
2020	19.2	19.2	12.4	16.8	-	20.9	20.9
2021	19.9	19.9	13.0	17.2	-	21.6	21.6
2022	20.5	20.5	13.4	17.6	-	22.2	22.2

* Projections in Author's F (Alternative 2) are based on an estimated catch of 11,497 t used in place of maximum permissible ABC for 2010. This was done in response to management requests for a more accurate one-year projection.

Table 3.11. Regional estimates of sablefish total biomass (Age 2+). Partitioning was done using RPWs from Japanese LL survey from 1979-1989 and domestic LL survey from 1990-2009. For 1960-1978, a retrospective 4:6:9 pseudo-exponential 3 - year average of proportions was used.

Year	Bering Sea	Aleutian Islands	Western Gulf of Alaska	Central Gulf of Alaska	West Yakutat	East Yakutat/ Southeast	Alaska
1960	83	99	43	124	39	59	447
1961	84	100	44	126	39	60	454
1962	96	114	50	144	45	69	517
1963	95	114	49	143	45	68	515
1964	94	113	49	142	44	68	510
1965	101	121	52	152	47	73	547
1966	111	133	58	167	52	80	600
1967	112	134	58	169	53	81	606
1968	113	135	59	170	53	81	612
1969	107	128	56	161	50	77	580
1970	98	117	51	148	46	71	530
1971	87	105	45	132	41	63	473
1972	76	91	39	114	36	55	411
1973	71	85	37	107	33	51	384
1974	64	77	33	97	30	46	347
1975	57	68	30	85	27	41	308
1976	54	64	28	81	25	38	290
1977	47	57	25	71	22	34	256
1978	42	52	22	63	20	31	231
1979	55	61	28	87	25	38	294
1980	61	80	32	89	29	44	335
1981	64	89	38	79	33	54	357
1982	75	86	53	100	40	59	413
1983	81	95	71	115	38	55	454
1984	91	113	77	116	35	53	485
1985	100	111	70	121	36	49	486
1986	106	105	68	124	42	53	497
1987	79	105	64	130	48	59	485
1988	47	92	60	144	46	59	449
1989	55	80	48	131	43	53	410
1990	57	61	40	114	43	57	372
1991	39	41	37	111	46	77	352
1992	23	36	25	102	51	85	322
1993	15	34	29	105	54	80	318
1994	18	34	32	97	45	69	294
1995	26	31	28	89	39	61	275
1996	25	27	28	94	33	53	259
1997	24	23	27	98	31	50	254
1998	21	31	27	85	28	50	243
1999	20	41	29	83	27	51	252
2000	20	43	34	87	27	50	260
2001	29	41	41	82	22	45	260
2002	39	43	42	92	23	44	284
2003	39	45	41	99	25	42	291
2004	38	44	36	103	27	41	289
2005	41	43	37	92	25	46	285
2006	43	38	39	83	25	47	275
2007	46	33	28	81	28	46	263
2008	48	31	24	78	24	42	247
2009	45	30	27	73	20	37	232

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

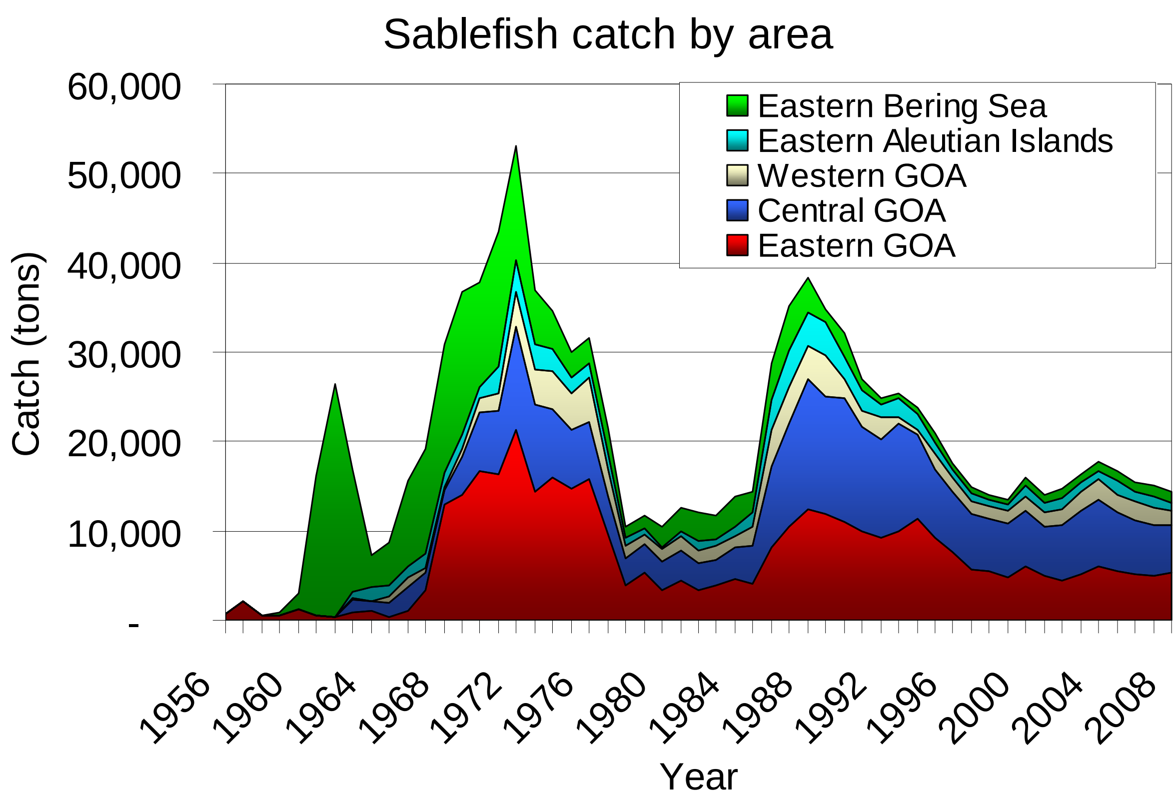


Figure 3.1. Sablefish fishery total reported catch (t) by North Pacific Fishery Management Council area and year.

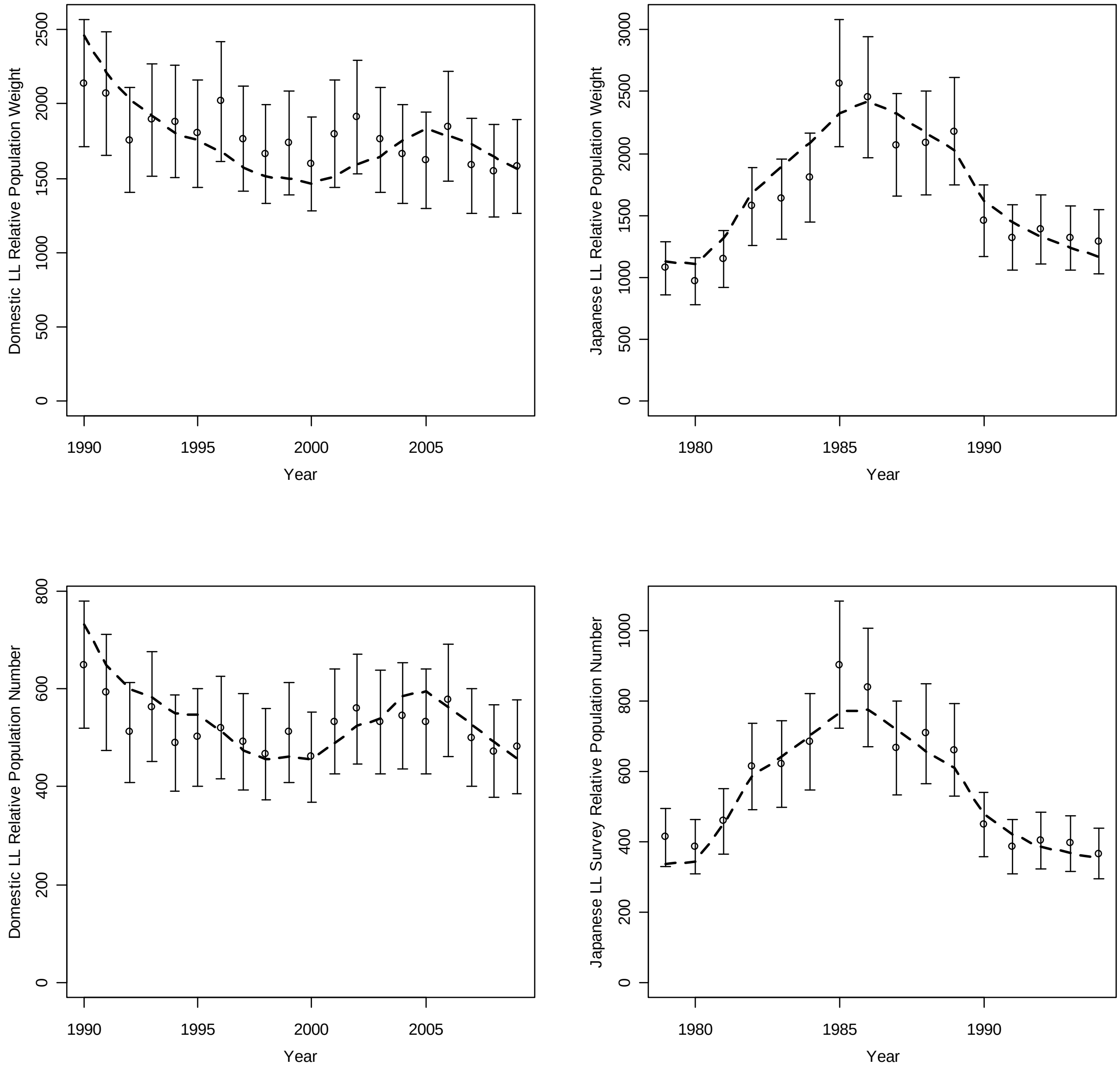


Figure 3.2. Observed and predicted sablefish relative population weight and numbers versus year. Points are observed estimates with approximate 95% confidence intervals, dashed line is model predicted.

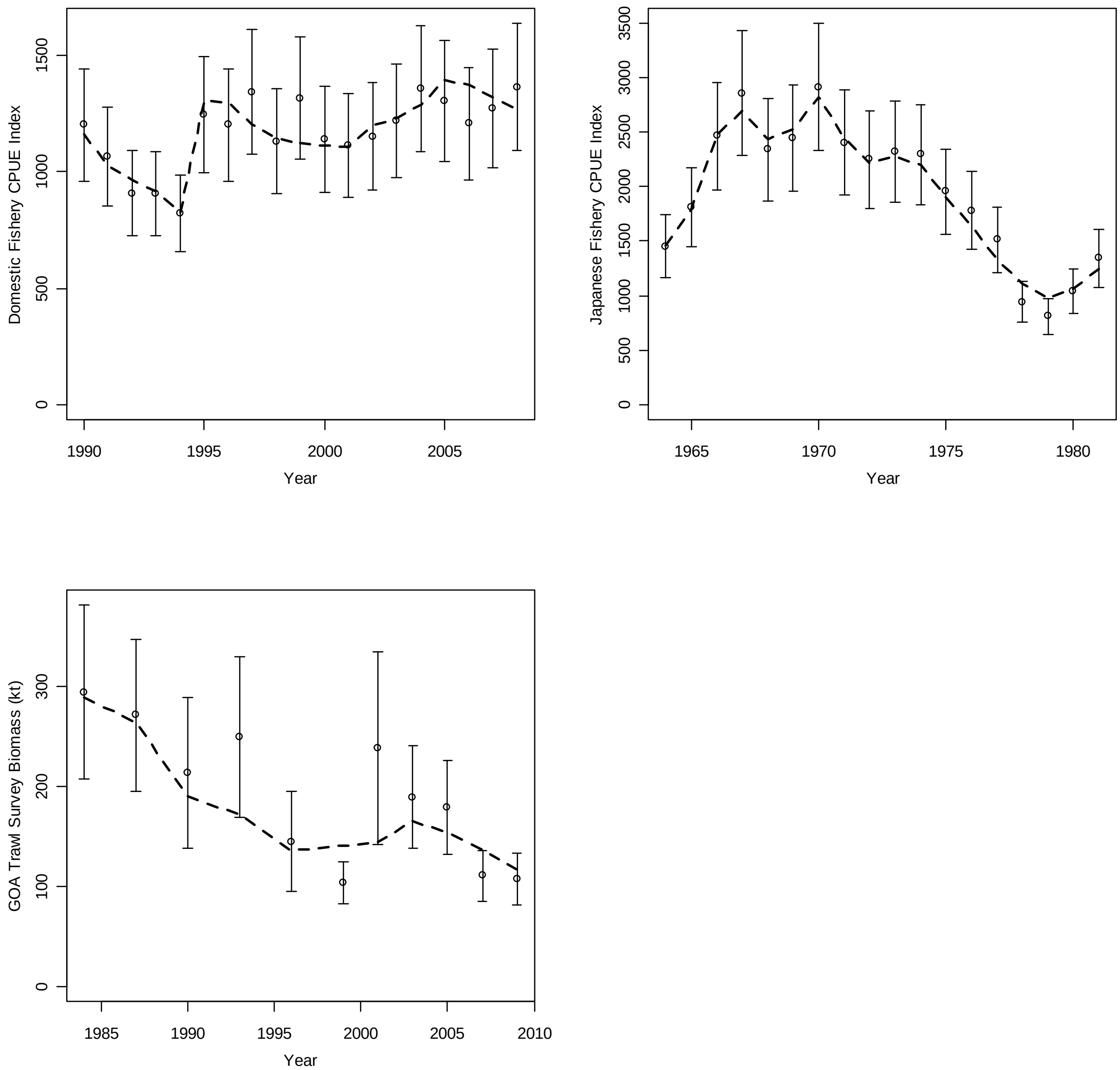


Figure 3.3. Observed and predicted sablefish abundance indices. Fishery indices are on top two panels, GOA trawl survey is on the bottom left panel. Points are observed estimates with approximate 95% confidence intervals while dashed lines are model predictions.

