3. Alaska Sablefish Assessment for 2008

by

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Executive Summary

Summary of major changes

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

Input data: Relative abundance and length data from the 2007 longline survey, relative abundance and length data from the 2006 longline and trawl fisheries, and age data from the 2006 longline survey and longline fishery were added to the assessment model. A NMFS Gulf of Alaska bottom trawl survey was conducted in 2007 and relative abundance and length data from it were added to the model. Older growth data (1981-1993) were updated, and new growth data were added (1996-2004) in the form of new age-length conversion matrices.

Model changes: Informative priors for catchability were added for all abundance indices.

Assessment results: The fishery abundance index was down 8% from 2005 to 2006 (the 2007 data are not available yet). The survey abundance index decreased 14% from 2006 to 2007 and follows a 13% increase from 2005 to 2006. Relative abundance in 2007 is 1% lower than 2000, and is now an all-time low for the domestic longline survey. Spawning biomass is projected to be similar from 2007 to 2008, and begin declining through 2012.

Projected 2008 spawning biomass is 37% of unfished biomass. Spawning biomass has increased from a low of 29% of unfished biomass during 2000-01 to a projected 37% in 2008. The 1997 year class has been an important contributor to the population but is now fully mature and comprises only 18% of 2008 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, but is only 75% mature and should also comprise 18% of spawning biomass in 2008.

Sablefish are managed under Tier 3 of NPFMC harvest rules. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 122,250 t (combined across the EBS, AI, and GOA), 0.093, and 0.111, respectively. Projected spawning biomass (combined areas) for 2008 is 111,607 t (91% 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 2008 catch (combined areas) of 18,030 t. The OFL fishing mortality rate is 0.101 which translates into a 2008 OFL (combined areas) of 21,310 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

We recommend a 2008 ABC of 18,030 t. The maximum permissible yield for 2008 from an adjusted $F_{40\%}$ strategy is 18,030 t. The maximum permissible yield for 2008 is a 10% decrease from the 2007 ABC of 20,100 t. Spawning biomass is projected to decline through 2012, and then is expected to increase assuming average recruitment is achieved. Because of the lack of strong year classes, the maximum permissible ABC is projected to be 16,476 t in 2009 and 15,881 in 2010 (using estimated catches, instead of maximum permissible, see Table 3.10).

In December 1999, the Council 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 2008 ABC and OFL.

Apportionments are based on survey and fishery information	**2007 ABC Percent**	**2007 Survey RPW**	**2006 Fishery RPW**	**2008 ABC Percent**	**2007 ABC**	**Authors 2008 ABC**	**Change**
Total					20,100	**18,030**	-10%
Bering Sea	15%	19%	14%	16%	2,980	**2,860**	-4%
Aleutians	14%	12%	15%	14%	2,810	**2,440**	-13%
Gulf of Alaska	71%	68%	70%	71%	14,310	**12,730**	-11%
Western	17%	13%	14%	15%	2,470	**1,890**	-24%
Central	43%	44%	41%	43%	6,190	**5,500**	-11%
W. Yakutat	15%	16%	15%	15%	2,100	**1,950**	-7%
E. Yakutat / Southeast	25%	28%	30%	27%	3,550	**3,390**	-5%

After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the ABC for West Yakutat is 2,120 t and for East Yakutat/Southeast is 3,220 t. This adjustment projected to 2009 is 1,940 t for W. Yakutat and 2,950 t for E. Yakutat.

Responses to SSC comments specific to the sablefish assessment

The December 2006 SSC minutes included the following comments:

"*In addition to the hypotheses listed on page 366 (BSAI SAFE) to explain reductions in growth, consider adding fishing effects on size at age*."

Sablefish have a long history of fishing mortality. Current analyses suggest growth has increased slightly during the period from which we have good age-length data (See Appendix C). Since fishery selectivity patterns usually negatively affect growth by selecting the fastest growing individuals, these growth changes are more likely due to environmental effects such as temperature and prey availability, sampling effects, or a change in migration patterns.

"*Incorporate new information on sablefish growth and maturity schedules when the analysis of these data is complete*."

New growth data were incorporated into the preferred model in this assessment (see Appendix C). Histological maturity work is still in progress and will be incorporated when it becomes available.

"*Include a second type of retrospective analysis where data are serially withheld from the preferred model*."

In this assessment we completed a five-year retrospective analysis on the preferred model. There appeared to be slippage in the biomass trajectories. This would appear to be partly due to a real retrospective trend, and partly due to actual decreases in estimated recruitments. This is presented in the ***Model Results*** section.

Responses to SSC comments in general.

"Phase-plane diagram. The SSC appreciates the addition of phase-plane diagrams to most stock assessments and reiterates interest in these diagrams for all stock assessments in which it is possible to do so using standardized axes (i.e., X axis of B/B_{target}; and Y axis of F_{catch}/F_{OFL}), formatted relative to harvest control rules. In addition, values from the most recent year should be provided annually by the assessment authors to the plan team. The plan teams are requested to provide a figure summarizing all stocks in the introduction section of the SAFE documents. This figure would show the most recent year's status for all stocks possible by plotting realized F relative to F_{OFL} versus biomass relative to target biomass. One point for each stock from the most recent year plotted relative to the harvest control rules would provide a snapshot of relative stock management performance for the group (see figure below as a potential example). One option could be to plot the last two years values as a line with an arrow head to show the change in each stock's performance from the prior year."

In this assessment we moved from the Goodman et al. (2002) style management path plot to one that incorporates the harvest control rules in Figure 3.17.

Plan team summaries

Area	Year	Biomass (4+)	OFL	ABC	TAC	Catch
GOA	2006	152,000	17,880	14,840	14,840	12,284
	2007	158,000	16,909	14,310	14,310	11,624
	2008	167,000	15,040	12,730		
	2009	164,000	12,924	11,633		
BS	2006	34,000	3,680	3,060	3,060	2,720
	2007	34,000	3,521	2,980	2,980	1,031
	2008	41,000	3,380	2,860		
	2009	40,000	2,908	2,613		
AI	2006	32,000	3,740	3,100	3,100	1,050
	2007	32,000	3,320	2,810	2,810	1,042
	2008	34,000	2,890	2,440		
	2009	33,000	2,513	2,230		

Year	2007				2008		2009	
Region	OFL	ABC	TAC	Catch	OFL	ABC	OFL	ABC
BS	3,520	2,980	2,980	2,720	3,380	2,860	2,908	2,613
AI	3,320	2,810	2,810	1,050	2,890	2,440	2,513	2,230
GOA	16,909	14,310	14,310	12,280	15,040	12,730	12,924	11,633
W	--	2,470	2,470	2,070	--	1,890	--	1,727
C	--	6,190	6,190	5,470	--	5,500	--	5,026
WYAK	--	2,280	2,280	1,650	--	1,950	--	1,782
SEO	--	3,370	3,370	3,090	--	3,390	--	3,098
Total	23,749	20,100	20,100	16,050	21,310	18,030	18,345	16,476

Introduction

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

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.

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

Japanese trawlers caught sablefish mostly as bycatch in fisheries targeting other species. Two trawl fisheries caught sablefish in the Bering Sea through 1972: the North Pacific trawl fishery which caught sablefish as bycatch 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 2007) was:

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Vessels	1,078	613	578	504	450	451	434	432	422	408	383	383	369

To calculate the total number of hooks deployed in the Federal fishery, we use observer catch and effort data and extrapolate it to the total catch in the fishery, including unobserved sets. Averages per year are presented for years 1990-1994 and 1995-2000. 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

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 common in the Alaska sablefish IFQ fishery (Sigler et al. 2007). Killer whale depredation commonly occurs in the Bering Sea, Aleutian Islands, and Western Gulf of Alaska. Sperm whale depredation is common in the Central and Eastern Gulf of Alaska. In October, 2006, fishermen and scientists from around the world, including sablefish fishermen and scientists from Alaska, participated in a depredation workshop focussed on mitigating the effects of depredation. Workshop abstracts and summaries are available at: http://depredation.org.