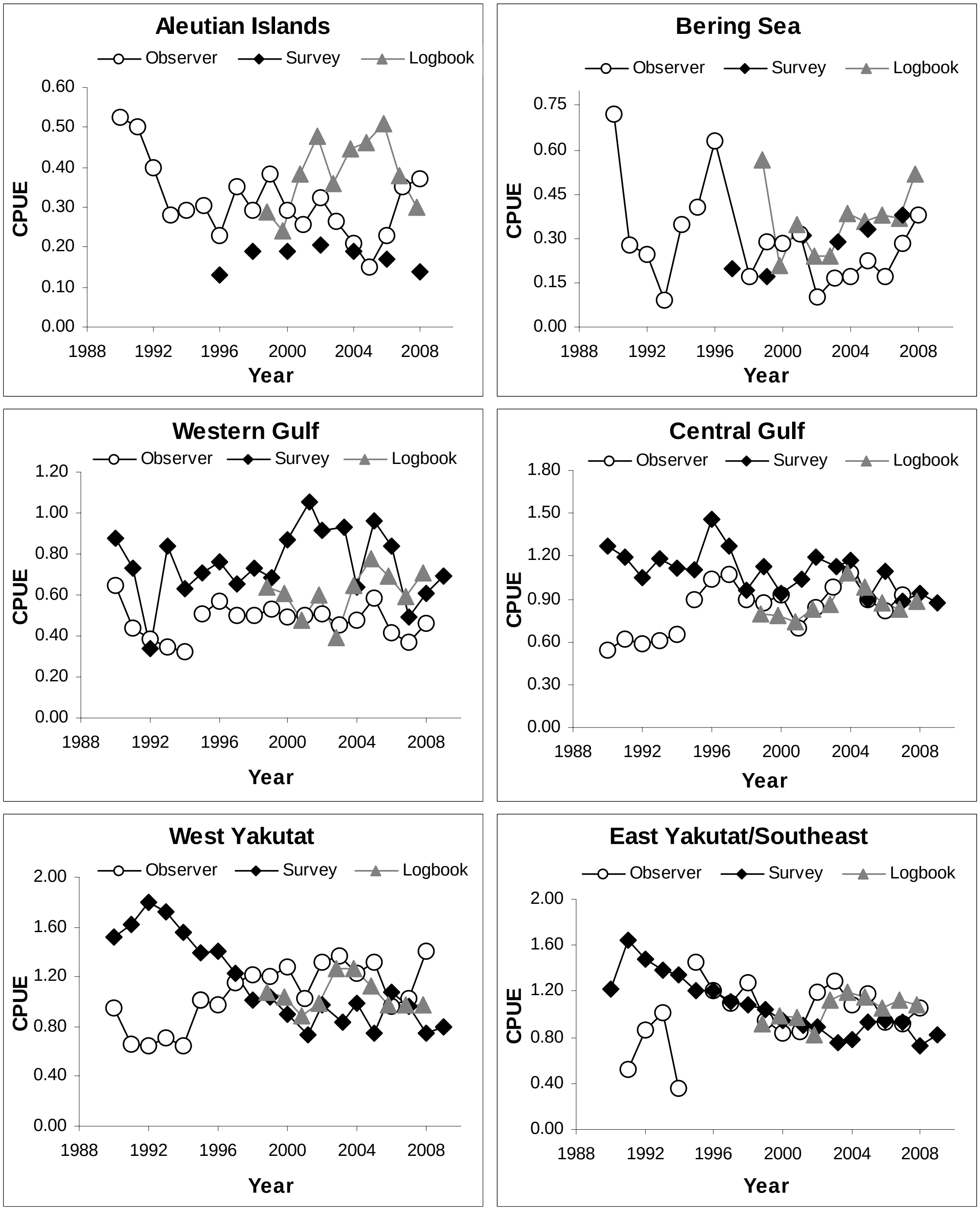


Figure 3.4. Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

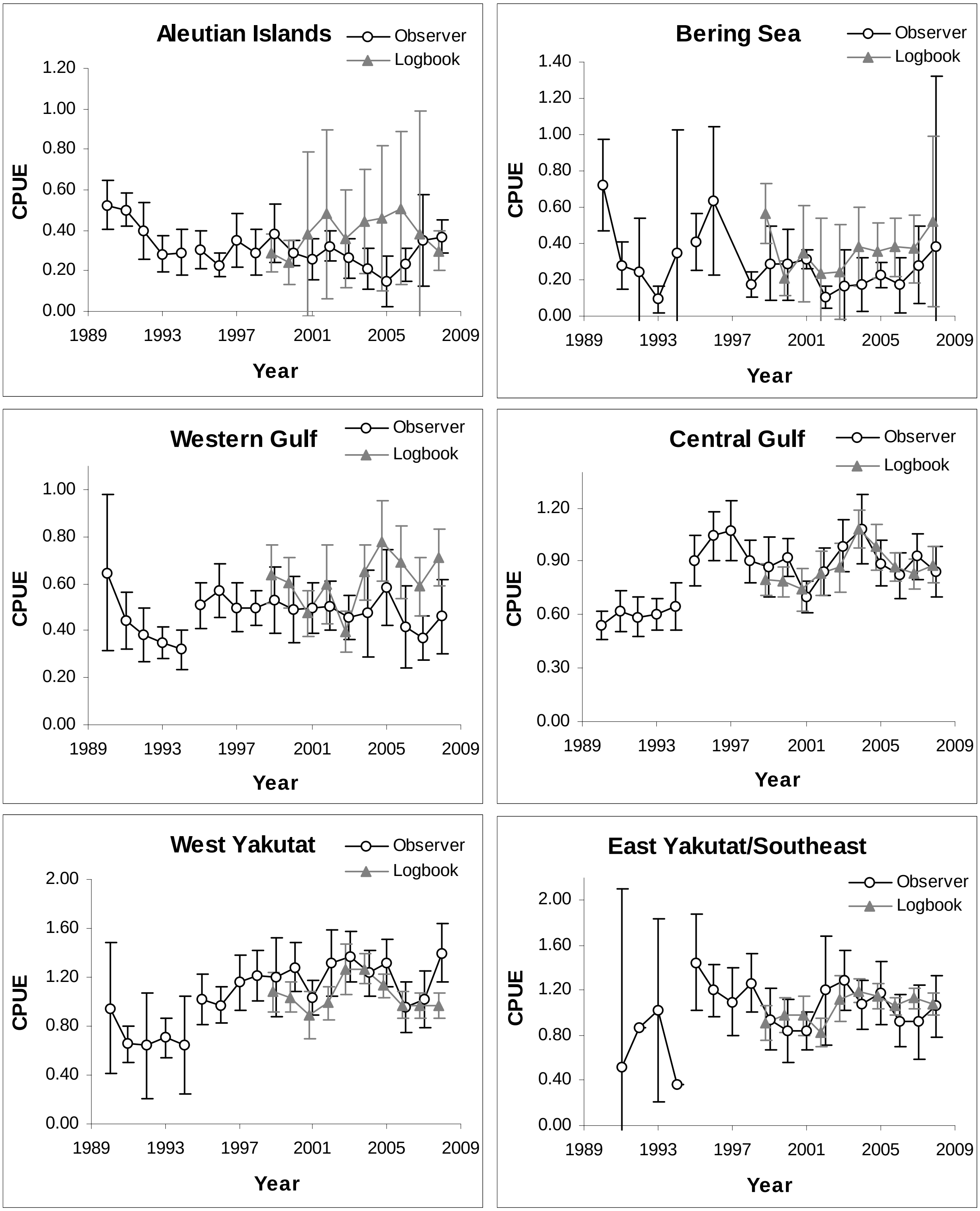


Figure 3.5. Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

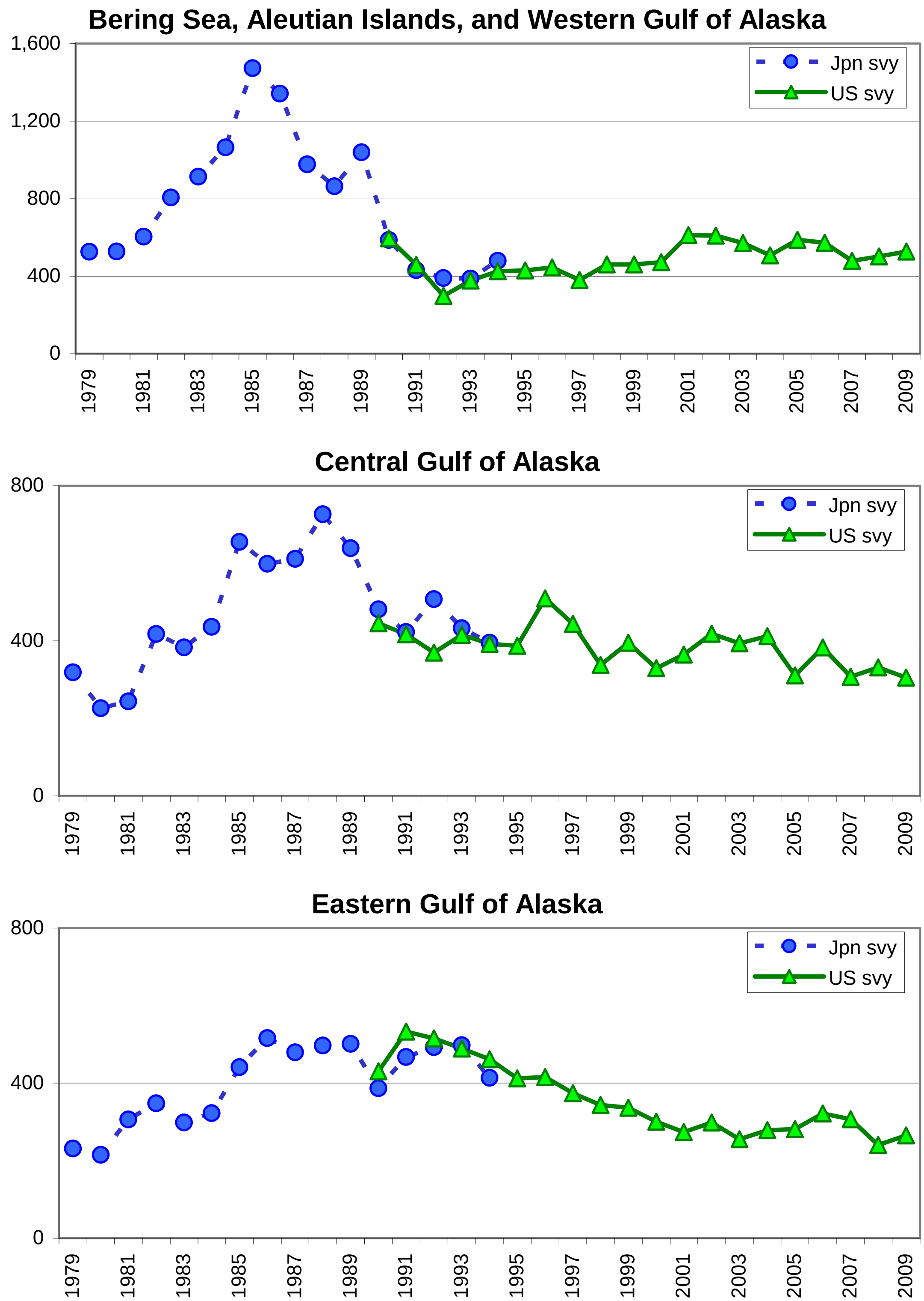


Figure 3.6. Relative abundance (weight) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the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

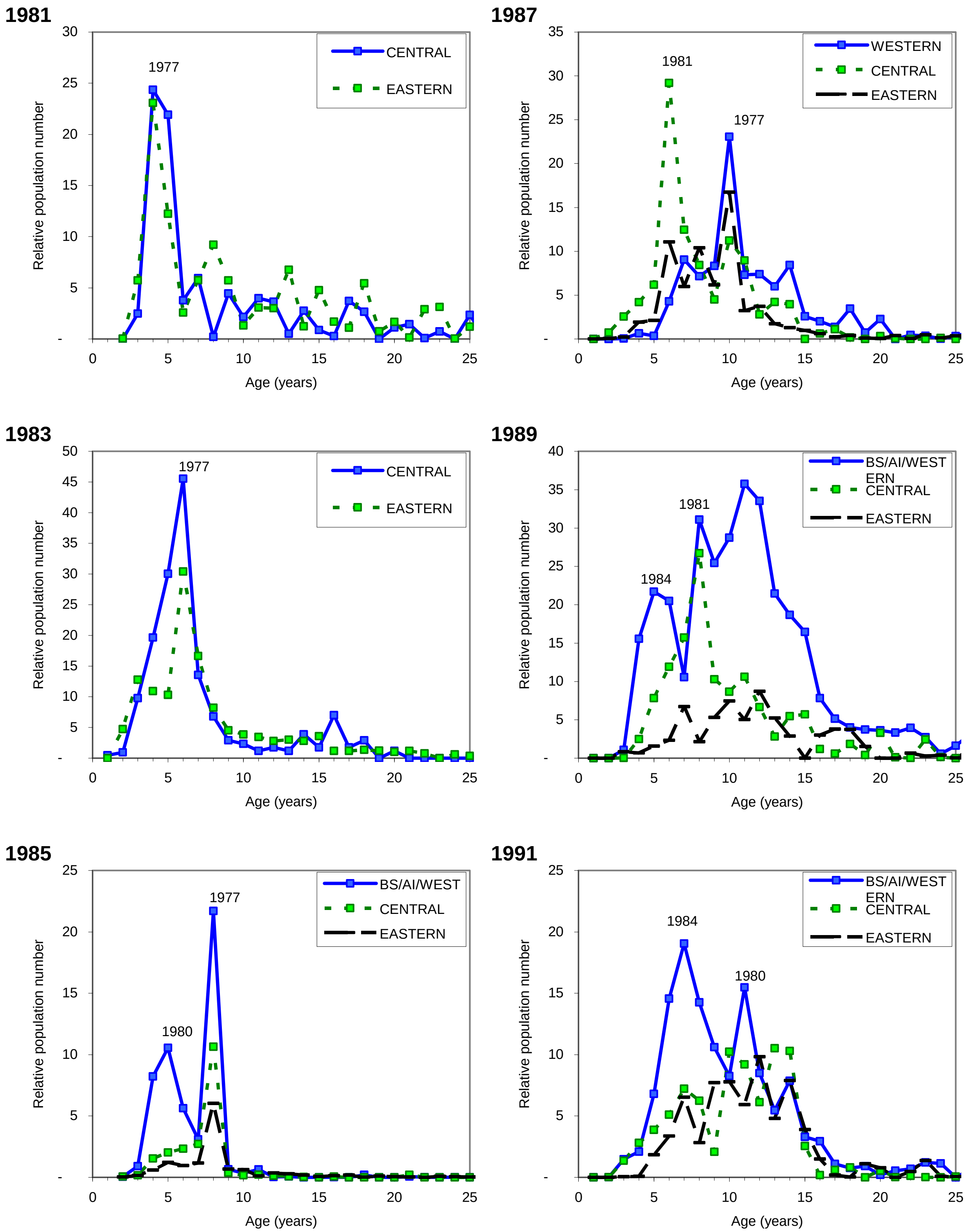


Figure 3.7. Relative abundance (number in thousands) by age and region from two surveys, the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

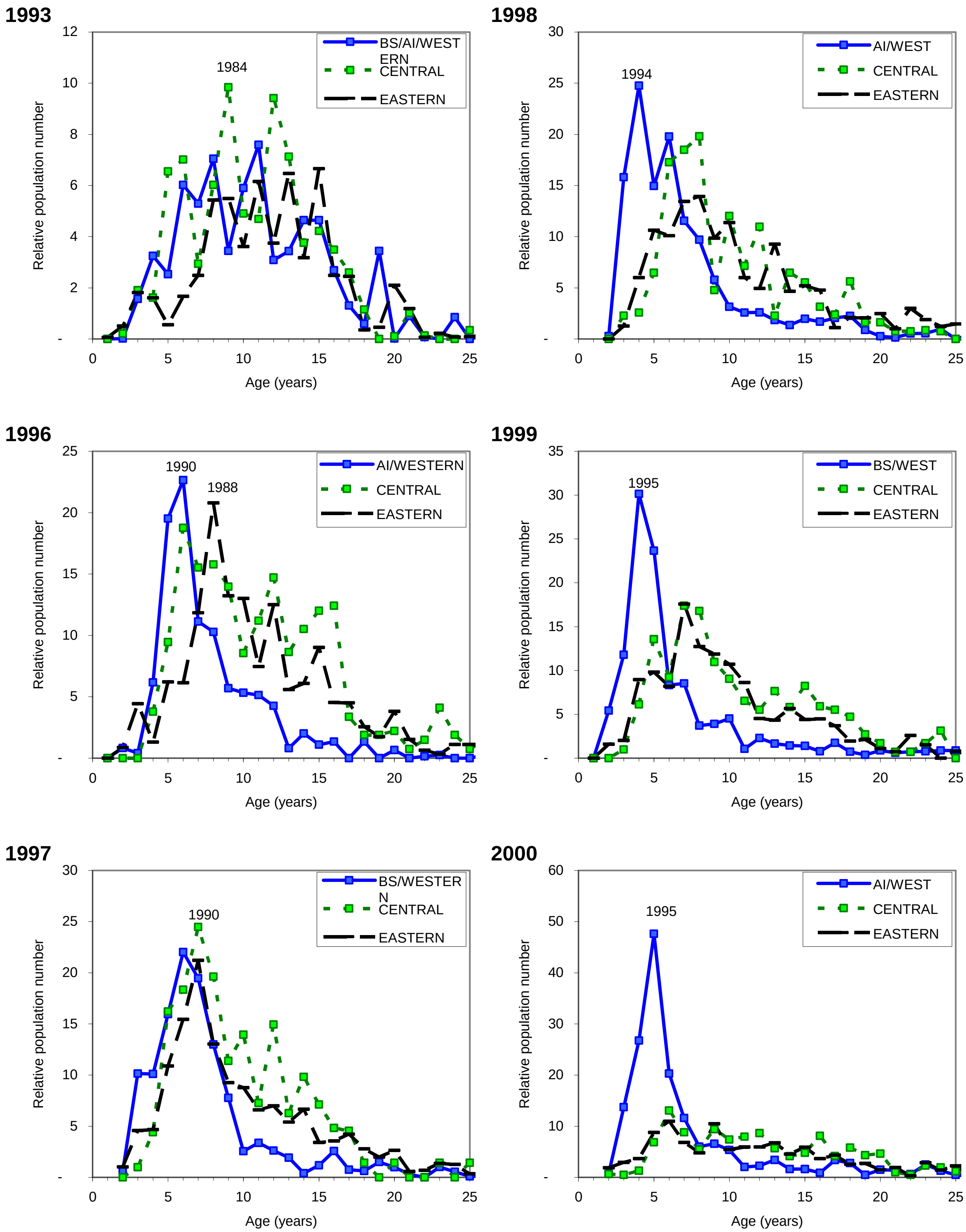


Figure 3.7 cont.

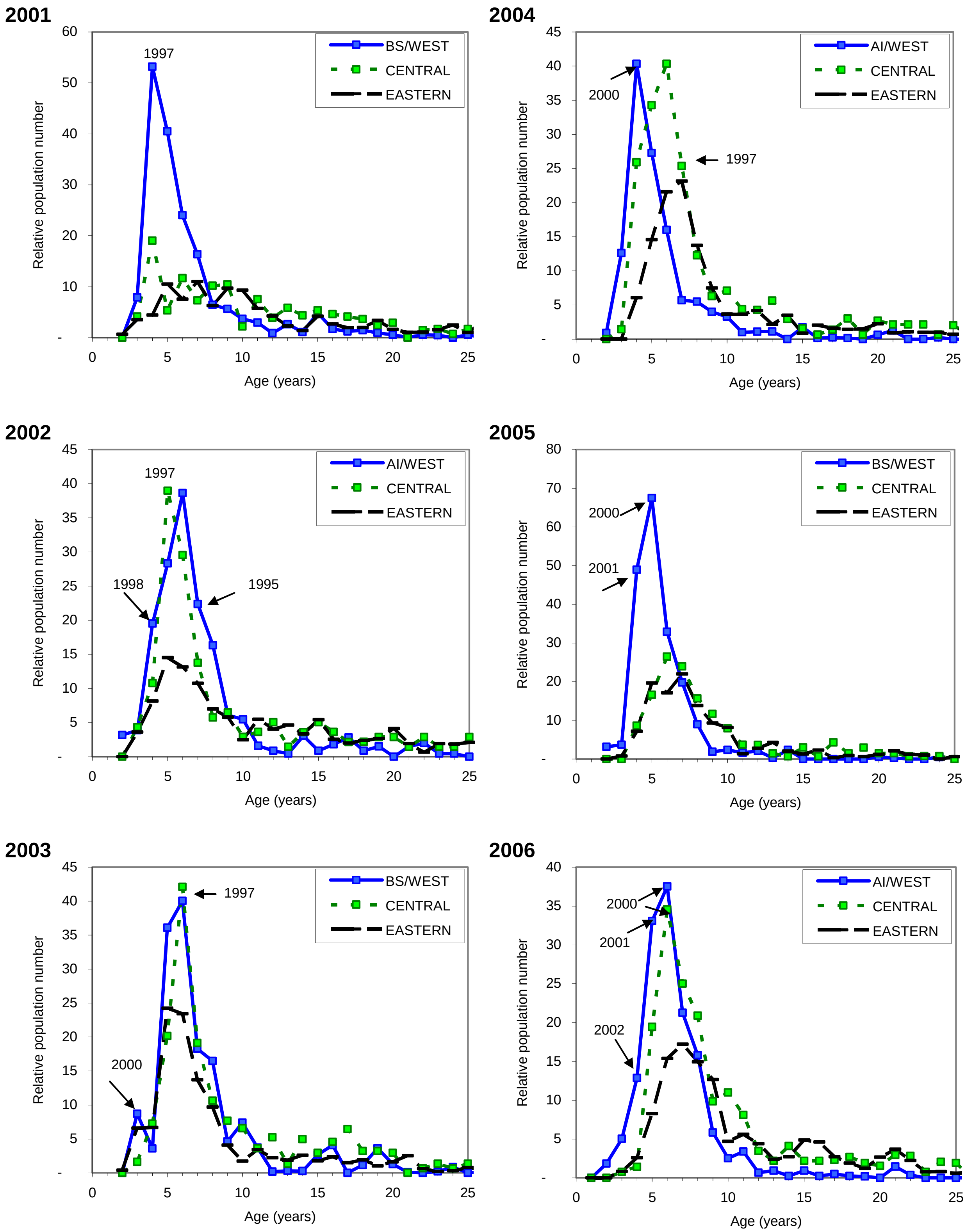


Figure 3.7 cont.

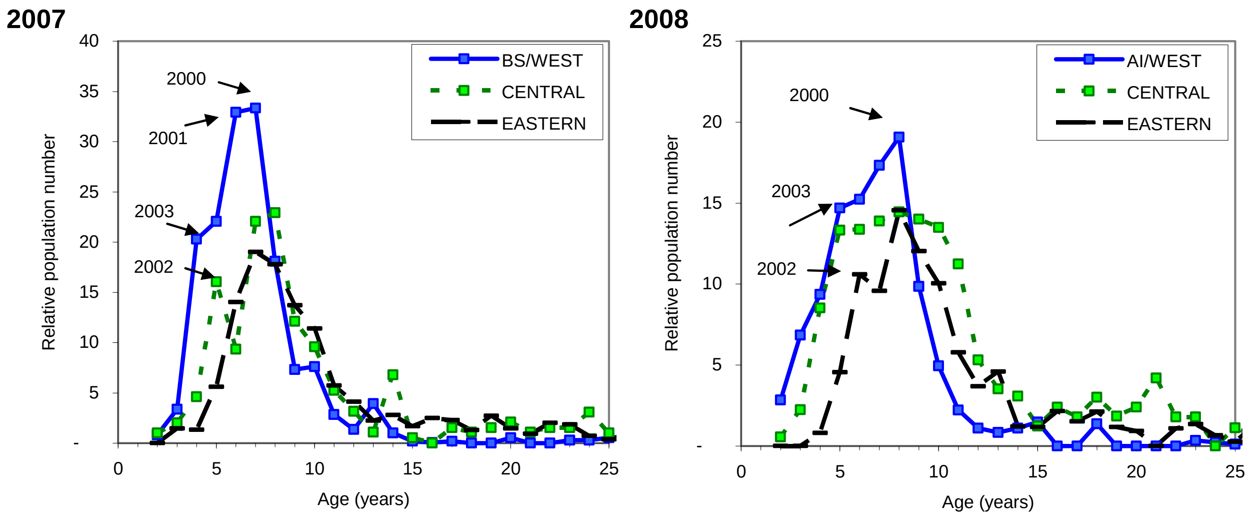


Figure 3.7. cont.

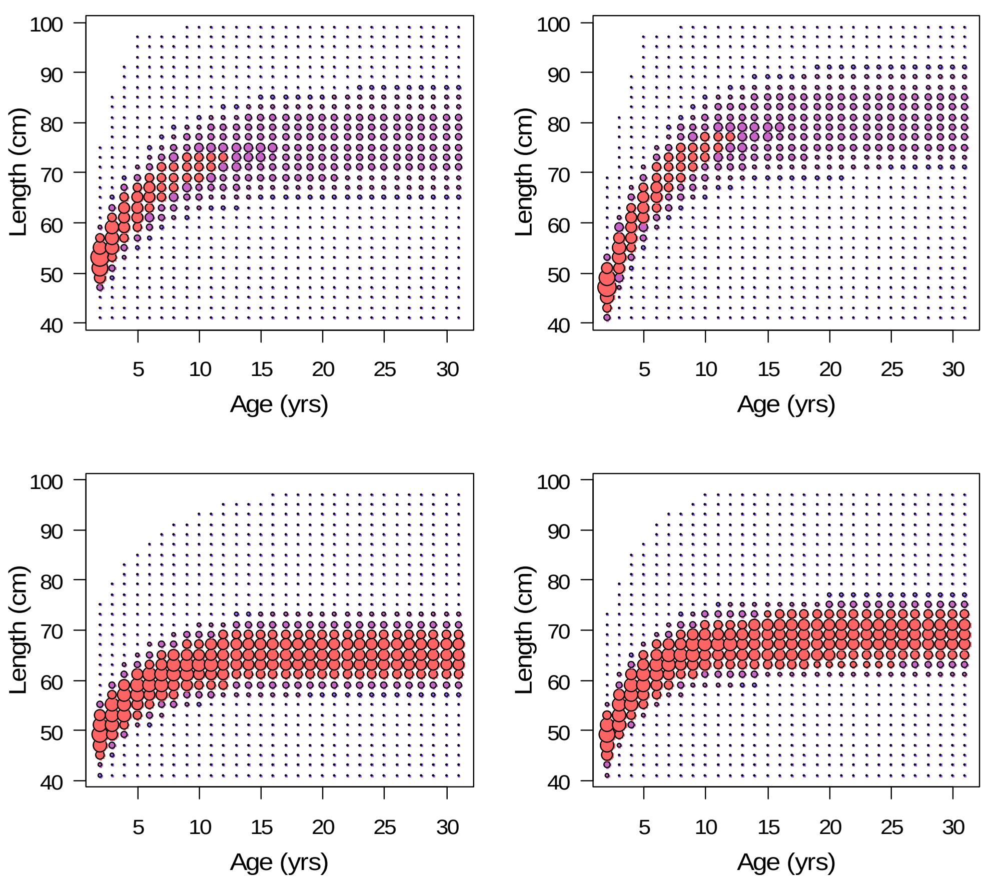


Figure 3.8. Age-length conversion matrices for sablefish. Top panels are female, bottom panel are males, left is 1981-1993, right is 1996-2004.

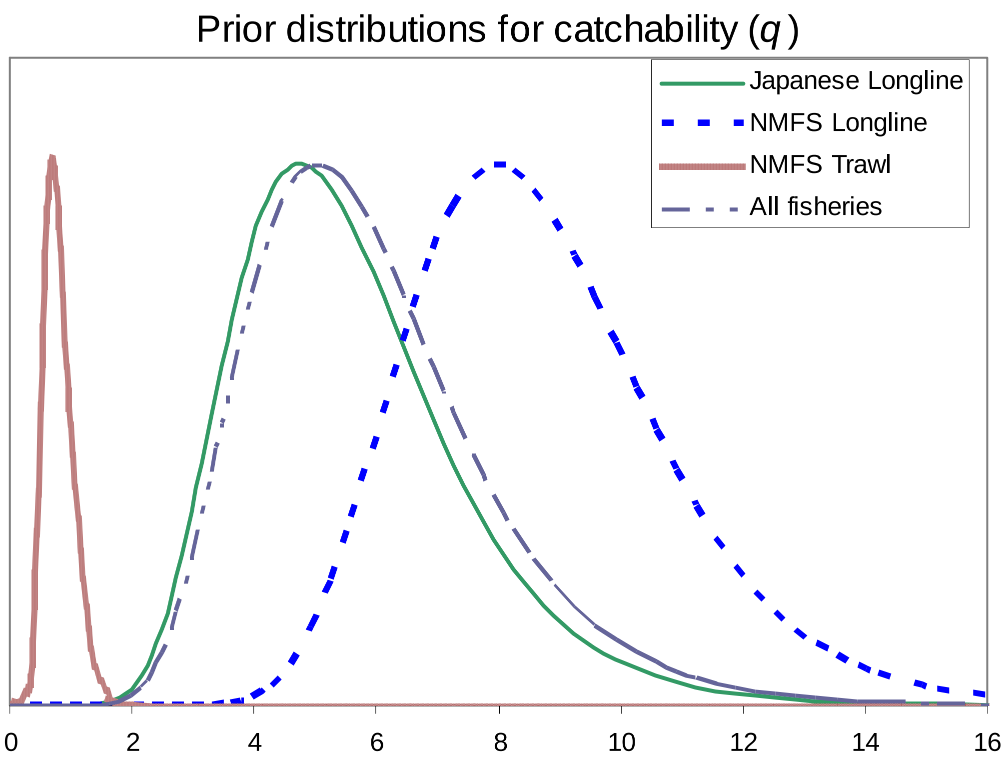


Figure 3.9. Prior distributions for catchability for four sablefish abundance indices.

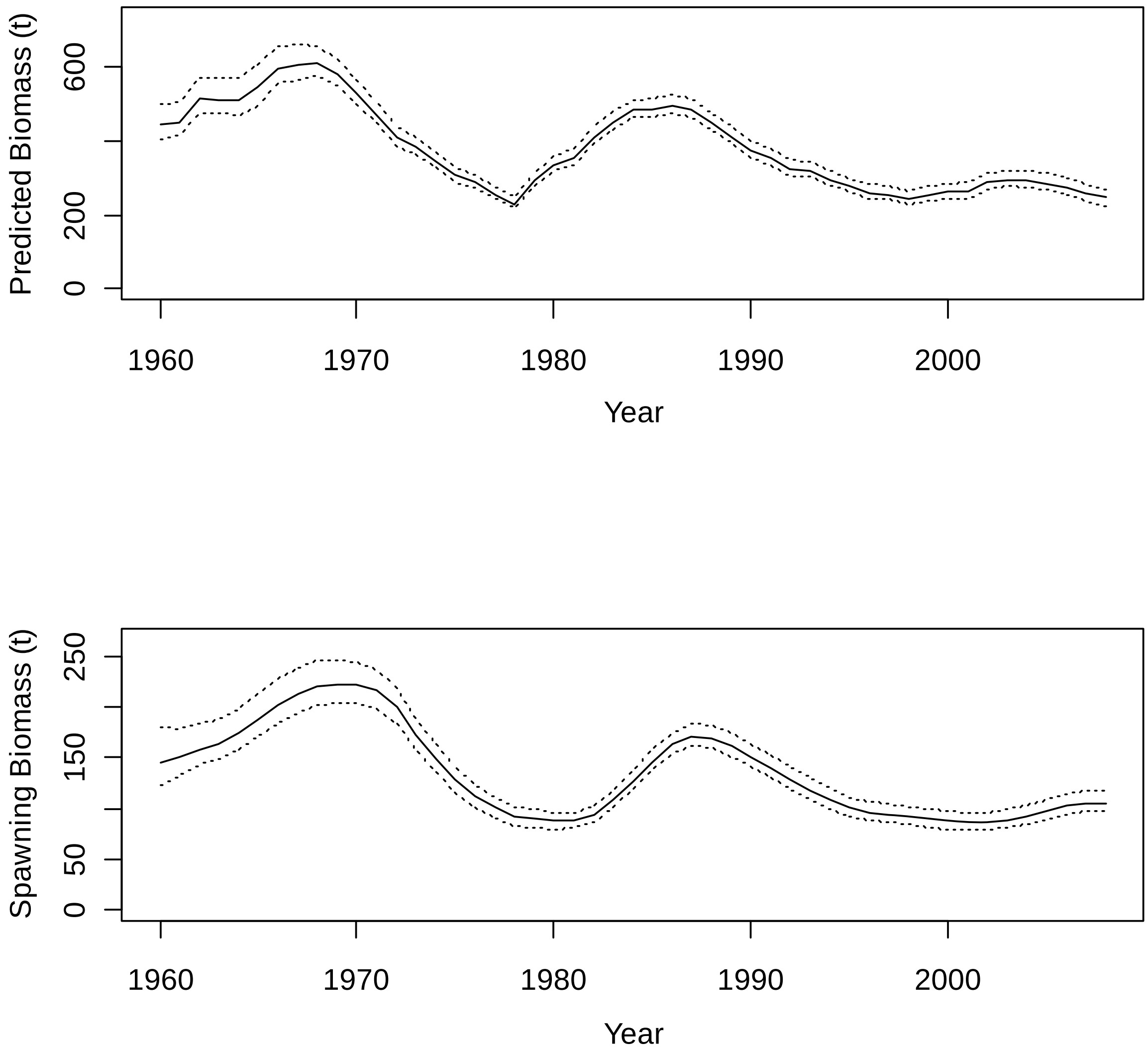


Figure 3.10.--Estimated sablefish total biomass (thousands t) and spawning biomass (bottom) with MCMC credible intervals.