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. The Plan Teams recommended that the different selectivity of pots and longline gear should be explored because of the increased use of pots in the Bering Sea. 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 16,000 t in the late 1990's, and have been near 20,000 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 averaged 473 t and an average discard rate of 3.4% (of total catch) in all longline fisheries and 590 t and an average rate of 26% in trawl fisheries during 1994-1999. From 2000-2006 the discards were similar, averaging 601 t (3.1%) for all longline fisheries and 610 t (27%) in the trawl fisheries (Table 3.2). Sablefish discards vary between gear, target fishery, and areas. In the longline fishery for 2003-2006, discards averaged 295 t with an average rate of 2.3% in the sablefish fishery, 22 t (22%, BSAI) in the Greenland turbot fishery, and 32 t (59%, BSAI, WGOA, CGOA) in the Pacific cod fishery. Discards averaged 167 t (16%) in the rockfish trawl fisheries for 2003-2006, 56 t (65%) in the deepwater flatfish fishery in the Central Gulf of Alaska, and 127 t (45%) in the arrowtooth flounder fishery in the Bering Sea, and Western and Central Gulf of Alaska.

Previous management actions

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

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

Maximum retainable allowances: Maximum retainable allowances for sablefish were revised in the Gulf of Alaska by a regulatory amendment, effective 10 April 1997. The percentage depends on the basis species: 1% for pollock, Pacific cod, Atka mackerel, “other species”, and aggregated amount of non-groundfish species. Fisheries targeting deep flatfish, rex sole, flathead sole, shallow flatfish, Pacific ocean perch, shortraker and rougheye rockfish, other rockfish, northern rockfish, pelagic rockfish, demersal shelf rockfish in the Southeast Outside district, and thornyheads are allowed 7%. Arrowtooth flounder fisheries are not allowed to retain any sablefish.

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

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

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

Year	Catch(t)	ABC	TAC	Management measure
1980	10,444		18,000	Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish
1981	12,604		19,349	
1982	12,048		17,300	
1983	11,715		14,480	
1984	14,109		14,820	
1985	14,465		13,480	Ammendment 14 of the GOA FMP allocated sablefish quota by gear tyoe: 80% to fixed gear and 20% to trawl gear in WGOA and CGOA and 95% fixed to 5% trawl in the EGOA.
1986	28,892		21,450	Pots banned in Eastern GOA
1987	35,163		27,700	Pots banned in Central GOA
1988	38,406		36,400	
1989	34,829		32,200	Pots banned in Western GOA
1990	32,115		33,200	Ammendment 15 of the BSAI FMP allocated sablefish quota by gear tyoe: 50% to fixed gear in and 50% to trawl in the EBS, and 75% fixed to 25% trawl in the Aleutian Islands
1991	27,073		28,800	
1992	24,932		25,200	Pot fishing banned in Bering Sea (57 FR 37906)
1993	25,433		25,000	
1994	23,760		28,840	
1995	20,954		25,300	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	17,577		19,380	Pot fishing ban repealed in Bering Sea except from June 1-30
1997	14,922	19,600	17,200	Maximum retainable allowances for sablefish were revised in the Gulf of Alaska. The percentage depends on the basis species.
1998	14,108	16,800	16,800	
1999	13,575	15,900	15,900	
2000	15,919	17,300	17,300	
2001	14,097	16,900	16,900	
2002	14,789	17,300	17,300	
2003	16,432	18,400	20,900	
2004	17,782	23,000	23,000	
2005	16,537	21,000	21,000	
2006	15,527	21,000	21,000	

Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1960-2007
Japanese longline fishery	Catch-per-unit-effort (CPUE)	1964-1981
U.S. longline fishery	CPUE, length	1990-2006
	Age	1999-2006
U.S. trawl fisheries	Length	1990,1991,1999, 2005, 2006
Japan-U.S. cooperative longline survey	CPUE, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	CPUE, length	1990-2007
	Age	1996-2006
NMFS GOA trawl survey	Abundance index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007
	Lengths	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007

Fishery

Catch, effort, and length data are collected from sablefish fisheries. The catch data cover several decades. Length and effort data were collected from the Japanese and U.S. longline fisheries (Table 3.3). Length data were collected from the Japanese and U.S. trawl fisheries. The Japanese data were collected by fishermen trained by Japanese scientists (L-L. Low, Alaska Fisheries Science Center, 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, pers. commun., 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 was lower again, but had 721 lengths so we used the 2006 length compositions.

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 are 100% observed. 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 adjusted the captain's estimate of catch per set using the ratio of IFQ landing report and logbook reported weight. Hook spacing for both data sets was standardized to a 39 inch (1m) spacing following the method used for standardizing halibut catch rates (Skud and Hamley 1978; Sigler and Lunsford 2001). Each set's catch rate was calculated by dividing the catch in weight by the standardized number of hooks, then used to compute average catch rates by vessel and NPFMC region.

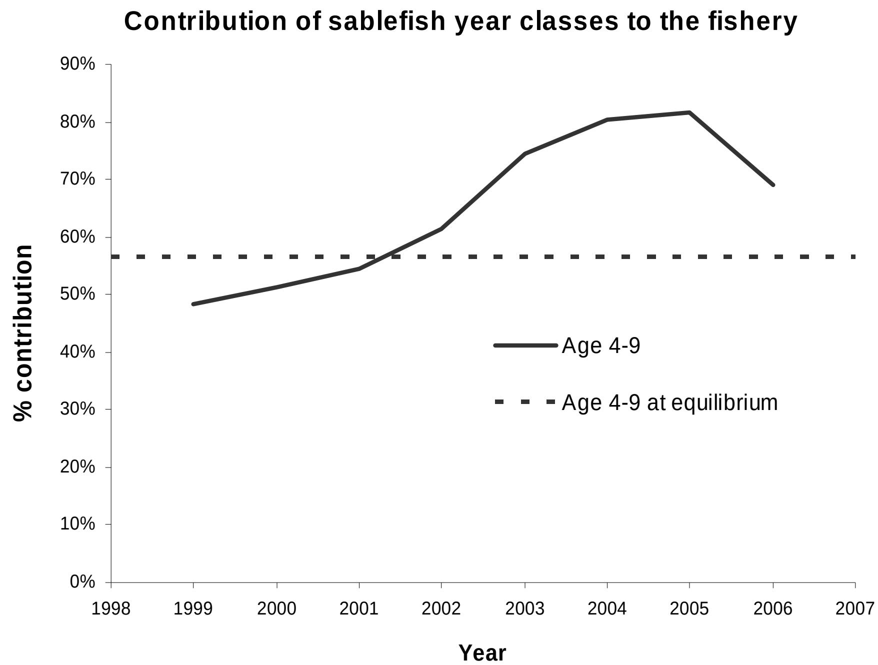
Extensive filtering of the logbook and observer data occurs before the catch information for a set is included in the analysis. The set was excluded whenever data were missing for a set and a catch rate could not be calculated or assigned to a season, area, or a year. All sets that experienced killer whale depredation were excluded in the observer fishery catch rate analysis since any depredation would bias CPUE downward. From 1990-2006 an average of 23% 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. Whale presence or depredation is not recorded in logbooks and therefore cannot be corrected for in the catch rate analyses. For logbooks, some sets have multiple gear configurations with more than one hook spacing. Calculating a catch rate is difficult because the number of sablefish caught on each configuration is unknown. Because catch rates cannot be effectively calculated, logbook sets with multiple configurations were excluded. A small number of sets were eliminated from the logbook data because skipper estimated trip weight was very different than the IFQ reported trip weight. Error in the captain's estimate of trip weight was analyzed in 2005 and we found that captains underestimated their true trip weight 63% of the time and this was most common on vessels over 100 feet. However, errors by individual captains were variable between trips, indicating no bias in catch estimation was occurring.