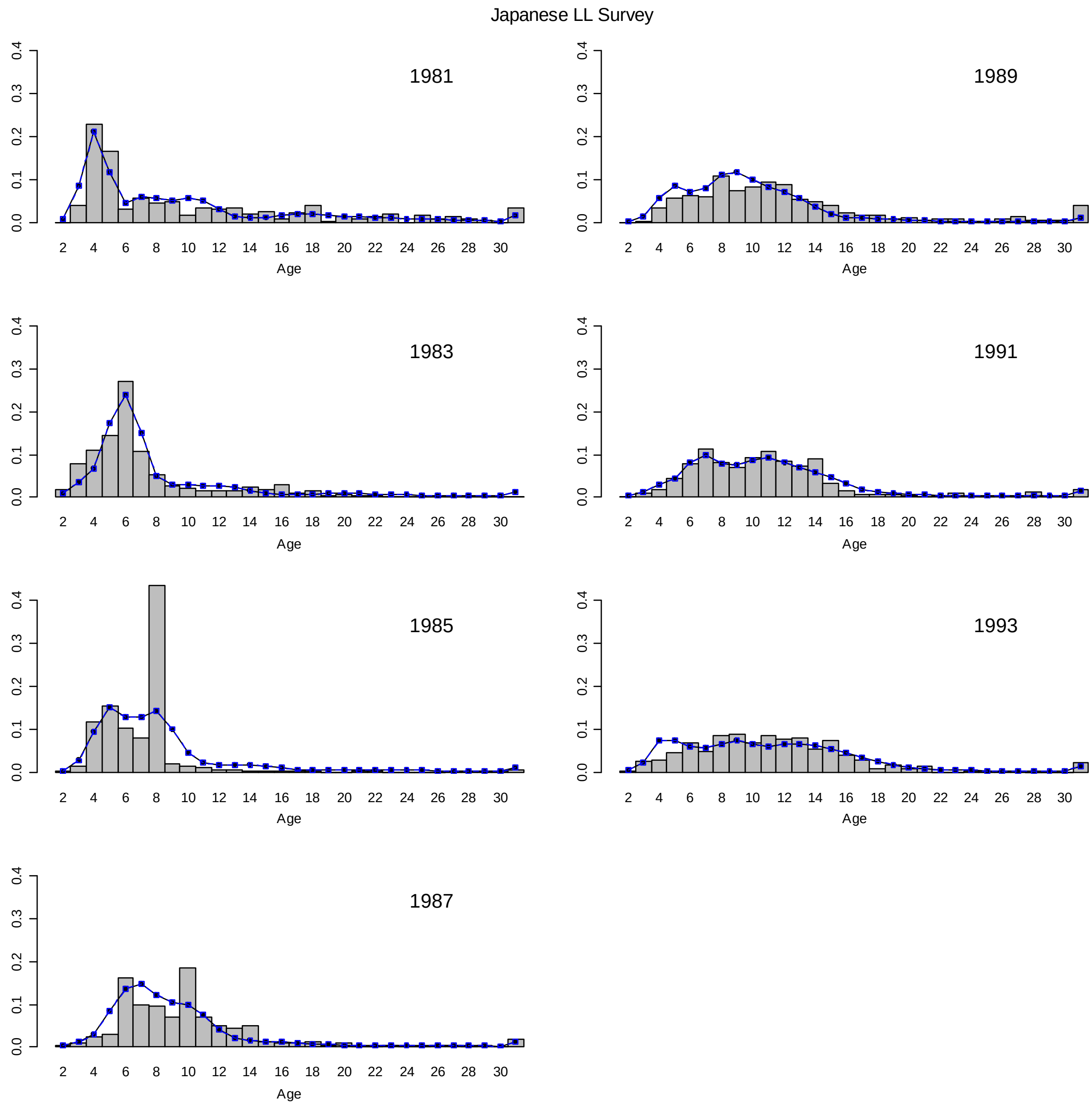


Figure 3.11. Japanese longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

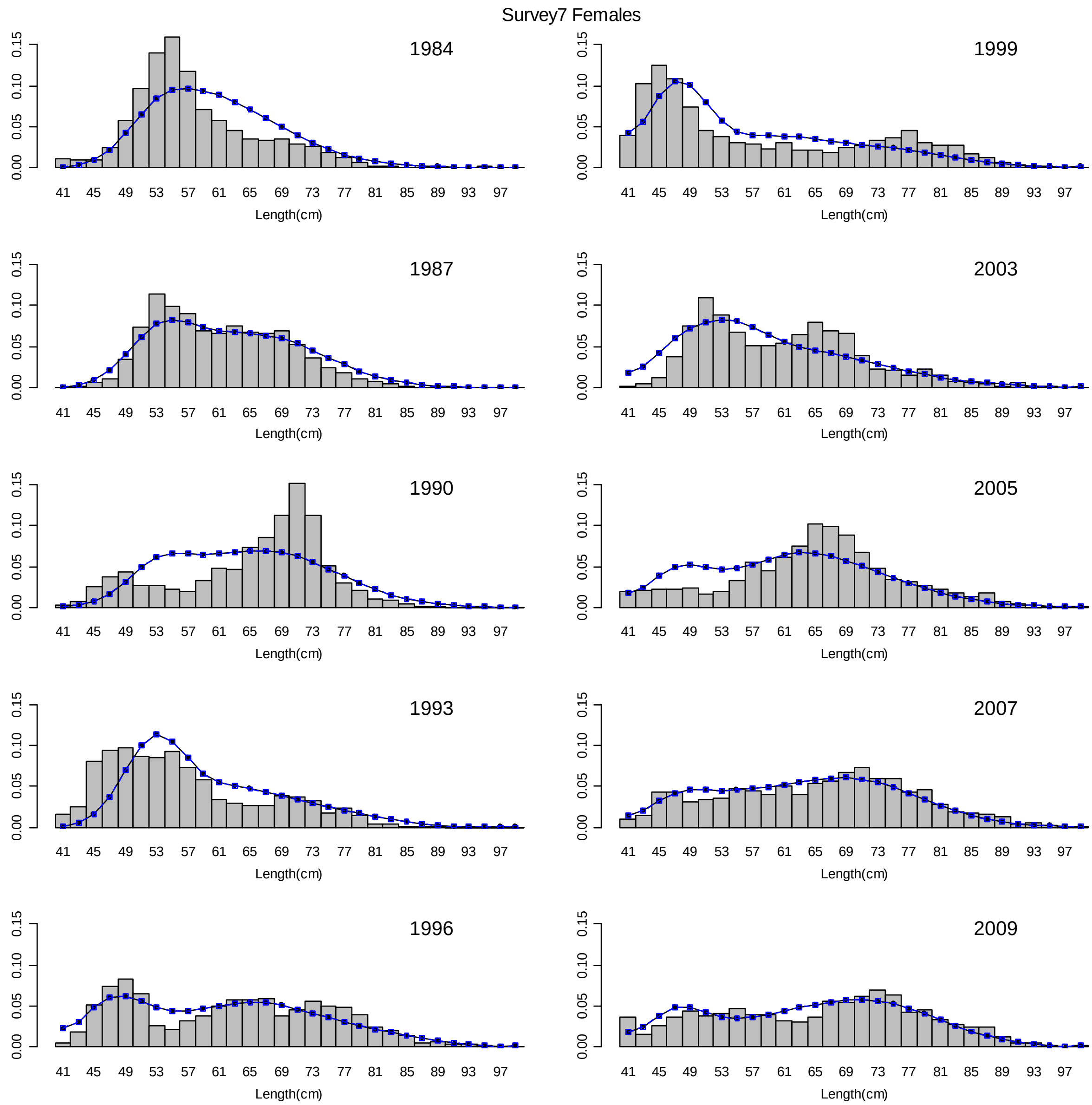


Figure 3.12. Gulf of Alaska bottom trawl survey lengths for female sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

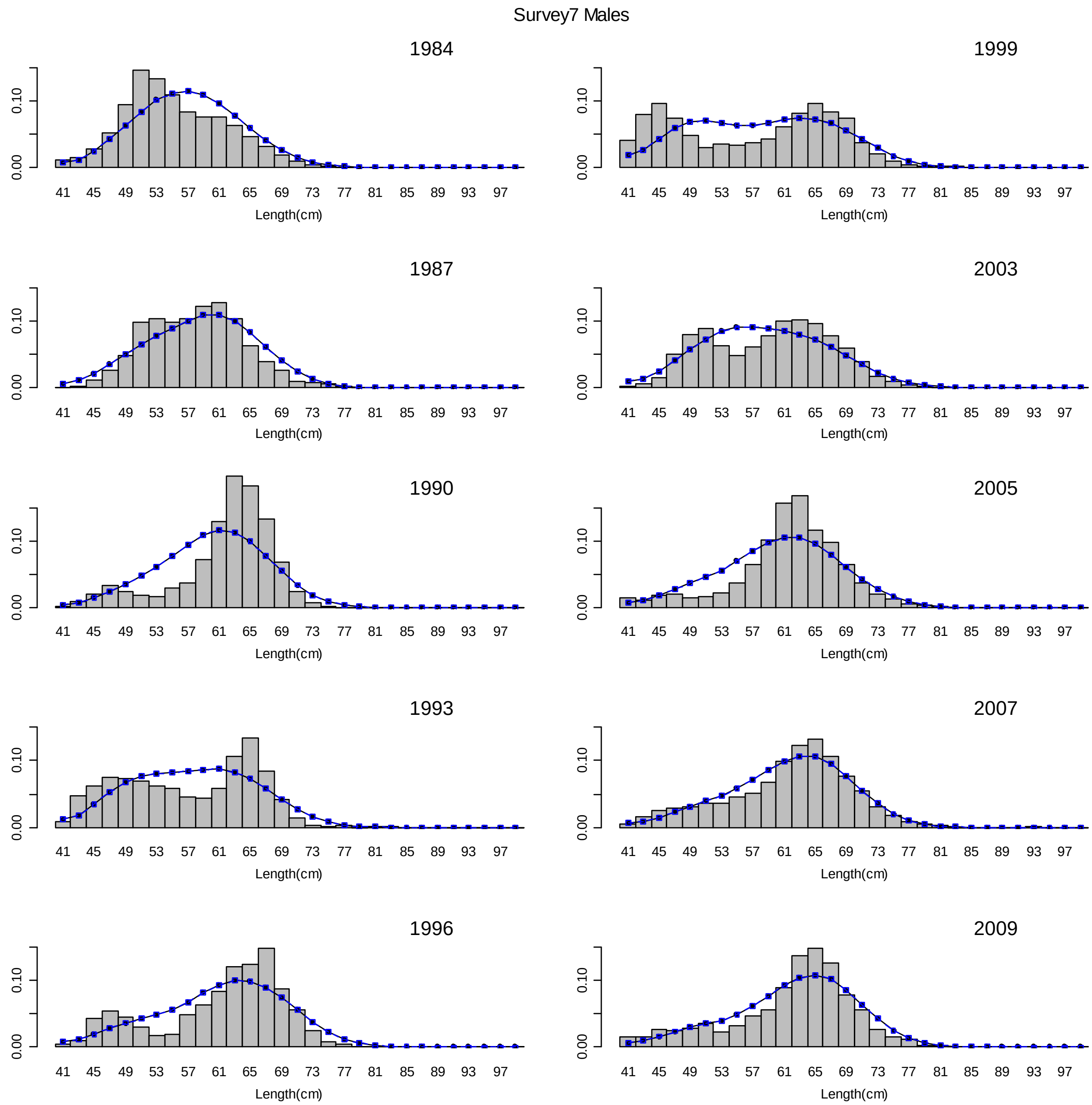


Figure 3.13. Gulf of Alaska bottom trawl survey lengths for male sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

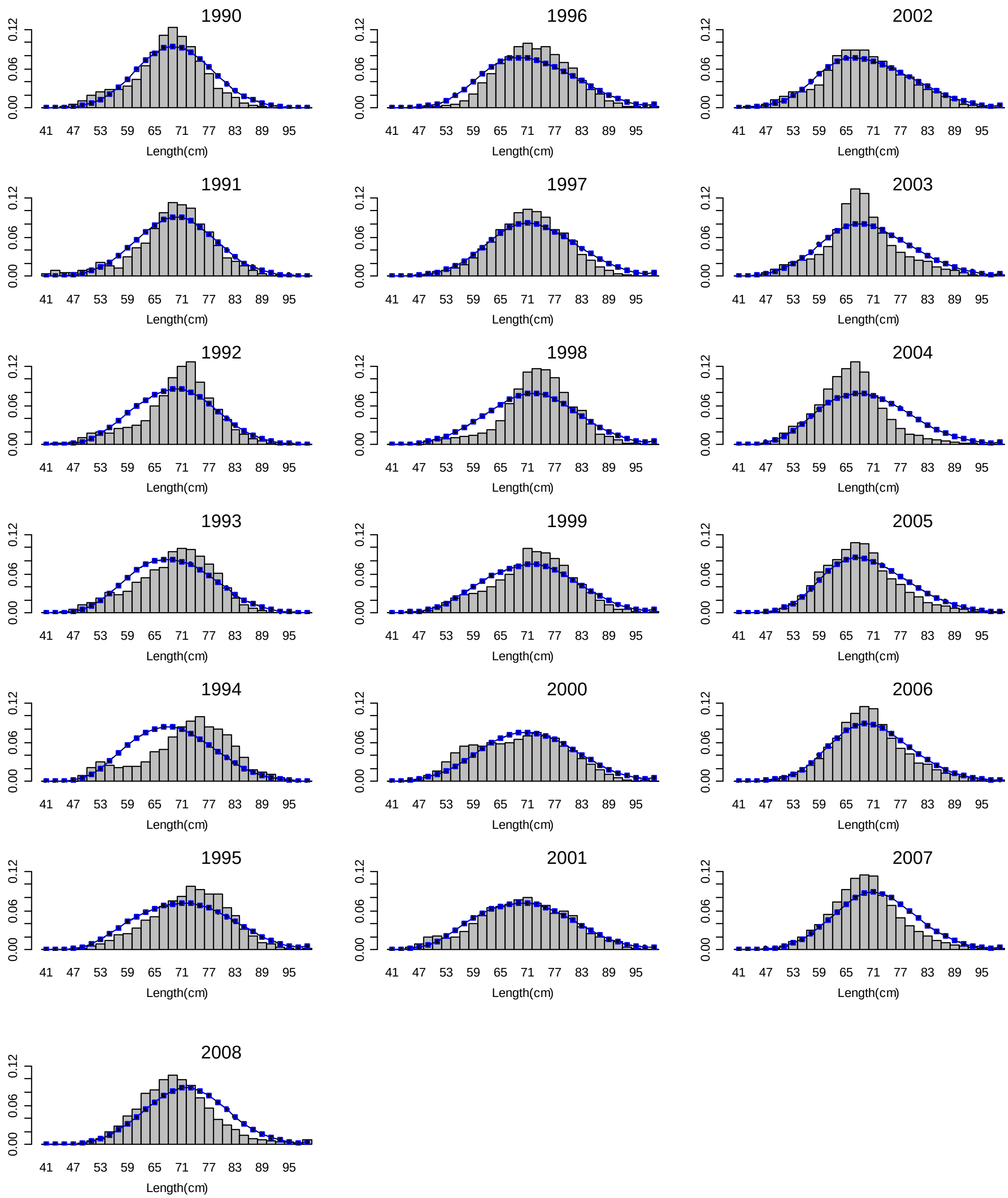


Figure 3.14. Domestic fixed gear fishery lengths compositions for females. Bars are observed frequencies and line is predicted frequencies.

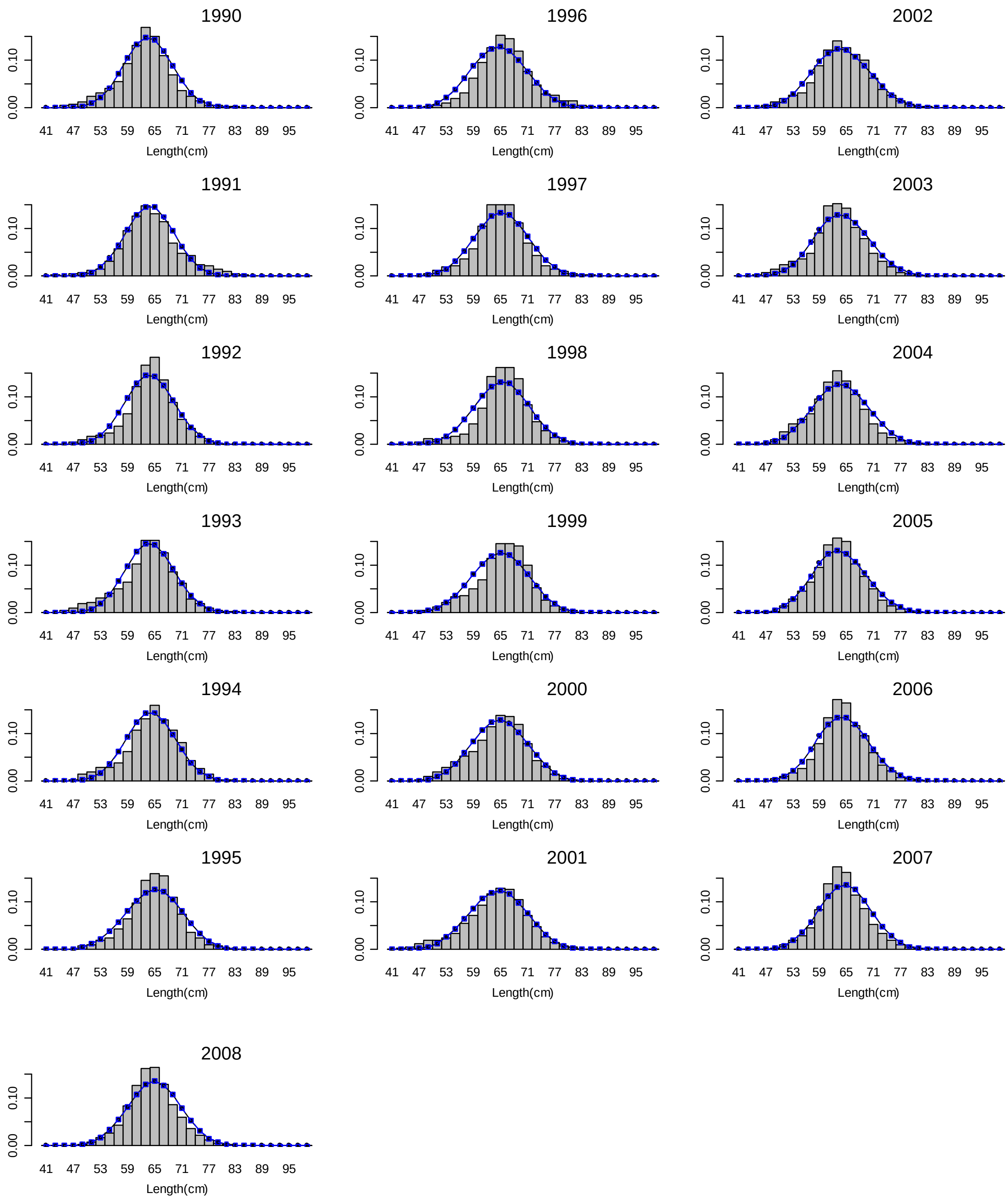


Figure 3.15. Domestic fixed gear fishery lengths compositions for males. Bars are observed frequencies and line is predicted frequencies.

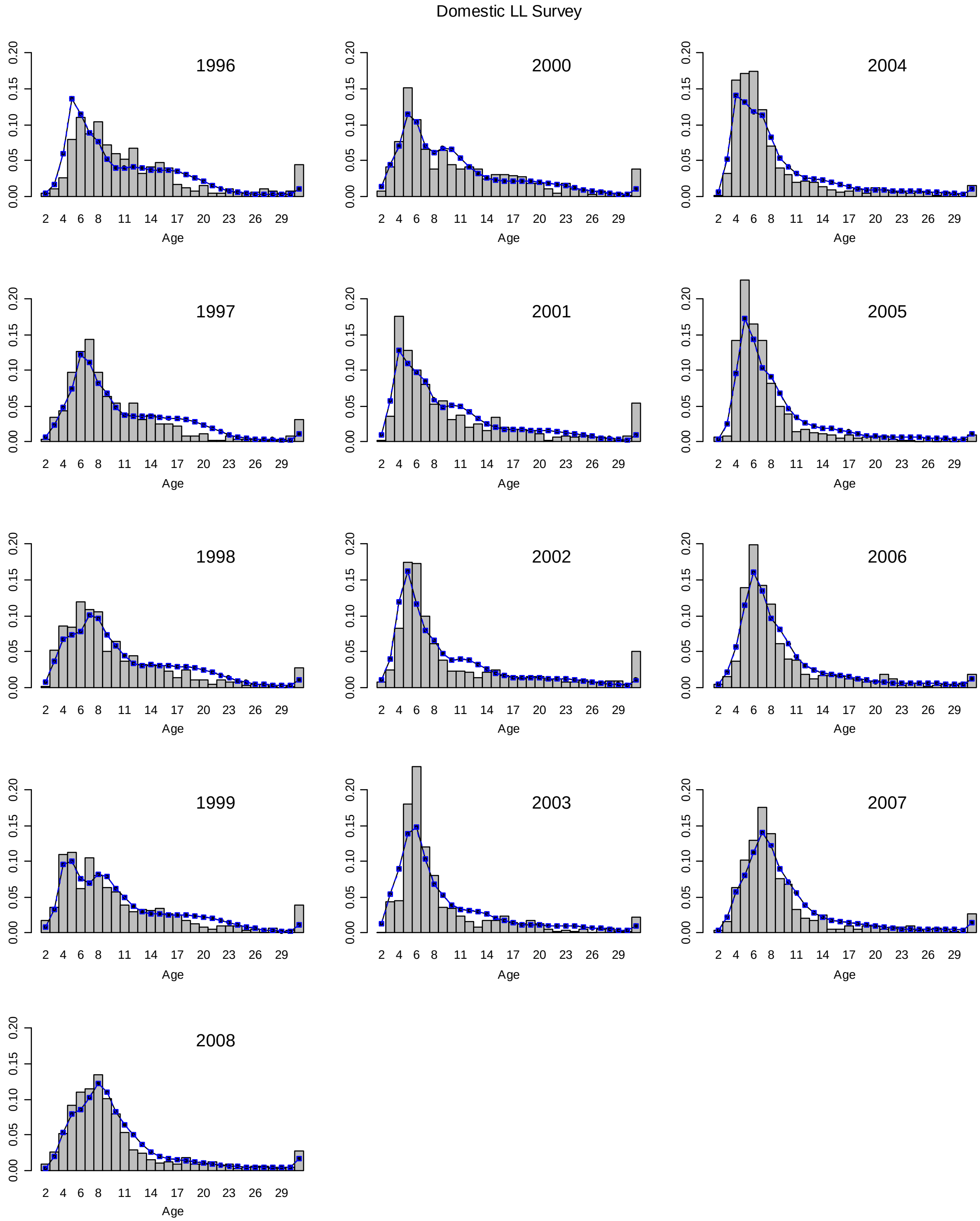


Figure 3.16. Domestic longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

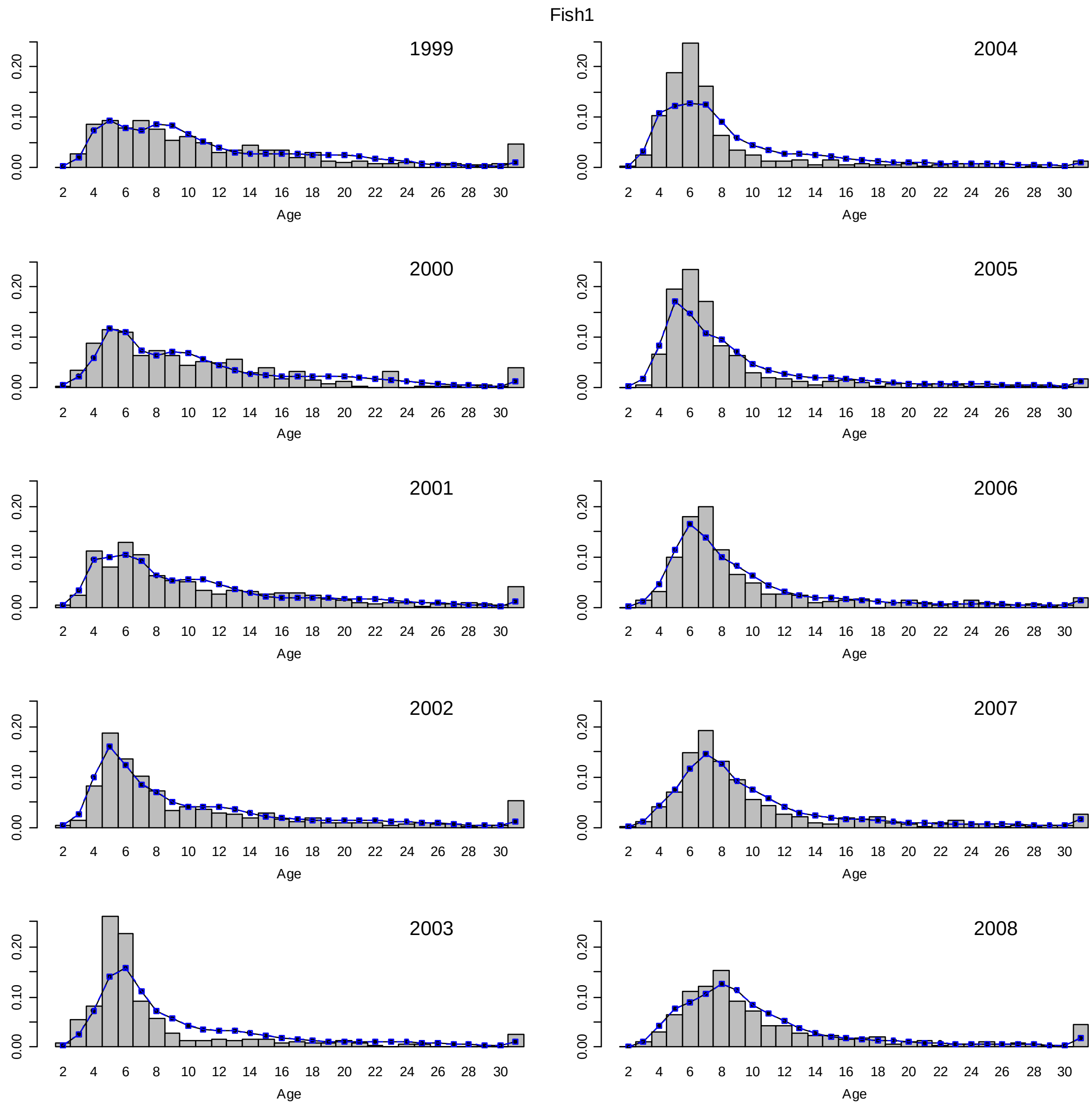


Figure 3.17. Domestic fishery age compositions. Bars are observed frequencies and line is predicted frequencies.

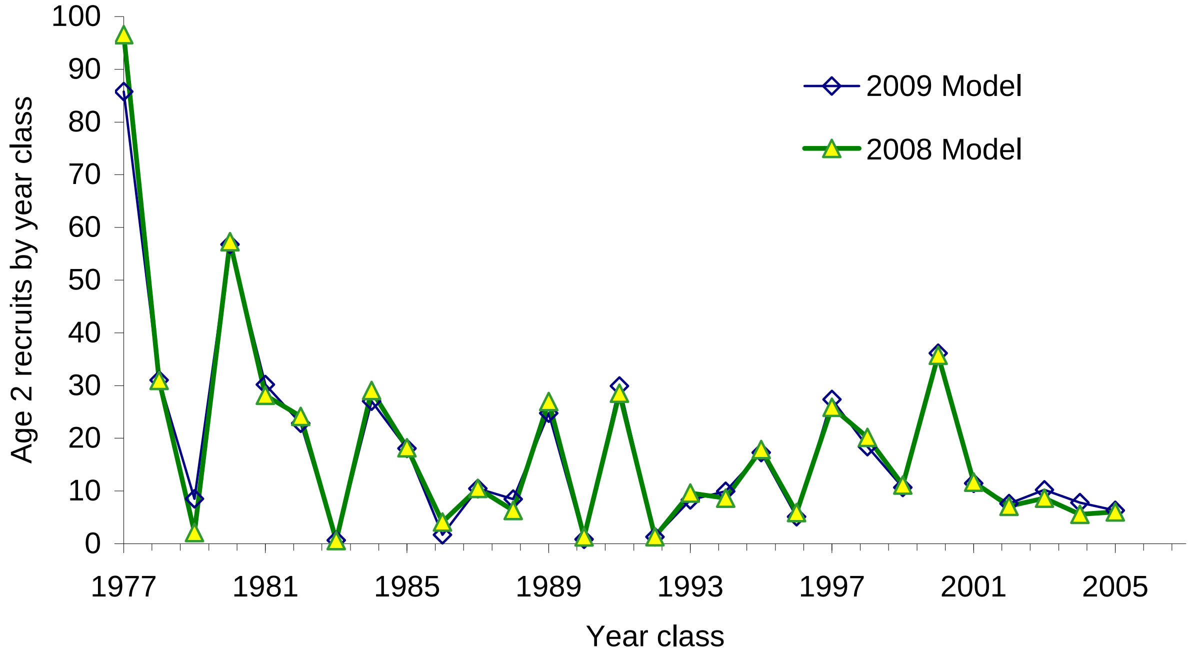


Figure 3.18a. Estimated recruitment (number at age 2, millions) versus year for 2008 and 2009 models.

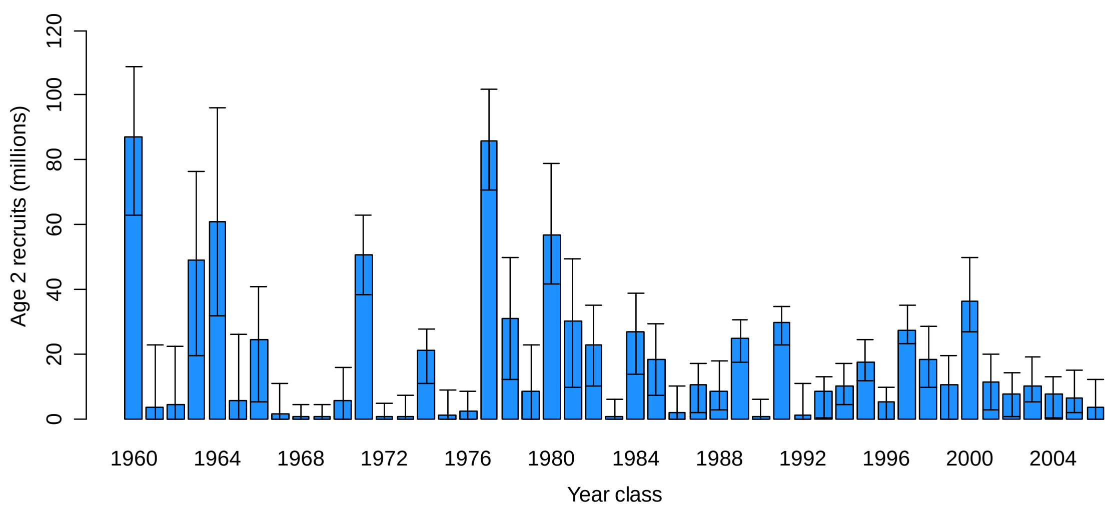


Figure 3.18b. Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on 5,000,000 MCMC runs.

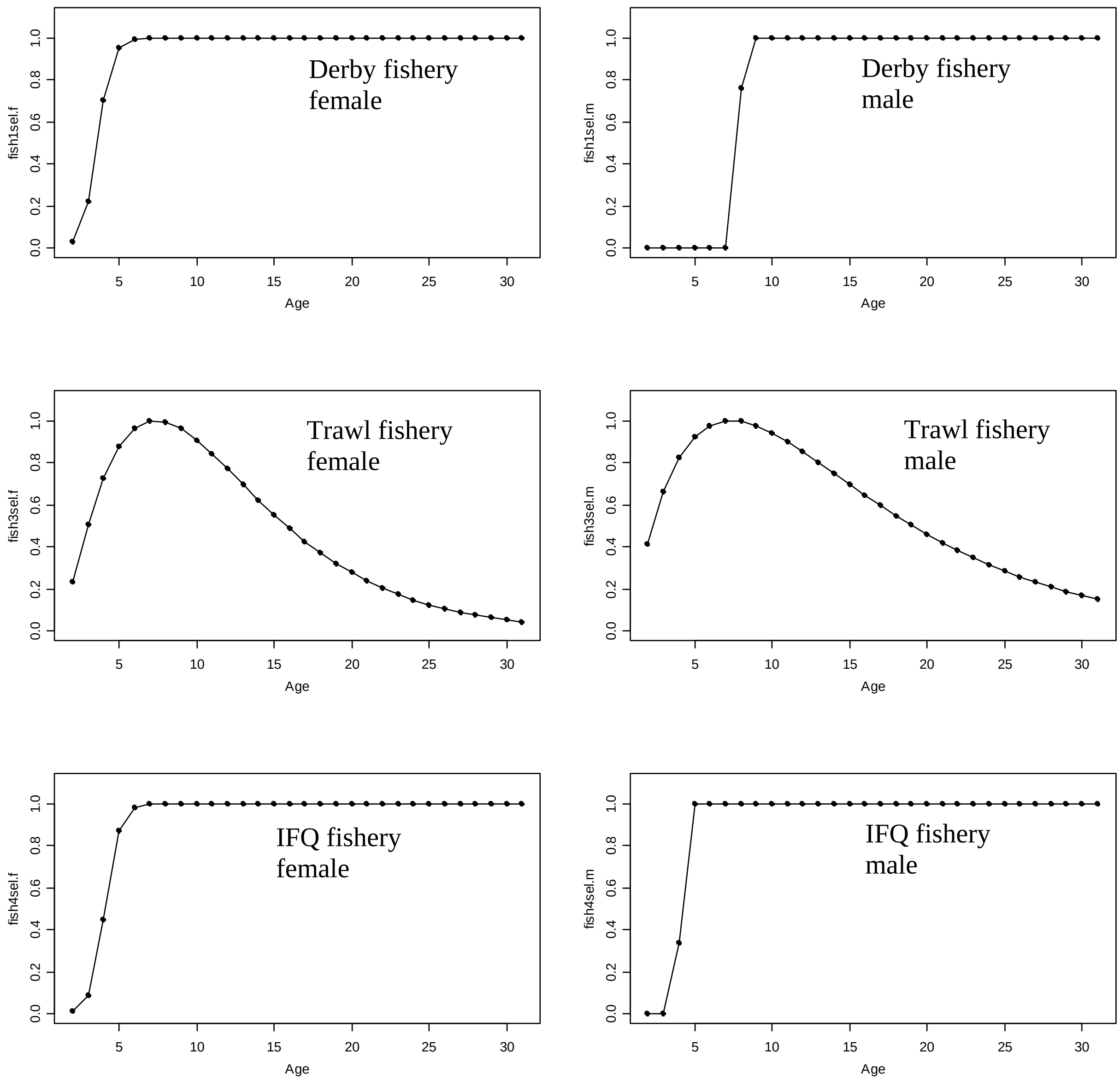


Figure 3.19a. Sablefish selectivities for fisheries.

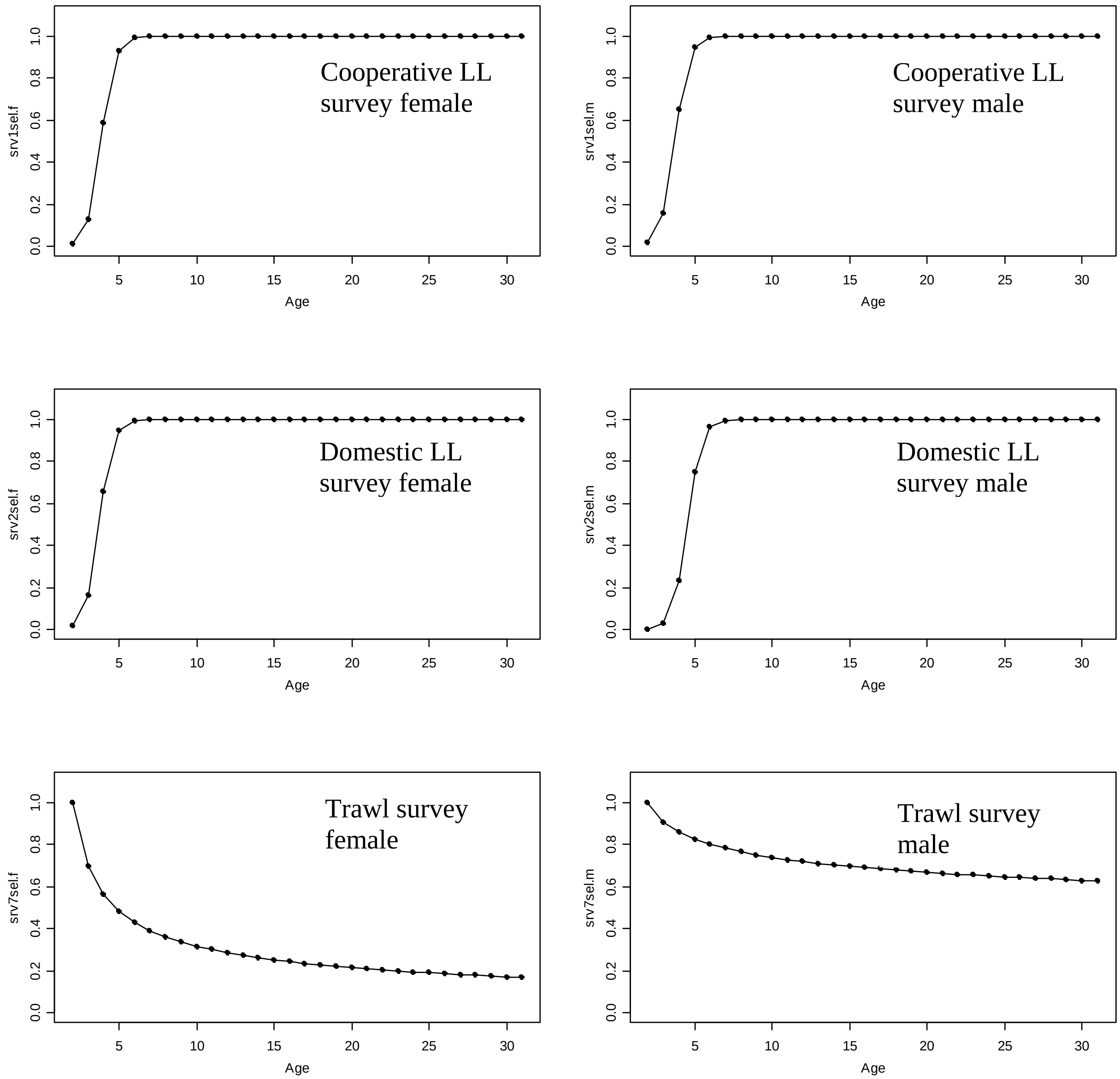


Figure 3.19b. Sablefish selectivities for surveys.