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 in 2006, 68 sets from 15 vessels were recorded. 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 nearly half of the catch in these areas and is not included in this analysis. Additionally, killer whales impact sablefish catch rates in these areas. In 2006, 38% of 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). 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. 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.

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 in 2006 in all areas except the Aleutian Islands. Year classes typically show up in the fishery beginning at age 4. The influence of the 1997 and 2000 year classes to the fishery are evident as catch rates generally increased during the years 2001-2005 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 2005. In 2006 the contribution of these cohorts to the fishery decreased to 69%. The



proportion of 4-9 year olds caught from 2001-2005 was much higher than would be expected if the population was at equilibrium (which it likely is not) indicating these year classes were being heavily fished during this time period. This may have depleted some of these year classes and may help explain why in 2006 catch rates decreased in most areas.

Longline spatial and temporal patterns: Changes in spatial or temporal patterns of the fishery may cause fishery catch rates to be unrepresentative of abundance. For example, fishermen sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). Overfishing of northern (Newfoundland) cod likely was made worse by an incorrect interpretation of fishery catch rates; assessment scientists did not realize that the area occupied by the stock was diminishing while the fishery catch rates remained level (Rose and Kulka 1999). We examined fishery longline data for seasonal and annual differences in effort and catch rate. We also examined longline data for spatial changes in fishing patterns from year to year and by season using mapping software. Such changes may cause fishery catch rates to be unrepresentative of abundance. In the longline data, seasonal changes in effort were minimal across years. The majority of effort occurs in the spring and less in the summer and fall. 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

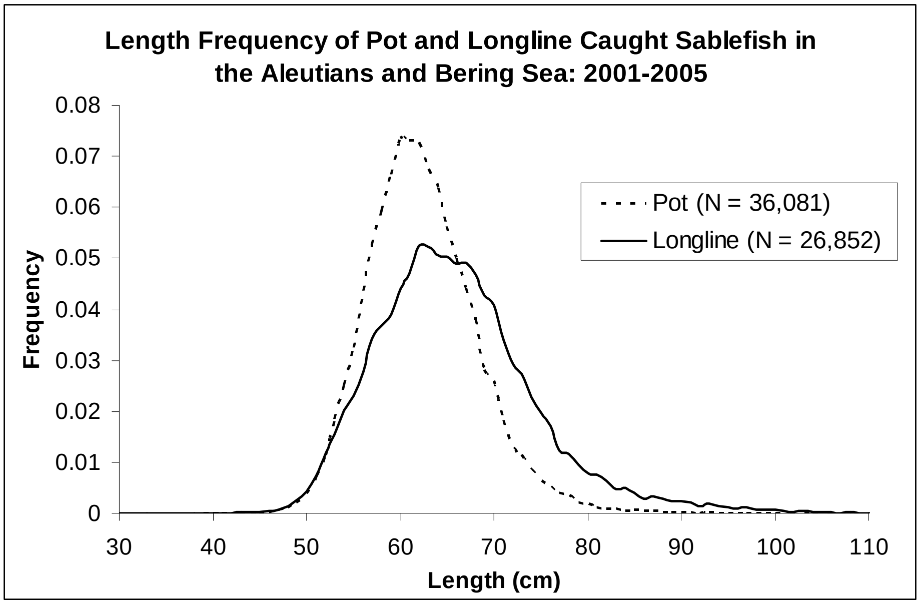
Pot sample sizes: Sablefish pot fishing has increased dramatically in the Aleutian Islands and the Bering Sea since 1999. Since 2004, pot gear has accounted for over half of the Bering Sea fixed gear IFQ catch and has averaged 34% of the catch in the Aleutian Islands. Fishery catch and effort data for pot gear are available from observer data from 1999-2006. However, due to confidentiality agreements, we cannot present these data. Pot fishery data are also available from logbooks from 2004-2006; however, these data are also sparse. The number of observed sets and the number of pots fished increased dramatically in 2005 and remained high in 2006. Even though the number of sets has been increasing, the number of vessels observed in recent years is still minimal. Over all years, the average number of pots used per set was 78.

Pot catch rates: Catch rate for pot gear is calculated as pounds per pot. There is more uncertainty in catch rates from 1999-2004 because there were few observed vessels during this period. From 2005-2006 the average catch rate was 25.3 lbs/pot. However, because there were few vessels observed in 2005 and 2006 there was high variability in the estimated catch rates. Because of the high variability, catch rates within areas were not significantly different in any years. For both the Bering Sea and Aleutian Islands, no trend in catch rates is discernable. The composition of species caught in pots in the Bering Sea and the Aleutian Islands was similar in 2005. Sablefish comprised most of the catch by weight (Bering Sea = 60%, Aleutian Islands = 69%) and the next most abundant fish by weight was arrowtooth flounder (Bering Sea = 13%, Aleutian Islands = 10%). Other species of fish and invertebrates contributed no more than 6% each to the total catch weight.

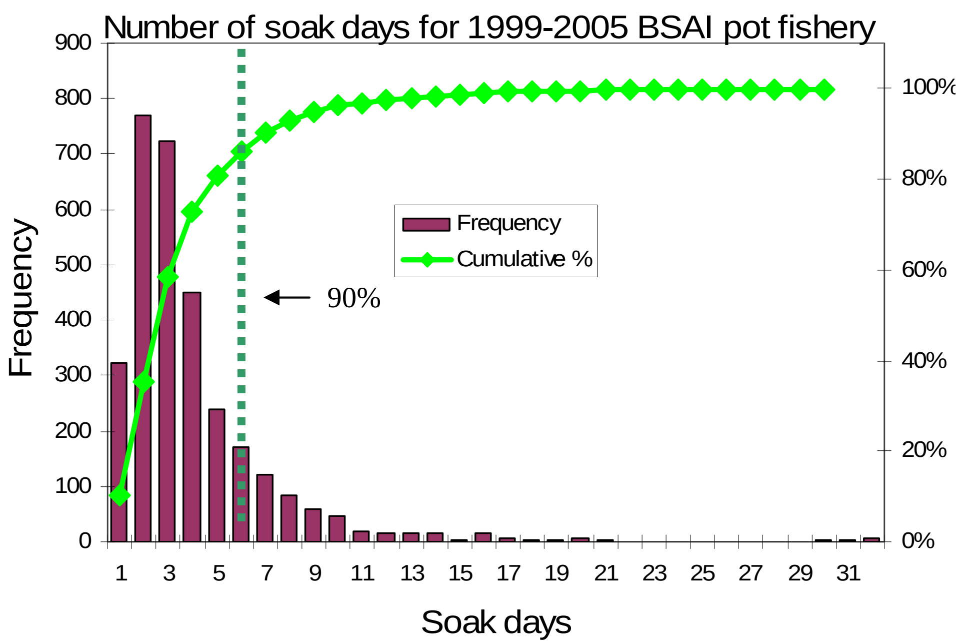
Pot spatial and temporal patterns: Seasonal changes in effort were examined closely, but no distinct trends were found. The patterns in seasonal effort were erratic and were largely driven by individual vessel fishing patterns because observed data are limited. It should be noted that sample sizes for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

In 2006 the Council requested additional information regarding pot fishing in the Bering Sea and Aleutian Islands in response to the dramatic increase in the pot fishery. In last year’s assessment we presented analyses which helped address the Council’s questions. In September 2007, a Council working group convened to discuss sablefish management issues and forwarded recommendations to the Council. Included here are the analyses presented in last year’s assessment.

Pot length frequencies: We compared the length frequencies recorded by observers from the 2001-2005 longline and pot fisheries. The average length of sablefish in the Aleutian Islands and in the Bering Sea was smaller for sablefish caught by pot gear (62.4 cm) than longline gear (66.0 cm), but the distributions indicate that both fisheries focus primarily on adults. In all years the difference between the two gear types was greatest in the Aleutian Islands. Pot and longline gear is set at similar depths in the Aleutians and Bering Sea and sex ratio of the catch is 1:1 in both gears. We do not believe that the difference in lengths is significant enough to affect population recruitment and did not see any indication that undersized fish were being selected by pots. In 2006, a special project was initiated through the observer program to examine the stomachs of sablefish caught in pot gear to determine if larger fish are cannibalizing on smaller fish while in the pots. Preliminary analysis of data collected in 2006 showed no evidence of cannibalism of juvenile sablefish in the pot fishery. Additional data have been collected in 2007, and a final report will be included in next year's 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:



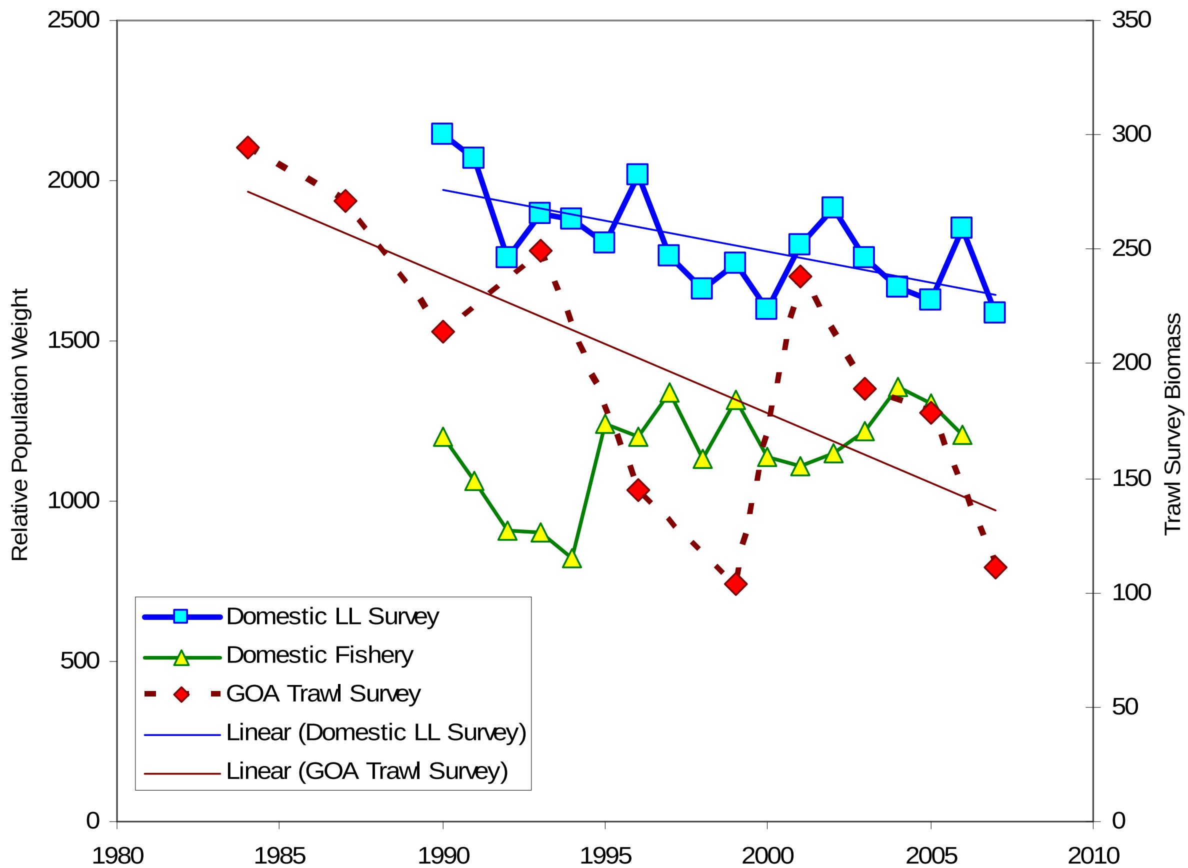
In an experiment examining escape mechanisms for Canadian sablefish, Scarsbrook et al. (1988) showed that in their control traps fish had only 5% mortality up to 10 days; in the current fishing environment, 90% of the pot sets were soaked for 7 days or fewer.

Potential issues with fishery catch-rate data

Fishery catch rate data are available from 1990-2006. Catchability was separately estimated for the "derby" (through 1994) and IFQ (1995 and later) fisheries. On average, fishery catchability is 1.8 times greater during the IFQ fishery, the same as estimated in an independent analysis of the effects of individual quotas on catching efficiency in the fishery (Sigler and Lunsford 2001). Like the selectivity effect, lower catching efficiency during the “derby” fishery likely occurred due to crowding of the fishing grounds, so that fishermen were pushed to fish areas where sablefish densities were less. Fishermen also fished the same area repeatedly, with associated decreases in catch rates due to “fishing down” the area.

Fishery catch rates often are biased estimates of relative abundance (e.g. Crecco and Overholtz 1990). We examined possible biases in US fishery catch rate data. When the fishery RPW data were first introduced in 1999, we tested the effect of including fishery catch rates in the assessment model. Both Japan and US fishery catch rate data are used in the assessment model; however, we only tested the effect of US fishery catch rate data because there was no alternative abundance index during most years of the Japanese longline fishery, unlike the US fishery which overlaps the same years as the longline surveys. Including US fishery catch rates had little effect on spawning biomass estimates in 1999, increasing spawning biomass estimates <1% for 1990-1999, the years of US fishery catch rate data in the model at that time. Since that time, the fishery RPW estimates have diverged from the survey RPW estimates and may now have an effect.

Catch rates from the IFQ fishery may be an inferior index of abundance to the previous derby fishery. From 1990-1994, the derby fishery CPUE and the domestic survey index were both declining (see following figure). The derby fishery turned into an IFQ fishery in 1995 and since then the fishery index remains stable while the surveys continue to decline. The IFQ fishery CPUE trend is indicative of hyperstability, where fishery catch rates do not decline while population abundance does because fishing effort shifts to areas of high density (Hilborn and Walters 1992). This occurs because as fishing vessels target concentrations of fish, they do not distribute randomly (Winters and Wheeler 1985, Salthaug and Aanes 2003). Another contributing factor can be increased catching efficiency due to technology and experience (e.g. Hutchings and Myers 1994). Hyperstability can cause misinterpretations of abundance trends leading to overfishing and stock collape such as with northern cod (e.g. Hutchings and Myers 1994). Harley et al. (2001) compiled the survey and fishery trends from 209 assessments and found that in 70% of the data sets CPUE remained high while abundance declined due to hyperstability. Some studies have suggested ignoring fishery indices altogether (e.g., Winters and Wheeler 1985), while others have focused on adjusting fishery catch rates for changes in spatial distribution, because as the population decreases the area fished also tends to decrease (e.g., Kulka et al. 1996, Salthaug and Aanes 2003, Walters 2003). We intend to revisit the usefulness of the IFQ fishery CPUE index for abundance estimation (not apportionment) since we have several continuing fishery independent surveys that cover some of the same areas.