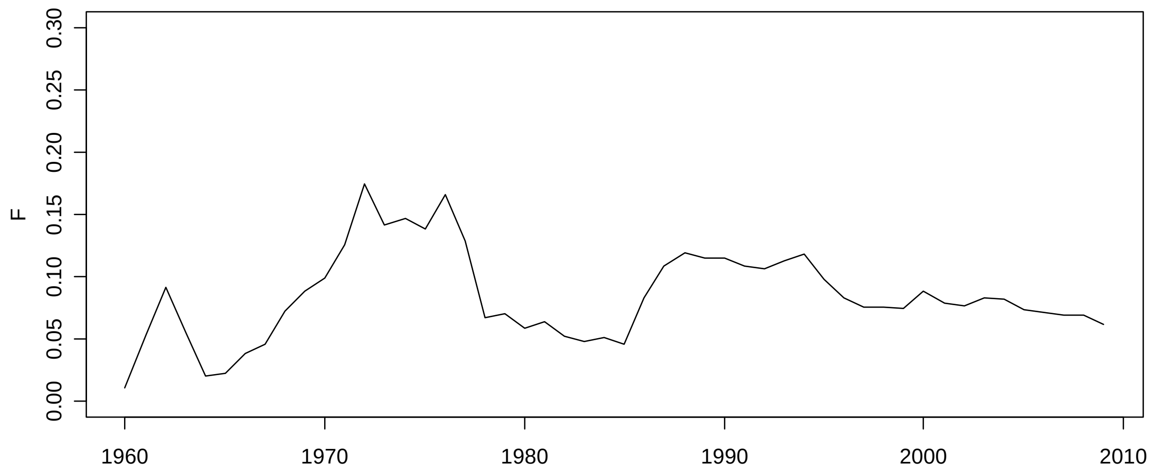


Figure 3.20. Time series of combined fully-selected fishing mortality for fixed and trawl gear for sablefish.

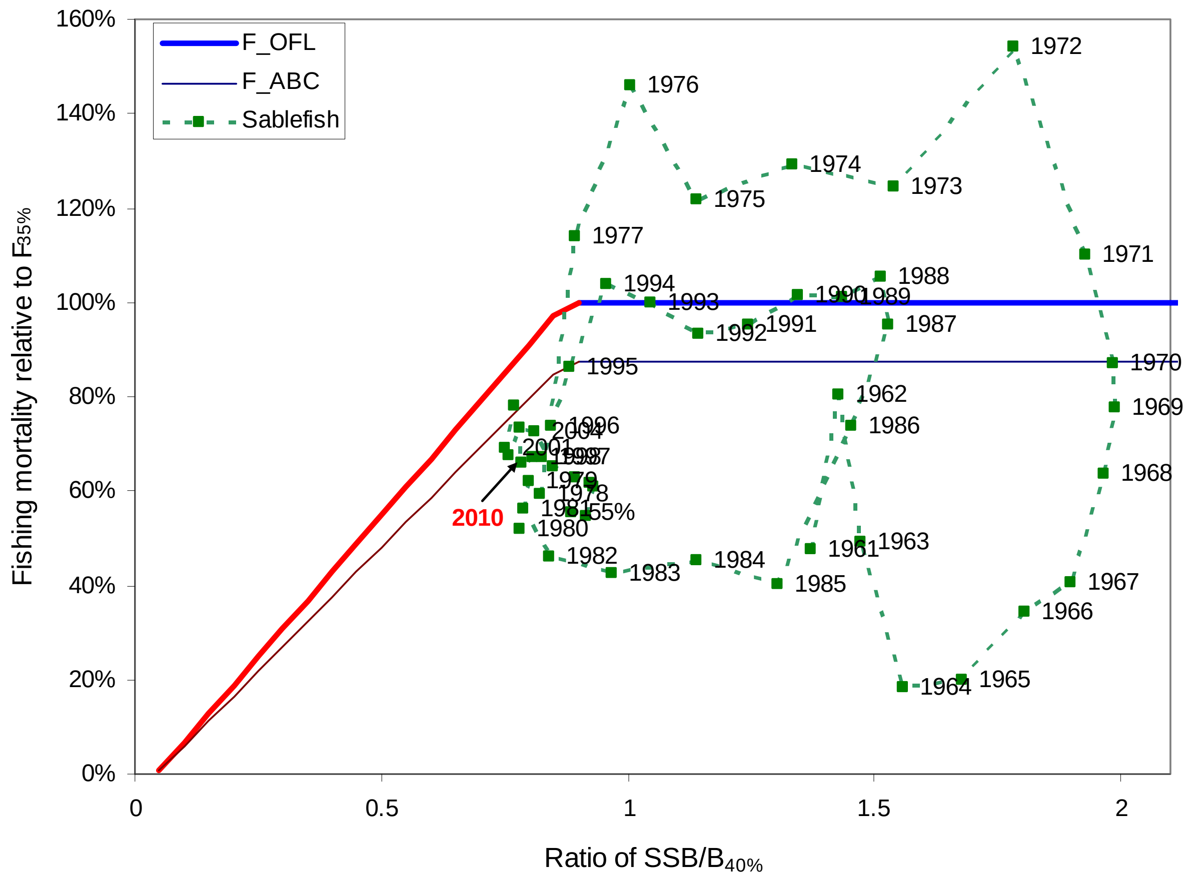
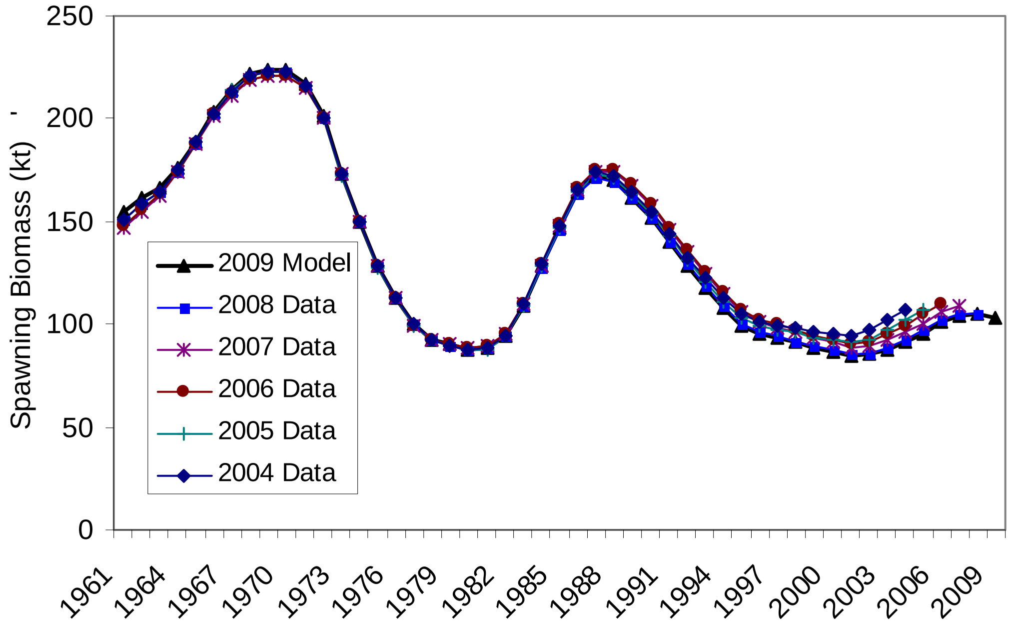


Figure 3.21. Phase-plane diagram of time series of sablefish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.



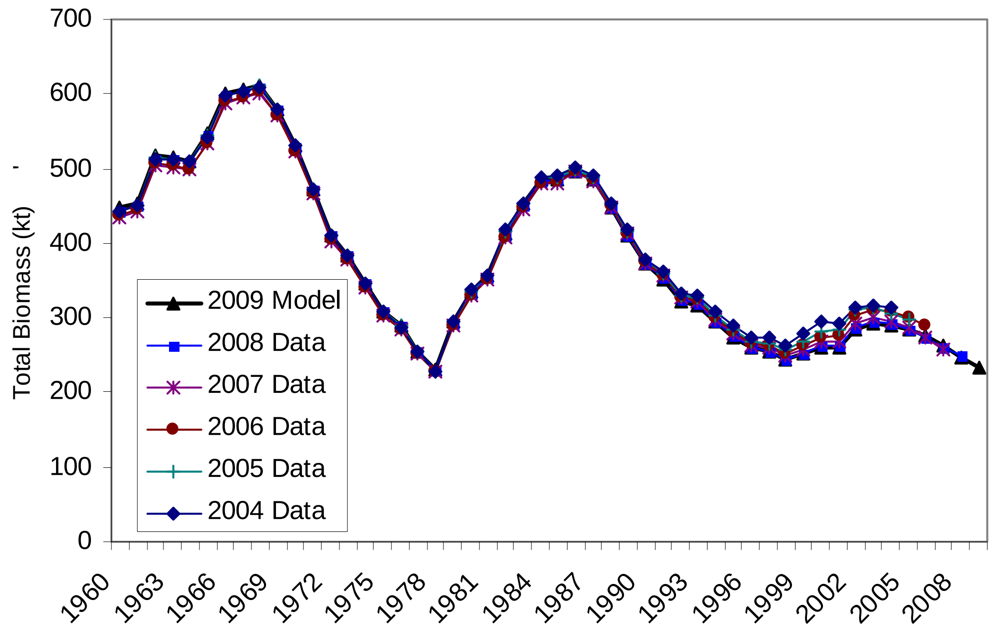


Figure 3.22. Retrospective trends for spawning biomass (top) and total biomass (bottom) from 2004-2009.

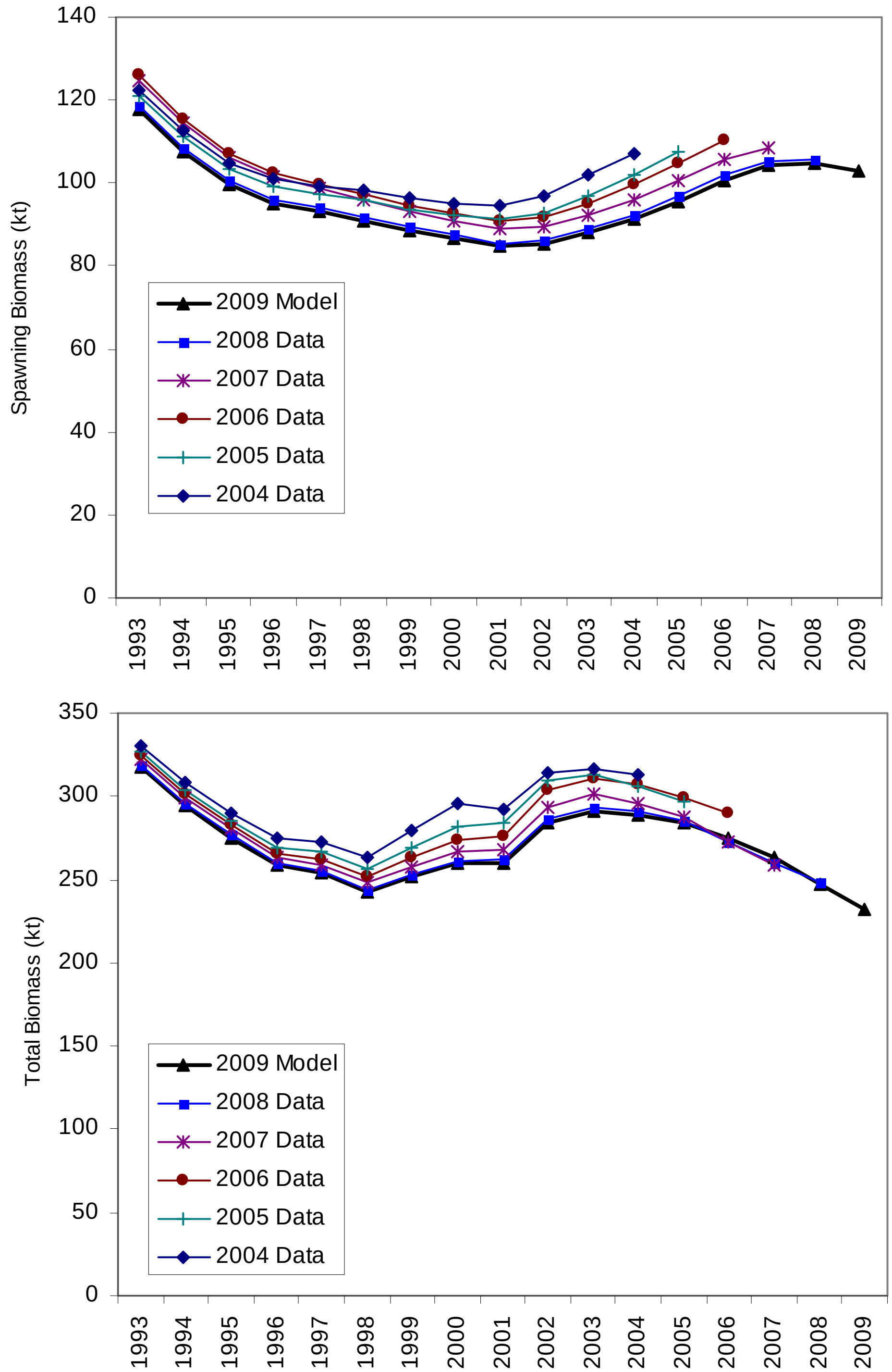


Figure 3.23. Recent retrospective trends for spawning biomass and total biomass 2004-2009.

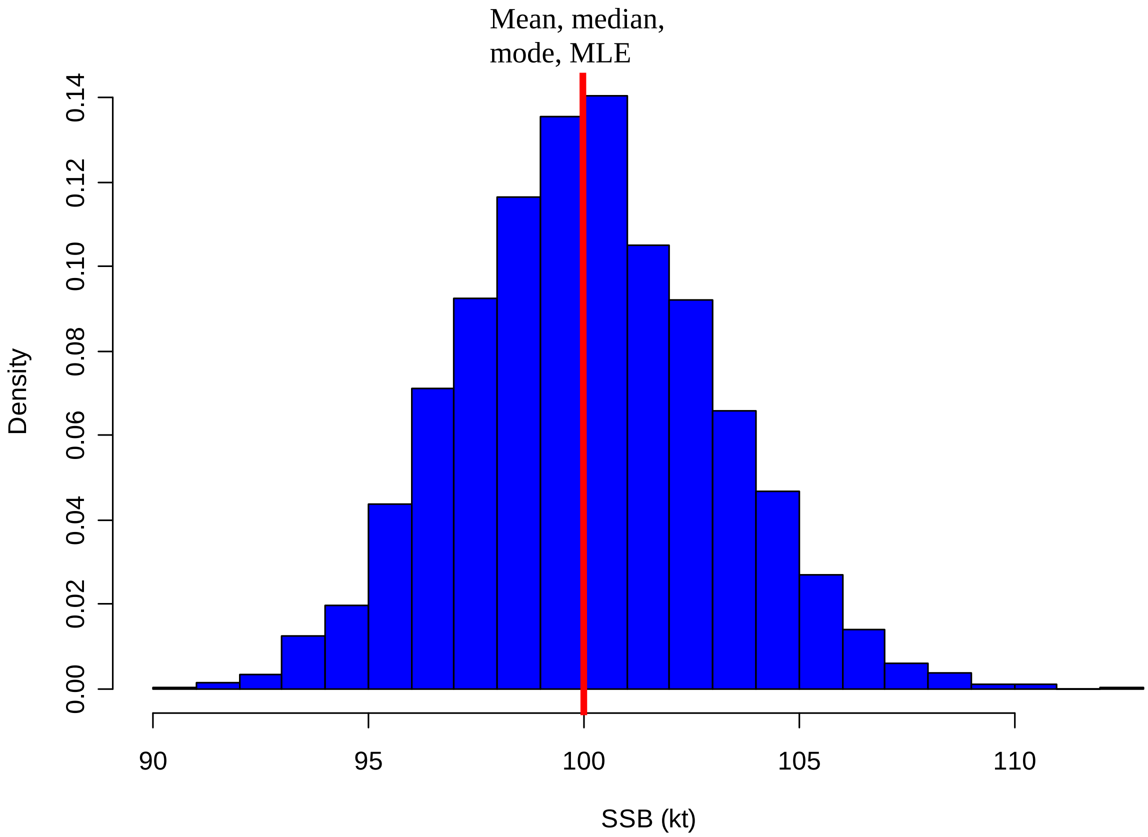


Figure 3.24. Posterior probability distribution for projected spawning biomass (thousands t) in 2010.