Longline surveys

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

Length data were collected for all survey years and sablefish otoliths were collected for most survey years. Not all otoliths collections were aged until 1996, when we began aging samples in the year they were collected. Otolith collections were length-stratified from 1979-94 and random thereafter.

Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 3.4). Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

Killer whale depredation of the survey's sablefish catches has been a problem in the Bering Sea since the beginning of the survey (Sasaki, 1987). The problem occurred mainly east of 170^{o} W in the eastern Bering Sea and to a lesser extent in the northeast Aleutians between 170^{o} W and 175^{o} W. The 1983 (Sasaki 1984), 1986 and 1987 (T. Sasaki, 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). Portions of the gear affected by killer whale depredation during domestic longline surveys already are excluded from the analysis of the survey data.

Sperm whale depredation may affect longline catches in the Gulf of Alaska. Data on apparent sperm whale depredation have been collected since the 1998 longline survey (Table 3.6). Sperm whales have been observed on 16% of survey sampling days, and were most common in the central and eastern Gulf of Alaska (98% of sightings). Catches were commonly preyed upon when sperm whales were present (65% of sightings). Apparent sperm whale depredation is defined as sperm whales being present with the occurrence of damaged sablefish. In the 2002 SAFE, an analysis was done using longline survey data from 1998-2001 and found that sablefish catches were significantly less at stations affected by sperm depredation. This work was redone in 2006 using additional data from 2002-2004 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 ($p = 0.34$). 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, t-test, 95% CI of (0.4 – 5.5%), $p = 0.02$, 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. Current abundance is unbiased if depredation has consistently occurred over time. If significant depredation began recently, then current biomass is underestimated because the relationship between the survey index and biomass has changed. However, if we adjust recent catch rates for sperm whale depredation when in fact it has happened all along, then current biomass will be overestimated. We do not plan to adjust longline survey catch rates for sperm whale depredation. We will continue to monitor sperm whale depredation of survey catches for changes in the level of depredation.

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

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted biennially or triennially since 1980 in the Aleutians, and 1984 in the Gulf of Alaska, and biennially since 1999. Trawl surveys of the Eastern Bering Sea slope were conducted biennially from 1979-1991 and in 2002 and 2004. 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 would 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) and length data (<500 m depth) as an index for the whole population, since the largest proportion of the population is located there. Biomass estimates for 1984-2007 are shown in Table 3.4

Trawl survey catches are tabled in Appendix B.

Relative abundance trends – long-term

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 3.4, Figures 3.2 and 3.3). The post-1970 decrease likely is due to heavy fishing. The 1985 peak likely is due to the 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 1997) appear in the central and eastern areas at the earliest age (4), whereas the remaining above average year classes appear in these areas at later ages (6-9).

In the East Yakutat/Southeast area, sablefish abundance decreased for many years until 2002, when the fishery 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. Recent increases notwithstanding, 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

The fishery abundance index was down 8% from 2005 to 2006 (2007 data are not available yet). The survey abundance index decreased 14% from 2006 to 2007 and follows a 13% increase from 2005 to 2006 (Table 3.4). This year's decrease in the survey now marks an all-time low for the domestic longline survey. The GOA 2007 trawl survey estimate fell 38% from 2005 and is near the all time low in 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. 2005) with split sexes to attempt to more realistically represent the underlying population dynamics of sablefish. This model was accepted by the Groundfish Plan Team and NPFMC in 2006 (Hanselman et al. 2006). 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	$\bar{L}_a = 75.6(1-e^{-0.208(a+3.63)})$	$\bar{L}_a = 80.2(1-e^{-0.222(a+1.95)})$	Appendix C
Length-at-age - males	$\bar{L}_a = 65.3(1-e^{-0.227(a+4.09)})$	$\bar{L}_a = 67.8(1-e^{-0.290(a+2.27)})$	Appendix C
Weight-at-age - females	$\ln\hat{W}_a = \ln(5.47)+3.02\ln(1-e^{-0.238(a+1.39)})$		Appendix C
Weight-at-age - males	$\ln\hat{W}_a = \ln(3.16)+2.96\ln(1-e^{-0.356(a+1.13)})$		Appendix C
Age-age conversion	N/A	N/A	Heifetz et al. (1999)
Recruitment variability (σ_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 had been previously estimated to reach average maximum lengths and weights of 69 cm and 3.4 kg for males and 83 cm and 6.2 kg for females.

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. These new matrices provided for a superior fit to the data. For this and future assessments we recommend use of 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 September 2007 and is presented in its entirety in Appendix C.

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 $m_a = 1/(1+e^{-0.84(a-6.60)})$.We also conducted a preliminary analysis of visual scan maturity data from the domestic longline survey from 1998-2003. The maturity curve from Sasaki (1985) for females is similar to the new preliminary data, but both are significantly to the right of the sexes-averaged maturity curve used prior to the 2006 assessment (Figure 3.8). 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 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	75
Average fishing mortality	μ_f	2
Fishing mortality deviations	ϕ_y	96
Fishery selectivity	fs_a	14
Survey selectivity	ss_a	14
Total		211

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 Appendix D. Lognormal prior distributions were used with the parameters shown below:

Index	U.S. LL Survey	Jap. LL Survey	Fishery	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 1933-2007.

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 1960-2007 for each fishery.

Selectivity is represented using a function and is separately estimated by sex for the longline survey, fixed-gear fishery, trawl 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 allowed to be dome-shaped (right descending limb) by using the three-parameter exponential-logistic function (Thompson 1994). 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 sampler 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. Fishermen may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the 1985-1994 “derby” fishery, when fishermen reportedly often fished in less productive depths due to crowding. In choosing their ground, they presumably target bigger, older fish, 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 5 million Markov Chain Monte Carlo (MCMC) simulations drawn from the posterior distribution and thinned to 4,000 parameter “draws” to remove serial correlation between successive “draws” and a burn-in of 1 million draws was removed from the beginning of the chain. 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 recruitment of the 1977-2003 year classes, 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, $y=1, 2,\ldots T$
T	Terminal year of the model
A	Model age class, $a = a_0, a_0+1, \ldots, a_+$
a_0	Age at recruitment to the model
a_+	Plus-group age class (oldest age considered plus all older ages)
L	Length class
Ω	Number of length bins (for length composition data)
G	Gear-type (g = longline surveys, longline fisheries, or trawl fisheries)
X	Index for likelihood component
$w_{a,s}$	Average weight at age a and sex s
φ_a	Mature female population proportion at age
μ_r	Average log-recruitment
μ_f	Average log-fishing mortality
$\phi_{y,g}$	Annual fishing mortality deviation
τ_y	Annual recruitment deviation ~ (0, σ_r)
σ_r	Recruitment standard deviation
$N_{y,a,s}$	Numbers of fish at age a in year y of sex s
M	Natural mortality
$F_{y,a,g}$	Fishing mortality for year y and age class a and gear g ($= s_a^g \mu_f e^{\phi_y}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=\Sigma F_{y,a,g}+M$)
R_y	Recruitment in year y
B_y	Spawning biomass in year y
$s_{a,s}^g$	Selectivities at age a for gear type g and sex s
$A_{50\%}$,$d_{50\%}$	Age at 50% selection and age at 50% "deselection" for descending limb
δ, φ	Slope and shape parameters for different logistic curves
$\mathbf{A}$	Ageing-error matrix dimensioned $a_+ \times a_+$
$\mathbf{A}^l$	Age to length 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 of sex s
$P_{y,a,s}^g, \hat{P}_{y,a,s}^g$	Observed and predicted proportion at observed age a for gear g in year y of sex s
ψ_y^g	Sample size assumed for gear g in year y (for multinomial likelihood)
n_g	Number of years that age (or length) composition is available for gear g
$q_{\mu,g}, \sigma_{q,g}$	Prior mean, 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
$s_{a,s}^g=\left(1-\varphi_s^g\right)^{-1}\left(\frac{\left(1-\varphi_s^g\right)}{\varphi_s^g}\right)^{\varphi_s^g}\frac{\left(e^{(\delta_{g,s}\varphi_s^g(a_{50\%,g,s}-a))}\right)}{\left(1+e^{(\delta_{g,s}(a_{50\%,g,s}-a))}\right)}$	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
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\frac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}w_{a,s}$	Survey biomass index (RPW)
$\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\frac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}$	Survey biomass index (RPN)
$\hat{P}_{y,\cdot,s}^g=N_{y,a,s}s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s$	Vector of fishery or survey predicted proportions at age
$\hat{P}_{y,\cdot,s}^g=N_{y,\cdot,s}s_s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s^l$	Vector of fishery or survey predicted proportions at length

Posterior distribution components	Model Description (continued)
$L_C=\lambda_c\sum_1^g\sum_y\left(\ln C_{g,y}-\ln\hat{C}_{g,y}\right)^2/\left(2\sigma_C^2\right)$	Catch likelihood
$L_I=\lambda_I\sum_1^g\sum_y\left(\ln I_{g,y}-\ln\hat{I}_{g,y}\right)^2/\left(2\sigma_I^2\right)$	Survey biomass index likelihood
$L_{age}=\lambda_{age}\sum_{i=1}^{n_g}-\psi_y^g\sum_{a_0}^{a_+}\left(P_{i,a}^g+v\right)\ln\left(\hat{P}_{i,a}^g+v\right)$	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 2007, and two new models that add new growth data and priors on catchability. The use of these models was reviewed by the Plan Team in September 2007. To compare new models with the base model from last year's assessment (Model 1) we continue with identical assumed variances on data sets between models and only compare the fit to the data components, as opposed to the penalized objective function. Our criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, and (3) a good visual fit to length and age compositions. The basic features of the model runs presented in the document are described in the following table:

Model Number	**Model Description**
1 (Base case)	Model from Hanselman et al. 2006, the base split-sex model with older growth data
Model 2	Older growth data (1981-1993) were updated and fit to a growth curve. New growth data (1996-2004) fit to growth curve. Two new age-length conversion matrices applied.
Model 3	Model 2 plus informative priors on catchability coefficients

For conciseness, we only show the recommended Model 3 in most figures.

Both models 2 and 3 fit the data better as new data and features were added (Box 2) as judged by the smaller data component to the objective function (the objective function is the negative log-likelihood, thus lower is more likely, given the data). Some of the primary differences between Model 1 and Models 2 and 3 with the new growth data are the fits to several of the data components.

There is a tradeoff between the fits of Model 1 versus Models 2 and 3. Model 1 fits the domestic LL survey RPW better, while Models 2 and 3 fit length compositions better. An example is a reduction in the patterned residuals in fixed-gear fishery length compositions (Figure 3.9). Models 2 and 3 fit the domestic LL survey lengths slightly worse, while fitting the Japanese LL survey, Domestic LL fishery lengths, and trawl survey lengths **substantially** better (Figures 3.10-3.11). Although Models 2 and 3 fit the age compositions better in terms of the objective function, the visual fits are nearly identical (Figures 3.12-3.13). A brief evaluation of the unique features of the individual models that we explored follows:

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

Model Likelihood Components (Data)	CV/Sample Size (ψ)	Base model, from 2006 assess Model 1	New growth data Model 2	New growth and priors Model 3
Catch	CV = 3%	3	3	3
Domestic LL survey RPW	CV = 5%	32	44	43
Domestic LL survey RPN	CV = 5%	24	24	23
Japanese LL survey RPW	CV = 5%	28	33	33
Japanese LL survey RPN	CV = 5%	30	31	32
Domestic LL fishery RPW	CV = 5%	16	16	16
Japanese LL fishery RPW	CV = 5%	11	12	12
NMFS GOA trawl survey	CV = 8-15%	46	48	47
Domestic LL survey ages	ψ = 250	450	431	430
Domestic LL fishery ages	ψ = 50	43	39	39
Domestic LL survey lengths	ψ = 49	95	110	110
Japanese LL survey lengths	ψ = 49	124	79	80
NMFS trawl survey lengths	ψ = 35-65	236	93	94
Domestic LL fishery lengths	ψ = 49	99	72	73
Domestic trawl fishery lengths	ψ = 10	24	22	22
Sum of common *L*		1260	1057	1057
Total objective function value		1279	1075	1087
Key parameters				
Number of parameters		211	211	211
B_{2008} *(Female spawning biomass)*		122	107	112
$B_{40\%}$ *(Female spawning biomass)*		124	120	122
B_{1960} *(Female spawning biomass)*		139	148	156
$B_{0\%}$ *(Female spawning biomass)*		310	300	306
SPR% current		39%	36%	37%
$F_{40\%}$		0.092	0.093	0.093
$F_{40\% \text{ (adjusted)}}$		0.091	0.082	0.084
ABC		20.9	16.9	18.0
$q_{\text{Domestic LL survey}}$		6.63	7.4	7.2
$q_{\text{Japanese LL survey}}$		8.3	9.2	8.8
$q_{\text{DomesticLL fishery}}$		3.8	4.2	4.0
$q_{\text{Trawl Survey}}$		1.1	1.1	1.1
$a_{50\% \text{ (domestic LL survey)}}$		3.9	3.9	3.9
$a_{50\% \text{ (IFQ fishery)}}$		4.1	4.2	4.2
μ_r *(average recruitment)*		20.8	20.1	20.5

Model 1: This is the sex-specific version (Hanselman et al. 2006) of the general modeling framework that has been used with some modifications since Sigler (1999). In contrast to assessments prior to 2006, we use separate maturity-at-age and weight-at-age for males and females. Selectivity is estimated by sex. Recruitment is expected to be equal for the two sexes at the age of recruitment, but then their subsequent numbers at age will differ as different fishing mortality and selectivity are applied to each sex. Growth is only modeled in one time period with partial data from 1981-1993.

Model 2: Growth parameters for Alaskan sablefish have not been updated for stock assessment purposes since Sigler (1994). Meanwhile, many more sablefish have been aged with better geographic coverage. In Appendix B, we updated and corrected for bias in the older length-stratified data (1981-1993), analyzed newer randomly collected samples (1996-2004), and estimated new length-at-age and weight-at-age parameters. After updating and correcting the older data (1981-1993), all data showed that sablefish were not growing as large as previously assumed in the model. However, our analyses showed that both male and female sablefish growth have changed significantly between the two time periods. Recently, sablefish are growing to a moderately larger maximum size. These data are applied to the stock assessment in two growth periods through corresponding age-length conversion matrices. This model fits much better than Model 1 overall. Generally, parameter estimates were similar to Model 1, with the exception that the catchability coefficients were about 10% higher, average recruitment and spawning biomass were slightly lower.

Model 3: Model 3 is identical to Model 2, except that we added informative prior distributions on the catchability coefficients for each abundance index. In Appendix C, we used NMFS trawl survey biomass estimates to estimate longline survey and fishery catchability and to estimate the relative catchability of the GOA trawl survey (<500 meters in depth) to total trawl estimated biomass. These values were then translated into Model 3 as prior distributions for estimating catchability of each abundance index. The results of Model 3 are very similar to Model 2 in terms of fit to the data. The objective function value is slightly higher, mainly due to the addition of the prior distributions. The overall effect on the model was a moderating of the rise in catchability coefficients from Model 1 and a resultant slight increase in spawning biomass and recruitment. Selectivities were biologically reasonable given our assumptions about each index and the data available (Figure 3.16).