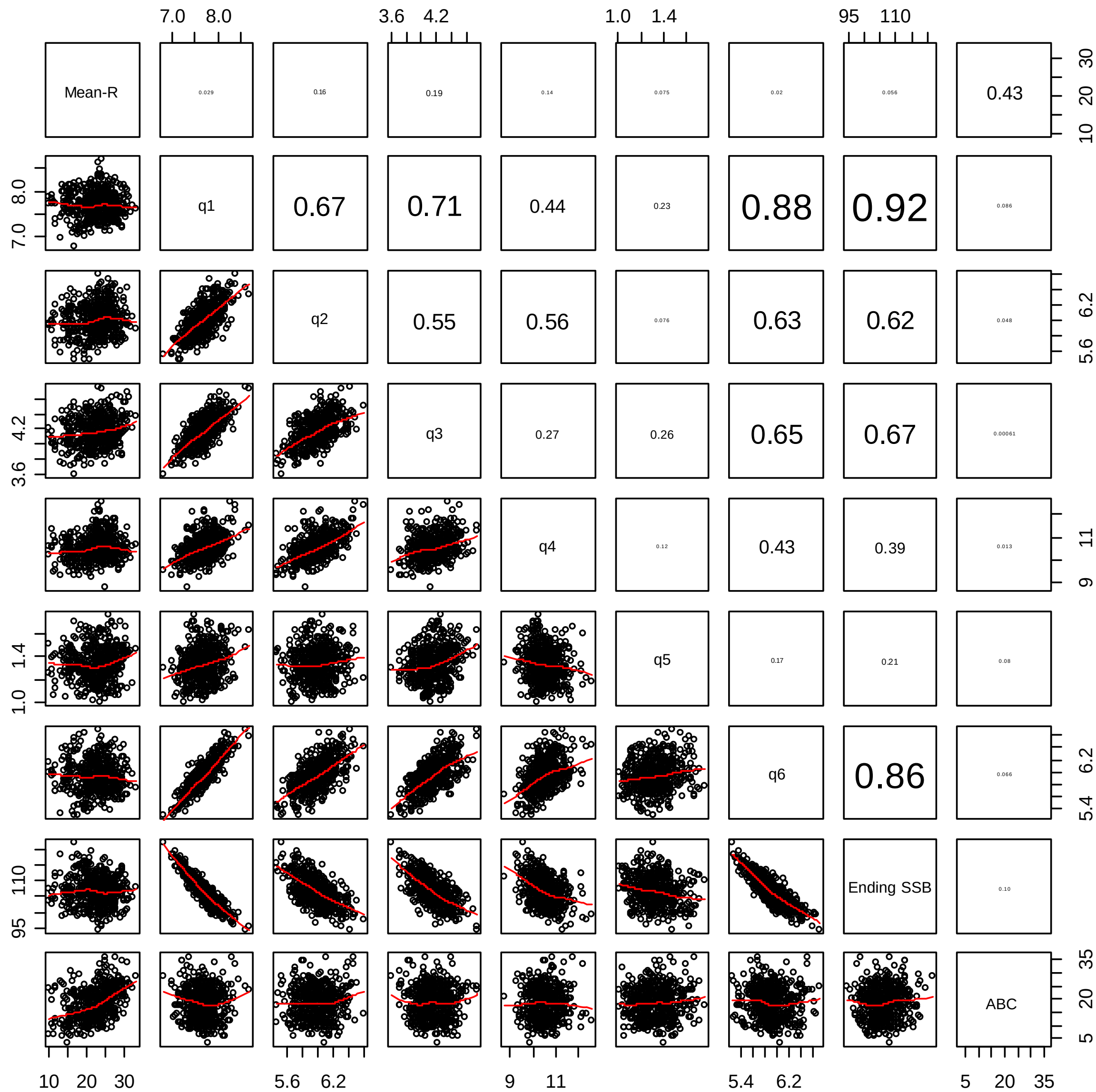


Figure 3.25. Pairwise scatterplots of key parameter MCMC runs. Red curve is a loess smooth. Numbers in upper right hand panel are correlation coefficients between parameters.

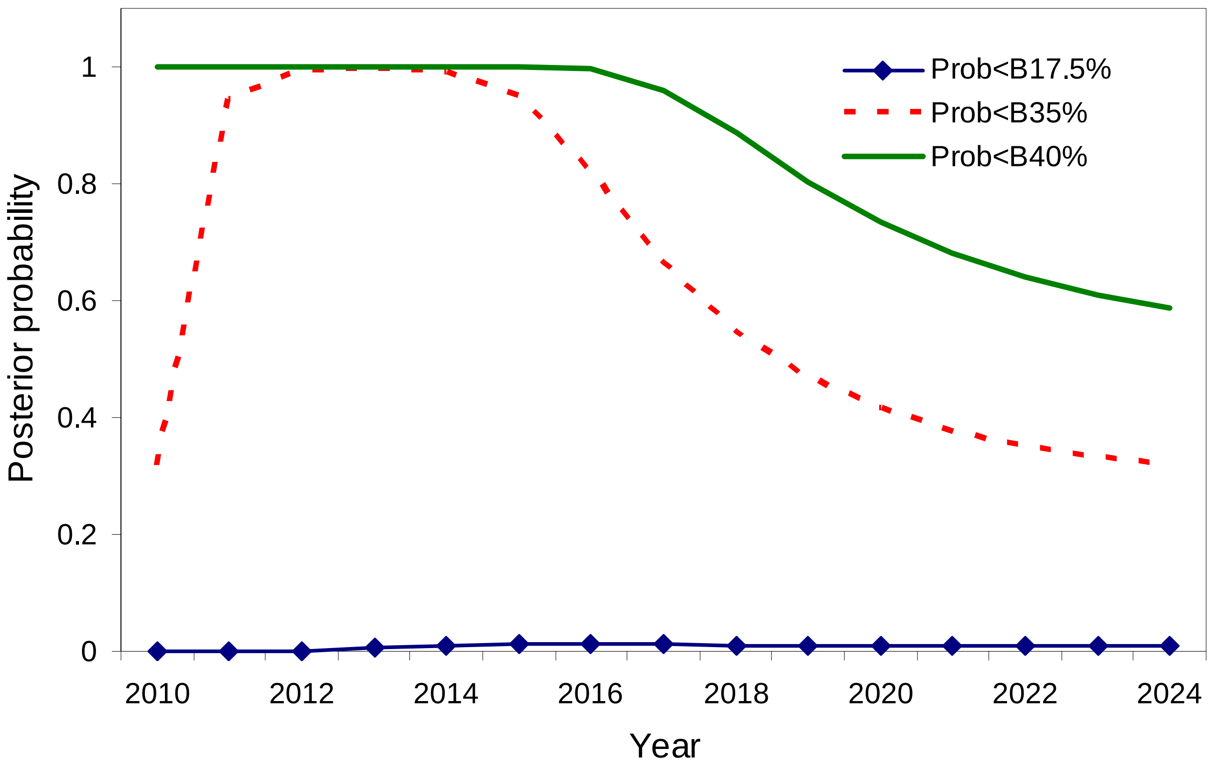


Figure 3.26. Probability that projected spawning biomass (from MCMC) will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

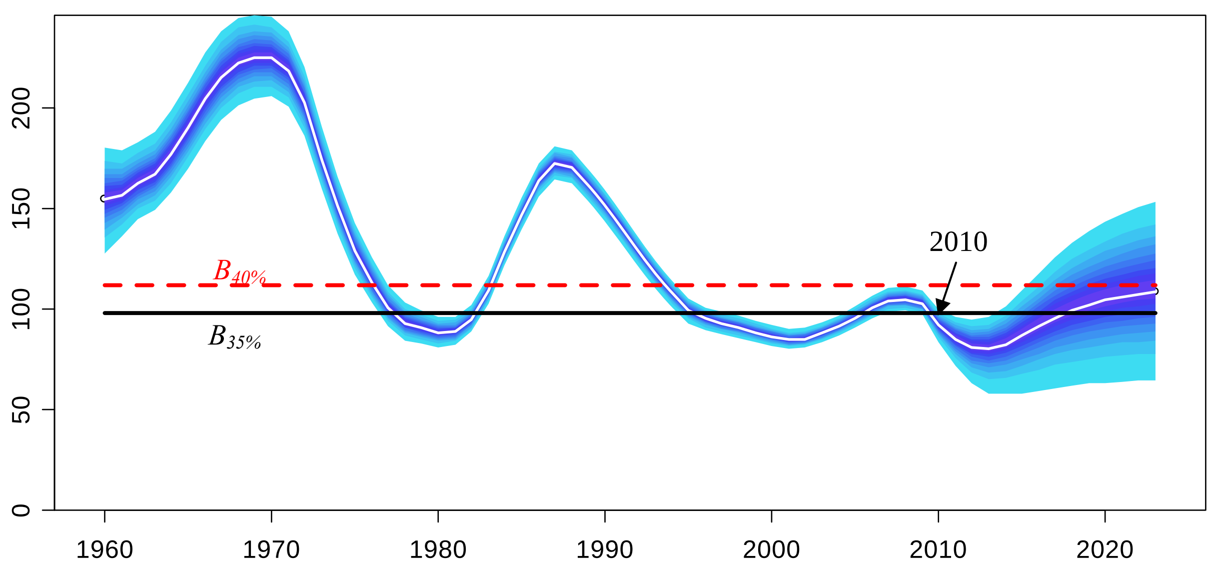


Figure 3.27. Estimates of female spawning biomass (thousands t) and their uncertainty. White line is the median and shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 10,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval. Harvest policy is least conservative with catch at maximum permissible ABC.

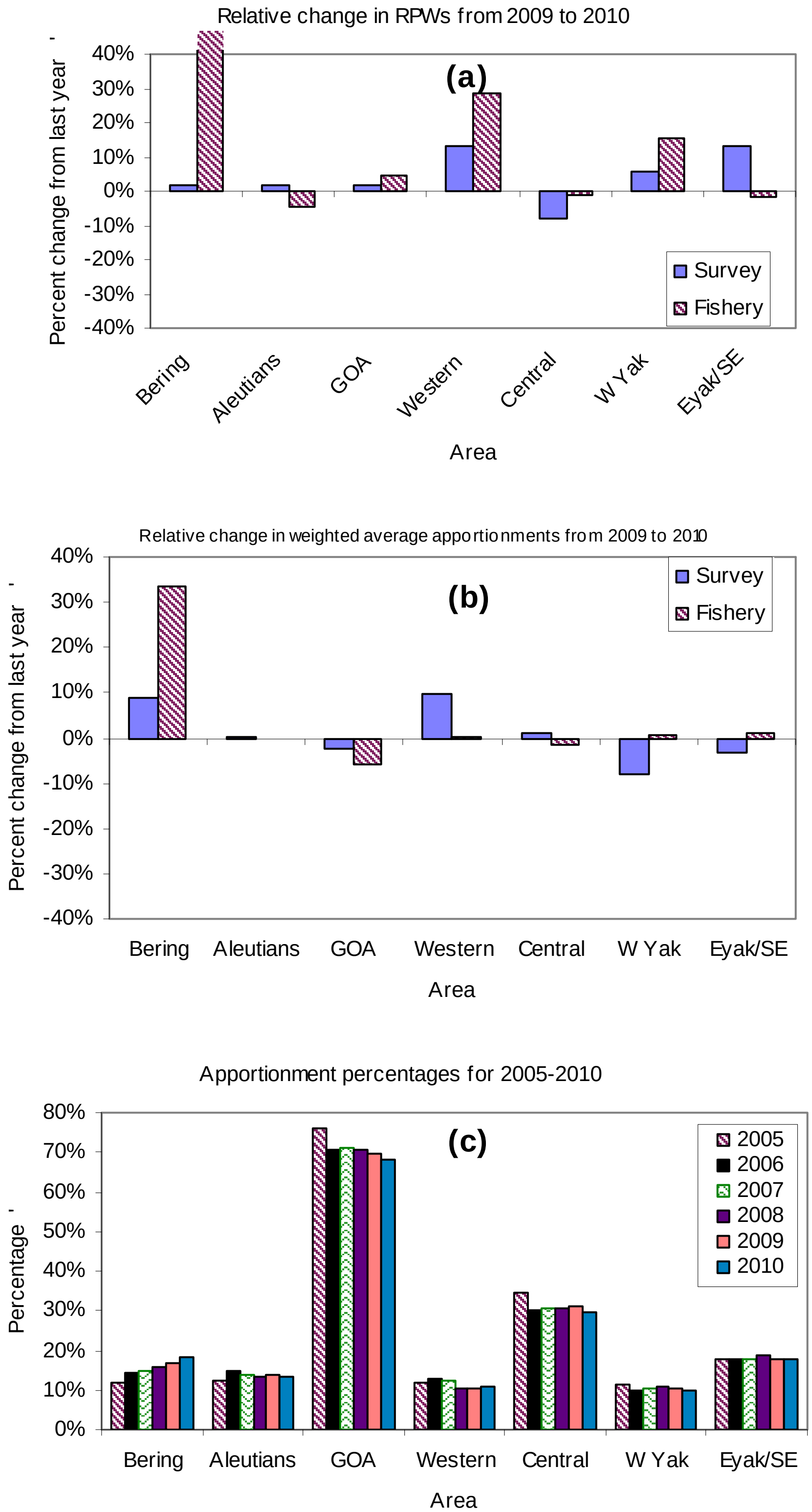


Figure 3.28. (a) The percentage change of each Relative Population Weight (RPW) index by area from 2009 apportionment to the 2010 apportionment. (b) The percentage change of the weighted average of apportionment by area. (c) The apportionment percentages by area of ABCs for 2005-2010.

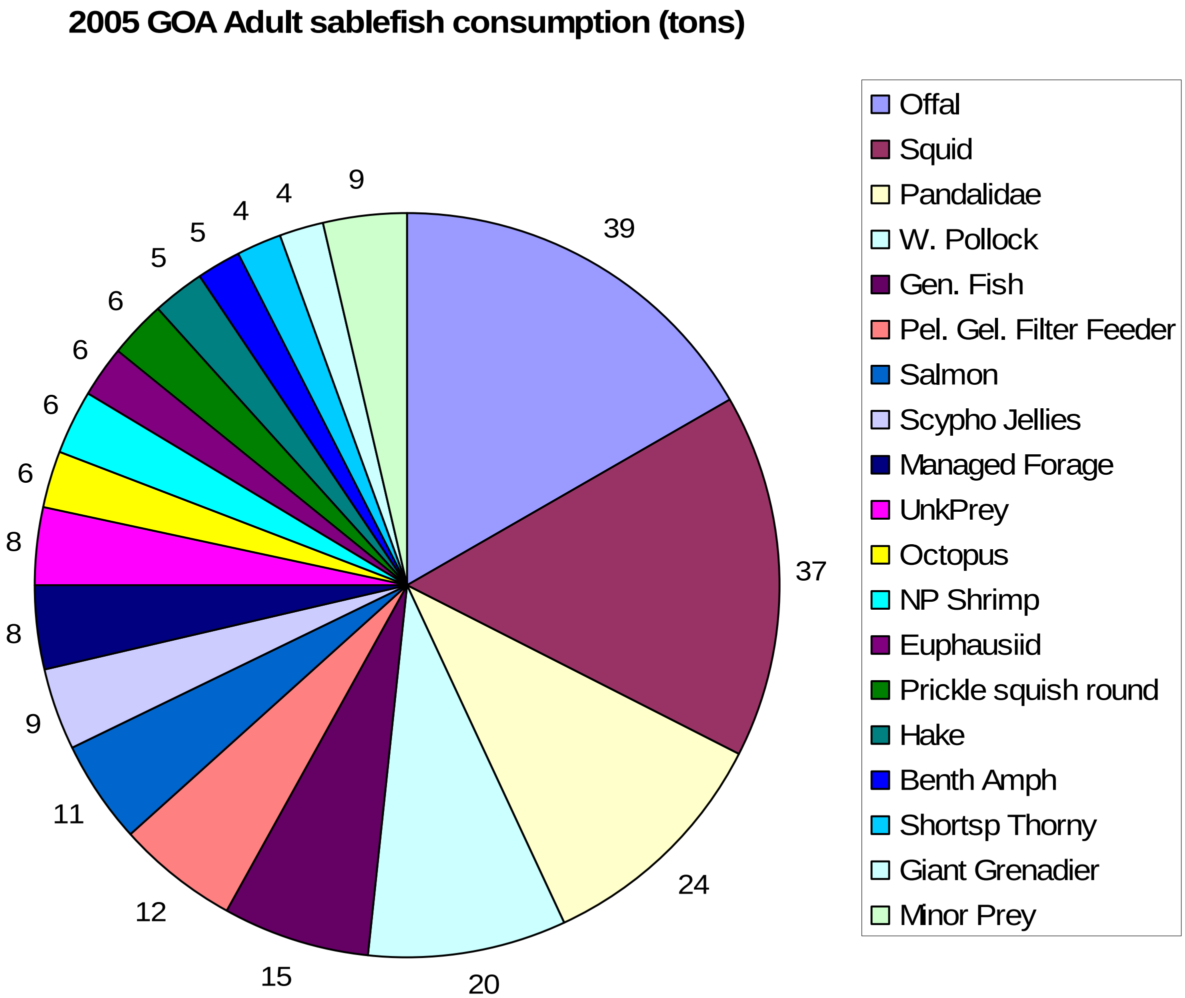


Figure 3.29. Consumption of prey in tons by sablefish in the Gulf of Alaska in 2005. Minor prey category are prey that totaled less than 4 tons of consumption.

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 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. 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 to avoid potential survey interactions.

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
2007	8	6	2	2	0	0	10	8
2008	2	2	2	2	0	0	4	4
2009	3	3	0	0	0	0	3	3

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions have been low except in 2006 and 2007. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance.