Model 3 fits all abundance trends well (Figure 3.2). One exception is the fit to the domestic LL survey RPW which has a period of positive residuals during 1995-2003 that the model is not fitting well. The predicted domestic LL survey RPN index over the same time period is much closer to the observed values. Both fishery CPUE indices fit well, particularly the Japanese CPUE index which has no conflicting data sources to influence the predictions. The predicted trawl survey index matches closely to most points except for the all-time low in 1999, where the prediction falls outside of the 95% confidence interval. Model 3 produces similar estimates of recruitment to Model 1, and seems to estimate more distinct year classes than model 1 such as years 1988-92 (Figure 3.15a), where Model 1 recruitment estimates appear to be smeared by the old age-length conversion matrix.

Summary: We recommend Model 3 for setting ABC and OFL for 2008. It provides a significantly better fit to the data than the base model. The major overall improvement of the fit to length and age data in models 2 and 3 confirms that the former growth information used was unable to describe all of the historical and current data. The addition of informative priors is a useful step that allows the application of data that is not inherent to the data used in the model, and preserves the relative linkages between abundance indices. Although the prior distributions are univariate with no correlation structure, even if the catchabilities move in opposite directions, this movement will be lessened than if non-informative priors were used (Model 2). While it does not particularly affect the overall fit of the model, it performs as a stabilizer to the model, so that catchability does not move extremely from assessment to assessment.

The net effect of overestimating all growth in previous models was to overestimate biomass, and recommend harvest rates that may have been above our desired target levels. If catches are maintained at the $F_{40\%}$ level for a long period, we would expect that, on average, spawning stock biomass would fluctuate around $B_{40\%}$, yet abundance has failed to exceed $B_{40\%}$ for some time despite the occurrence of two strong year classes. If we have moved closer to estimating the true sablefish growth, and are more realistically describing the population by modeling males and females separately, this should result in more conservative management in the short term, but more catch stability in the future.

This assessment year we were confronted with data that were unusual because multiple data sources were all telling the same general story. Both surveys' indices were down substantially. The fishery CPUE index was not down as much, but was down in the areas with the densest sablefish population. New age compositions from both the fishery and survey continue to show the same two year classes (1997 and 2000) that have comprised much of the recent catch, with no new year classes of any significance on the horizon.

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 2 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 3.14) 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 3.15); spawning abundance peaked again in 1987. The population then decreased because these strong year classes dissipated. Models 2 and 3 estimate that spawning biomass decreased in the 1990's more than the previous base model estimated. Conversely, both models did not estimate the peak of spawning biomass in 1987 as high as the previous base model. All models show an increasing trend in spawning biomass since the all-time low in 2000, but are exhibiting a steady decrease in total biomass since 2003 (Figure 3.14).

Projected 2008 spawning biomass is 37% of unfished biomass. Spawning biomass has increased from a low of 29% of unfished biomass during 2000-01. The dominant 1997 year class is beginning to be reduced but is fully mature and comprises 18% of 2008 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, but is only 75% mature and should also comprise 18% of spawning biomass in 2008.

Recruitment trends

Annual estimated recruitment varies widely (Figure 3.15b). 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 and 2007 trawl survey (Figure 3.10). The 2001 year class appeared to be an above-average year class in the Aleutian Islands/Western Gulf in the 2005 longline survey age compositions. However, the 2001 year class appeared moderate in the Central Gulf in the 2006 survey age composition (Figure 3.7) and is still low in the overall age compositions (Figure 3.12). The 2002 year class appears weak in the 2005 and 2006 longline survey age composition. However, several more years of data are needed to assess the strength of such a recent year class.

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. For 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 shows that the last five year classes (2001-2005) were either average or weak.

Model 3

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

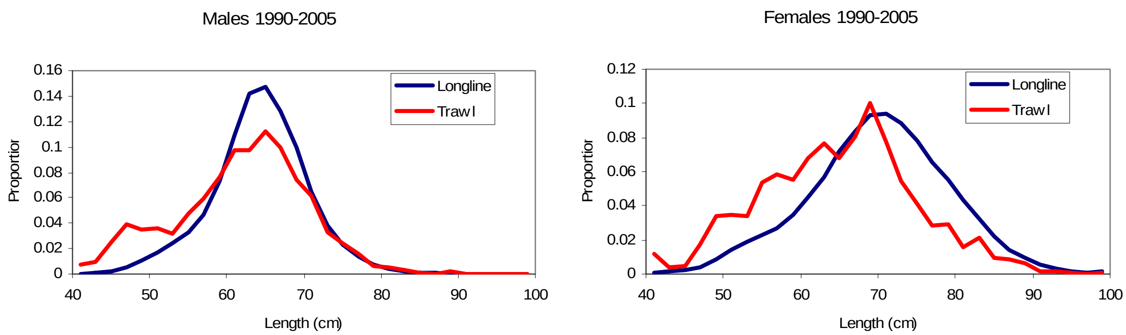
Average recruitment for the 1977-2003 year classes is 20.5 million 2-year old sablefish per year which is similar to the average recruitment for the 1958-2003 year classes. Estimates of recruitment strength during the 1960's are uncertain because they depend on less data and because the abundance index is 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 3.15), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success also is related to recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1961 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). 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

The age of 50% selection is 3.9 years for females in the longline survey and 4.2 years for the IFQ longline fishery in Model 3 (Box 2). The fishery selectivity for the derby fishery is very steep compared to the IFQ selectivity (Figure 3.16a). Selectivity is asymptotic for the longline survey and fisheries and dome-shaped (or descending right limb) for the trawl survey and trawl fishery (Figure 3.16a, b). Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishermen were pushed to fish shallower water that young fish inhabit (Sigler and Lunsford 2001). 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 (Figure 3.16a) is somewhat erratic in shape, but the trawl fishery length data are very sparse and do not form a pattern from year to year, making trawl selectivity difficult to estimate. The trawl survey selectivity (Figure 3.17a) has a reasonably smooth descending shape that probably describes trawl selectivity to 500 m in the Gulf of Alaska (Figure 3.16b)



Fishing mortality and management path

Fishing mortality was estimated to be high in the 1970s (Figure 3.17) 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 3.18 suggests that management has generally constrained fishing mortality below the limit rate, but has not been able to keep the stock above the $B_{40\%}$ target recently.

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 about twice the standard deviation. $F_{40\%}$ was estimated lower by the maximum likelihood and shows some skewness because of 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
$q_{domesticLL}$	7.16	7.13	7.13	0.13	0.25	6.66	7.63
q_{coopLL}	8.77	8.69	8.69	0.12	0.27	8.15	9.23
q_{trawl}	1.05	1.05	1.05	0.02	0.04	0.98	1.12
$F_{40\%}$	0.093	0.103	0.099	0.023	0.029	0.059	0.170
Ending Female SSB (kt)	112.3	112.9	112.8	4.1	4.9	103.4	123.0
2000 Year Class (millions)	38.0	38.6	38.5	5.0	4.9	28.9	48.1

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, total biomass and the six catchability parameters for five years (2003-2007). 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 five years, there has been a downward drift in recent spawning biomass estimates for the current time period (Figure 3.19). 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 3.19). This reversal is unlikely a model bias, but a reflection of new data influencing the current estimates of stock size.

These types of trends in stock status can be caused by changes in parameters that are normally considered to be invariants. One such parameter is catchability. Over the five year period, all six catchability parameters show an upward drift as data are added (Figure 3.20). This is likely a result of, not a cause of the downward bias in spawning biomass.