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

Year	Echo integration trawl	Trawl	Japan US longline survey	IPHC longline survey*	Domestic longline survey
1977		3,126			
1978	23	14,302			
1979		27,274	103,839		
1980		69,738	114,055		
1981	813	87,268	150,372		
1982		107,898	239,696		
1983	44	45,780	235,983		
1984		127,432	284,431		
1985		185,692	390,202		
1986	80	123,419	395,851		
1987		116,821	349,424		
1988		14,570	389,382		302,670
1989		3,711	392,624		367,156
1990	94	25,835	272,274		366,236
1991		3,307	255,057		386,212
1992	168	10	281,380		392,607
1993	34	39,275	280,939		407,839
1994	65	852	270,793		395,443
1995					386,169
1996	0	12,686			430,447
1997	0	1,080			395,579
1998	5	25,528		50,103	324,957
1999	0	43,224		48,648	311,358
2000	0	2,316		53,185	289,966
2001	2	11,411		47,963	326,274
2002	154	2,607		58,174	309,098
2003	141	15,737		97,815	279,687
2004	53	1,826		97,825	287,732
2005	244	17,915		91,730	254,762
2006	19	1,816		63,544	286,518
2007	8	16,670		47,845	266,477
2008	0	3,077		45,783	261,636
2009	18	14,329			242,360

* IPHC survey sablefish catches are released and estimates from mark-recapture studies suggest that these catches are expected to produce low mortality

Appendix 3C: Responses to CIE recommendations for the Alaska sablefish assessment

3C.1 Introduction

This document is a point by point response to specific recommendations raised in the panel summary of the 2009 Alaska sablefish assessment review. Recommendations or specific criticisms by the review panel are in **bold**. Our responses are in *italics*.

Terms of reference (TOR)

TOR 1: Evaluation, findings, and recommendations on quality of input data and methods used to process them for inclusion in the assessment.

TOR 2: Evaluation, findings, and recommendations on the level and adequacy of knowledge and incorporation of life history, ecology and habitat requirements.

TOR 3: Evaluation, findings, and recommendations of the analytical approach used to assess stock condition and stock status.

TOR 4: Evaluation, findings, and recommendations of areal apportionment of harvest strategy as related to optimizing spawning stock biomass.

TOR 5: Recommendations for further improvements.

3C.2 TOR 1: Input data and processing

Station locations. The panel noted that many of the locations for stations used to compute the survey index were originally selected by the Japanese fishing masters using knowledge of the spatial distribution of sablefish to set in areas with the highest possible catch rates whilst spreading them out as much as possible along the coast. This selection of stations could lead to bias in the survey index. The additional stations in gullies, which are not used in the assessment, could provide a useful check on this. **An analysis to check for differences in trends between the gully and non-gully stations may be a useful analysis to evaluate possible bias in the survey index.**

While the Japanese fishing masters may have located many stations in areas of high sablefish abundance, the survey does cover depths from 100 to 1,000 meters which includes a large range of sub-optimum sablefish depths. A comparison of gully versus standard survey stations will be presented in the 2009 SAFE report.

GOA bottom trawl survey. The Panel concluded that the inclusion of the GOA bottom trawl survey (to 500m) is potentially useful for indices of abundance for incoming year classes; and although the survey should help estimate recent year class strength, **the current assessment does not fit this index as well as the longline survey indices**.

While the trawl survey index generally supports a similar trend as the longline survey indices, the amount of weight given it in the model is small compared to the longline survey because of the use of both RPNs and RPWs and because it is assigned a higher annual sampling variability. Since the trawl survey only covers the depth range of younger sablefish, it is an index of year-class strength and we expect it to be variable and more difficult to fit closely. This issue should be alleviated when we use RPNs only for the 2009 assessment (see assessment section below).

Commercial longline fishery catch rates. The Panel concluded that the use of fishery CPUE is appropriate for the current assessment. **The practice of postscreening fishing operations to derive target-specific effort may lead to unwanted bias in the CPUE indices, and the Panel suggested that a better approach to evaluating the fishery CPUE would be to undertake a statistical (GLM) analysis.**

We are currently evaluating the use of Generalized Linear Models (GLM) to account for variables that may affect fishery CPUE. To avoid bias, sets will not be screened by deriving a target. This will not be finished for the 2009 assessment cycle, but will likely be incorporated in the 2010 assessment.

Accuracy of landings/total catch and stock structure. The Panel considers the current treatment of stock area and total catches as adequate for assessment and associated management. Nevertheless, the following points were noted:

> **State catches are not included in the assessment but their exclusion is unlikely to have a significant effect on the assessment results.**

With the implementation of Annual Catch Limits (ACLs) in the coming assessment cycles, all state and research catches will be included in the catch estimates.

> Catches from the western Bering Sea in the earlier part of the time period are unknown, and the overall catch figures for the earlier period when the fishery was open to international fleets is likely to be generally of poorer quality than in later years. The likely effect of underestimated catch on the assessment results is not quantifiable but is unlikely to have any significant effect on the recent stock biomass estimates. There is anecdotal information of high-grading during

different years. **The sensitivity of the assessment to alternative plausible catch history has not been investigated**.

Multiple attempts at alternative catch histories have been modeled throughout the history of the sablefish assessment to account for unknown Bering Sea catches, larger reported fish market reports in Japan than reported catch, and high-grading (Sigler et al. 1995, Sigler et al. 1999, etc). The current catch history is considered the most reasonable given the data available.

Age-length sampling. The Panel noted that the adequacy of length-age sampling has improved in recent years. Vessels accounting for 30% of the catch are sampled, which is relatively good coverage and indicates that the effective sample size is high. Trawl fishery data are sparse, but the longline fishery was well sampled. **The adequacy of existing sample size in terms of precision should be investigated.**

The tradeoffs between actual sample size and effective sample size will be an important part of upcoming modeling efforts.

The age-length conversion matrix appears to be appropriate. It was noted that the change in growth is modeled with a step-change. **An improvement may be to have a gradual change over a number of years.**

We agree that the abrupt growth change may induce unwanted residual patterns. In the future we will look at a smooth transition between growth regimes or consider estimating growth within the model.

Voluntary logbook scheme. The voluntary logbook program was seen as helpful to evaluate the under-60' fleet, which is otherwise only monitored based on fish-ticket data. Some concerns were raised that the coverage for this fleet was very low historically. **The implications of this low sampling level for this fleet component on the derived abundance index should be investigated.**

Voluntary logs from under-60 ft vessels are indistinguishable from required logs of vessels over 60 ft because of confidentiality agreements between the data collecting agency (the International Pacific Halibut Commission, IPHC) and the vessels. Proportions of voluntary and required logs are reported in the SAFE. However, because of our inability to separate the log data by vessel size, an analysis of the effects of increased coverage of the under-60 ft fleet is not possible. However, in the aforementioned standardization of observed fishery data using GLM's, vessel size will be analyzed.

Data not currently included in current assessment. A number of data sources not currently used in the assessment were identified as candidates for inclusion in future assessments and their utility should be investigated:

Combined sex data from early fishery size composition data

We may include these data in the 2009 assessment cycle in order to estimate selectivity for the early Japanese fisheries.

Sex ratio data can potentially be used in fitting the model

We have made some effort to include sex ratio data in the past, but are still working on a consistent method. Since we have compositional data from a number of different data sources that span different time periods, it is difficult to fit a time series of sex ratios. We agree that the implied sex ratio is potentially important to model results.

The time-series of sablefish CPUE from IPHC surveys

We have briefly investigated sablefish CPUE data from the IPHC commission. A table of the time series, for years when they were collecting relatively consistent sablefish data, will be included in the assessment document.

EBS slope surveys (although there are concerns regarding the sex ratio and a predominance of large males need to be investigated)

We will monitor the time series of EBS slope surveys. At this time the series is quite short, but a table will be included in the assessment document.

State surveys (recognizing potential issues with applicability to the AK-wide stock)

It is highly unlikely we would be able to use state surveys, which are regionalized, in the Alaska-wide assessment. If we move toward a spatially-explicit model in the future, we will investigate the utility of regionalized surveys.

3C.3 TOR 2: Life history, ecology, and habitat requirements

Maturity. The use of separate maturity ogives for female and male sablefish represents the most appropriate use of maturity data for computing spawning biomass rather than the use of a combined-sex maturity ogive. The Panel notes that the ogives currently used are from data collected prior to the mid-1980s, and that more recently collected and histologically verified maturity data are available and should be used in future assessments. The new data indicate a slightly higher age at 50% maturity in females. **Temporal trends in maturity should be monitored. However, given the observed changes in growth, it would be valuable to quantify the age and length dependence of maturation.**

We agree new age at 50% maturity estimates are needed but have not been able to acquire funding to conduct these studies. AFSC scientists are pursuing maturity sampling during the winter, weeks or *months before sablefish likely spawn in Alaska. Samples from this time of year are necessary for definitive maturity staging for use in age-at-maturity analyses. Investigations of using gonad samples from late in the IFQ fishing season (October-November) for age-at-maturity analyses are also in progress.*

Ecosystem aspects and competition/predation levels that potentially impact sablefish stocks. The Panel supports efforts to quantify ecosystem effects on sablefish dynamics. **In particular, studies on factors affecting conditions for pre-recruits would be useful to provide insights on medium-term future trends. Such studies would benefit from reliable data on abundance trends for young sablefish from suitable surveys.** Large changes in predator/competitor species (e.g. the recent substantial increase in arrowtooth flounder abundance) may affect population trends of sablefish.

We agree. Several studies are underway looking at recruitment dynamics of sablefish in relation to climate forcing in Alaska. In addition the recent funding of the large Gulf of Alaska Integrated Ecosystem Research Plan has a major focus on recruitment dynamics of sablefish for the next several years.

3C.4 TOR 3: Analytical Approach

The Panel concludes that the analytical approach was appropriate and provides an acceptable basis for management advice. There was some double-use of longline relative indices (i.e. both RPNs and RPWs). Sensitivity analyses and diagnostics were requested and examined during the review.

Abundance indices. **It was recommended that the RPN versions of the Japanese and domestic longline indices should be used and RPW values should be omitted since these indices are highly correlated.** Use of both number and weight effectively doubles the weight given to these data in model fitting.

The current authors are in agreement with the CIE's thoughts on the double-use of this index and its potential to mask other data sources. We intend to remove the RPWs for the 2009 assessment cycle.

Retrospective pattern. The current assessment has a retrospective bias where successive assessments revise the entire biomass series downwards, with the largest bias occurring in the recent period up to 2006. The bias appears much reduced over the last two years of the assessment. The causes of this bias require further investigation, particularly in relation to the appropriateness of the current model configuration. **The impact of the bias on ABC estimates is uncertain and also warrants further investigation**.

We will continue to investigate the retrospective pattern in light of proposed changes to the model to see if some potential model misspecification has been alleviated.

Diagnostics and sensitivity analysis. The Panel requested some standard assessment diagnostics and sensitivity analyses:

> A comparison of input and output CVs for abundance indices. The base model configuration tended to produce larger output CVs than input CVs. **Results suggest that the CVs for all indices in the base model should be doubled.**

During the process of removing the RPW indices we will attempt to adjust the overall weights in the model to more accurately reflect the underlying uncertainty in each data source.

> A comparison of input and effective sample sizes for compositional data. These indicate that the input N may be overestimated for the cooperative and domestic longline survey age data, and underestimated for other compositional data.

As mentioned above, as we remove the RPW indices it will require us to consider the relative input Ns in the compositional sources. We will include plots/tables of effective N and deviation of the normalized residuals (*SDNR) in future assessments.*

3C.5 TOR 4: Areal apportionment (and whales)

Use of survey indices and fishery CPUE data. The apportionment scheme provides more weight to the longline survey data for regional abundance than to the fishery CPUE data. The Panel agrees that, given the data available, this is appropriate, even given factors such as trends in fishery interaction and whale depredation with the survey. Although the longline survey covers only part of the fishing season, whilst the fishery CPUE data arises from information over the full 8-month season, the survey has the advantage of using a standardized design over the full area. Variation between areas and times in the fishery CPUE data may not fully reflect the pattern of abundance of sablefish due to targeting and differences in fishing gears. **The Panel recommends the use of region-specific selectivity/availability estimates be explored as a possible modification to the apportionment scheme.** This may lead to better use of the fishery and survey data for apportionment. Projections taking such selectivity factors into account could be used to evaluate the performance of different apportionment strategies.

We have previously explored simple methods such as apportioning based on the amount of fish at 50% selection or 50% maturity. While such schemes are appealing we generally contend that within a reasonable range, the apportionment scheme is not crucial biologically. We believe that socioeconomic objectives need to be clarified before any new apportionment scheme is devised. We are also directed by the SSC and Council process to use the current scheme. Because of the socioeconomic objectives, we feel any changes must be endorsed by the SSC and Council unless the apportionment scheme becomes a biological concern.

Tagging model. The Panel noted that movement estimates using results from the updated tagging model should be used for evaluating the impact of different apportionment schemes.

Updated results from tagging data appear to show that movement patterns have changed. This data will be taken into consideration in the design of any new apportionment scheme.

Whale depredation. The various impacts of whale depredation were examined. This was identified as potentially affecting the abundance index and the regional apportionments. The removal of killer whale depredated sections of sets from the longline survey index does not appear to create a bias but is likely to add to the uncertainty (i.e., higher variance due to smaller sampling effort). Killer whale depredation appears to be relatively stable over time. **Despite these observations there may be merit in evaluating methods of "in-filling" the removed skates using a GLM or spatial modeling techniques, rather than just leaving them out.** Simply leaving out the skates will only be unbiased if they are a random selection of all skates in a stratum.

A study using data from 1998-2004 suggests that the impact of sperm whale interactions on catch rates is small (~2% for sets with observed depredation). However, there are concerns that the depredation extent is increasing in recent years (in particular, for 8 stations in the W and E Yakutat slope area). The depredation rate is similar to that observed in other fisheries in other parts of the world. Industry views were expressed that the depredation rate is higher than these estimates. Significant changes in the depredation rate will impact both the index of abundance and apportionment schemes. **The Panel supports the proposals to develop better ways to quantify impacts including acoustic techniques, hook monitoring, deterrents, set/skate classification (depredated or not), masking vessel noise, and innovative ways to compare between indices (e.g., parallel pot sets).**

Whale depredation is an issue for fishery CPUE data, as encounters typically lead to vessels leaving an area or in some areas changing to pot gear as they have in the Bering Sea. Quantifying the effect may however be difficult, because the recording of whale depredation incidences in logbooks is incomplete and may not provide a reliable indicator of the true incidence of depredation and its consequences for vessel activity.

We agree. Killer whale depredation, while steady over time, is variable among stations. Simply removing stations greatly increases variability depending on whether it was a high station or low station from the previous years. Sperm whale depredation effects are even more elusive, but certainly could bias the index if they are focused on certain high or low stations that were previously not depredated. We will investigate GLMs to standardize survey and fishery abundance indices and include killer and sperm whale interactions as variables in the model. This is a goal for the 2010 assessment cycle.

3C.6 TOR 5: Recommendations for further improvements

Age and length data. The Panel recommends that comparisons between the length frequency distribution of the age-samples with the overall length frequency be undertaken as an internal consistency check for sampling bias. Furthermore, it would be desirable to develop age-length keys (ALKs) and apply these to the observed length frequency distributions to compare the resulting raised age composition estimates with the randomly sampled age compositions.

We have done this informally in the past and it has yielded similar results for length frequencies of age samples and overall length frequencies. We will use the ALK diagnostic when we are examining a smooth growth regime transition or internally estimated growth.

Spatial structure. **An area-disaggregated assessment approach should ideally be developed and may lead to improved management advice**. Abundance trends and size/age composition vary by area, and spatially separable index and composition data and movement data from tagging are available. Such a model can also provide better insight on the impact of apportionment policies. Area disaggregation options include:

o Treating areas as separate fisheries, fitting area-specific selectivity.

o Modeling movement between areas using tagging information.

A spatially explicit model has its tradeoffs with parsimony. It is well known that spatially-explicit modeling is demanding in terms of the amount of data that needs to be collected. While we agree that the aggregated area model has its limitations in terms of biological realism, it may be more robust in terms of withstanding future changes in the environment or data collections. That being said, it is our goal to evaluate the potential and limits of the scale for which we have sufficient data to provide meaningful results.

Size selectivity. Selectivity is currently modeled by age separately by sex, and the difference in the fitted selectivity curves appear to be largely due to growth differences by sex. **The Panel recommends that size-based selectivity be implemented in future assessments, and that single combined-sex selectivity curves be tested for each fishery.** This will potentially reduce the number of selectivity parameters used by the model.

We have intended to evaluate size-based selectivity for some time. While we have currently been spending time working on sex disaggregating the model, we agree that size based selectivity might be a way to reduce parameters, which will be needed if moving to spatially explicit models.

Sensitivity analyses. **Sensitivity of estimated depletion and recommended ABC to important fixed parameters should be part of the assessment documentation**.

We intend to be more explicit as to the sensitivity of certain assumptions about key parameters such as natural mortality and catchability in future assessments.

Model building/specification. It would be useful to have a more formal examination of the basis for decision making when building towards the final model configuration and adding individual data sets. Also, the impact of “smoothing” factors (e.g., annual fishing mortality and recruitment) should be evaluated and avoided if unnecessary.

When recommending a new model configuration, we present the addition of each data source or change separately as a possible model. However, one of our goals is to track the progression of the model configurations over time in the assessment document. Current "smoothing" factors have a minimal effect on the model and aid in model convergence.

Growth parameter estimation. Growth parameters should be estimated within the assessment model so that the impact of size-based selectivity is properly accounted for. The sablefish growth parameters have high t_0 values that may be symptomatic of not accounting for selectivity when fitting growth models.

We agree it is worthwhile to attempt to estimate growth within the model, particularly while evaluating size-based selectivity. One disadvantage is that model input files become increasingly cumbersome as thousands of age-length-weight observations are input for every year.

Simulation testing. The current model should be validated by simulation testing using simulated data to ensure that biomass and recruitment trends are reasonably reproduced.

We have done some simulation testing of the model using a simpler operating model with results that support the results of the current model. We will attempt to formalize that work in the future.