Revealing retrospective trends can show potential biases in the model, but may not provide insight to what those biases are or what there source is. Consistent patterns in retrospective analysis may indicate structural problems with the model. Since each retrospective pattern is unique, it is difficult to ascertain the source of the pattern. We will attempt to further 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	306
Reference point spawning biomass, $B_{40\%}$	122
Reference point spawning biomass, $B_{35\%}$	107
Spawning biomass	112
Total (age-4+) biomass	268
Maximum permissible fishing level	
$F_{40\%}$	0.093
$F_{40\%}$ adjusted	0.084
$F_{40\%}$ adjusted Yield	18.0
Overfishing level	
$F_{35\%}$	0.111
$F_{35\%}$ adjusted	0.101
$F_{35\%}$ adjusted Yield	21.3
Authors' recommendation	
F	0.084
ABC	18.0

We recommend an ABC of 18,030 t for 2008, which is a 10% decrease from 2007. This decrease is supported by an all-time low in the domestic longline survey RPW and near an all-time low in the trawl survey index. Spawning biomass is projected to decline through 2012, and then is expected to increase assuming average recruitment is achieved. With these declines and no promising year classes yet appearing in the surveys or fishery, ABC may decline further for the next several years.

Reference fishing mortality rates

Reference point values, $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and adjusted $F_{40\%}$ and $F_{35\%}$ based on projected 2008 spawning biomass, are shown in the summary table above. Reference biomass values were computed using the average recruitment from the 1977-2003 year classes. Projected 2008 spawning biomass is 37% of unfished spawning biomass and 92% of $B_{40\%}$. A downward adjustment to the reference fishing mortality rates is required to set the maximum Acceptable Biological Catch under Tier 3b. Recent reference point values for fishing mortality are less than assessments prior to 2006. For example, $F_{40\%}$ is 0.093 for the 2007 assessment, but was 0.112 in the 2005 assessment.

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

Population projections

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

For each scenario, the projections begin with the vector of 2007 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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 2007 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 2008, 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 2007 to the ABC recommended in the assessment for 2007. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2008 and 2009 to determine the catch for 2008 and 2009, then maximum permissible thereafter. This was suggested to help produce more accurate projections for fisheries that do not utilize all of the TAC.
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2008 and 2009, 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 2020 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 2008 and 2009. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2008 and 2009 to determine the catch for 2008 and 2009, then set catch at maximum permissible thereafter.

Spawning biomass currently is at 37% of the unfished level, and is projected to decline through 2012. Abundance is projected to decline because year classes following the strong 1997 and 2000 year classes are estimated to be 60% below average. In addition, recent fishing pressure has focused on young fish. Because of the lack of strong year classes, the maximum permissible ABC is projected to be 16,683 t in 2009 and 16,032 t in 2010 (using estimated catches instead of maximum permissible, see Table 3.10).

Status determination

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

Bayesian analysis

The estimates of ending spawning biomass are well-defined by the available data. Most of the probability lies between 106,000 and 120,000 t (Figure 3.21). 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 3.22). The plots indicate that the parameters are reasonably well defined by the data. As expected, survey catchability and ending spawning biomass are confounded as are $B_{40\%}$ and ending spawning biomass.

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 ending spawning biomass was below $B_{35\%}$ was 0.30 (Figure 3.23a). During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of falling below $B_{35\%}$ is 0.60, and the probability of staying below $B_{40\%}$ is 0.40 (Figure 3.23b).

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 5,000,000 MCMC (burnt-in and thinned) using the standard Tier 3 harvest rules. The projection shows wide credible intervals on future spawning biomass (Figure 3.24). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1977-2003 year classes, and this projection predicts that the median spawning biomass will dip below $B_{35\%}$ by 2010, then return to $B_{40\%}$ if average recruitment is attained.

Acceptable biological catch

We recommend a 2008 ABC of 18,030 t. The maximum permissible yield for 2008 from an adjusted $F_{40\%}$ strategy is 18,030 t. The maximum permissible yield for 2008 is a 10% decrease from the 2007 ABC of 20,100 t. Spawning biomass is projected to decline through 2012, and then is expected to increase assuming average recruitment is achieved.

Spawning biomass currently is at 37% of the unfished level, and is projected to decline through 2012. Abundance is projected to decline because year classes following the strong 1997 and 2000 year classes are estimated to be 60% below average. In addition, recent fishing pressure has focused on young fish. Because of the lack of strong year classes, the maximum permissible ABC is projected to be 16,683 t in 2009 and 16,032 t in 2010 (using estimated catches, instead of maximum permissible, see Table 3.10). The following table shows the maximum permissible ABC, and ABCs recommended by the stock assessment authors, Plan Teams, SSC, and NPFMC, by fishing year 1997-2007.

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

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 RPW's. Exponential weighting is implied under certain conditions by the Kalman filter. The exponential factor is the measurement error variance divided by the prediction error variance (Meinhold and Singpurwalla 1983). Prediction error variance depends on the variances of the previous year’s estimate, the process error, and the measurement error. When the ratio of measurement error variance to process error variance is r, the exponential factor is equal to $1-2/(\sqrt{4r+1}+1)$ (Thompson 2004). For sablefish we do not estimate these values, but instead 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 2008 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	**2007 ABC Percent**	**2007 Survey RPW**	**2006 Fishery RPW**	**2008 ABC Percent**	**2007 ABC**	**Authors 2008 ABC**	**Change**
Total					20,100	**18,030**	-10%
Bering Sea	15%	19%	14%	16%	2,980	**2,860**	-4%
Aleutians	14%	12%	15%	14%	2,810	**2,440**	-13%
Gulf of Alaska	71%	68%	70%	71%	14,310	**12,730**	-11%
Western	17%	13%	14%	15%	2,470	**1,890**	-24%
Central	43%	44%	41%	43%	6,190	**5,500**	-11%
W. Yakutat	15%	16%	15%	15%	2,100	**1,950**	-7%
E. Yakutat / Southeast	25%	28%	30%	27%	3,550	**3,390**	-5%

After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the ABC for West Yakutat is 2,120 t and for East Yakutat/Southeast is 3,220 t. This adjustment projected to 2009 is 1,940 t for W. Yakutat and 2,950 t for E. Yakutat.

This year's apportionment reflects a large overall decrease in the longline survey index across all regions in Alaska, except for a small increase in the Bering Sea. The Western Gulf of Alaska showed large decreases in survey and fishery RPWs. The only area to have increases in fishery RPWs was the Aleutian Islands (Figure 3.25a). The standard weighted average approach described above, which includes values from 2003-2007 for survey RPWs and 2002-2006 for fishery RPWs, greatly alleviates the effect of an individual year's change in RPW (Figure 3.25b). Changes in ABC by area for this year are mostly in line with the overall decrease in ABC with the exception of the Western Gulf of Alaska. The current apportionment is characteristic of most prior years except for 2005 (Figure 3.25c).

Alternative apportionment

Stakeholders recently testified at the SSC and requested that the authors evaluate a change in the current apportionment scheme of weighting the survey data twice that of the fishery data. Recent improvements in sample size of observer and logbook collections have reduced the variance on the fishery sources. Because the variance is now similar to survey estimates, it does not necessarily mean that the fishery data should be weighed as heavily as the survey data. Generally, a fishery dependent index is not as meaningful in terms of tracking abundance as a fishery independent index. Fishery data are comprised of Observer collected data and logbook data. There is approximately three times the amount of logbook data, but this information is dependent on "soft money" funding and is not guaranteed to extend into the future. Relying on Observer data alone will change the overall sample sizes and associated variances. In the last two years, placing even weight on survey and fishery data would have made little consistent difference (Figure 3.26), but in previous years it may have made fairly large differences in some areas. However, the authors neither endorse nor refute any alternative apportionment scheme that does not become widely disproportionate to perceived abundance. If this scenario is preferred, the alternatively apportioned ABCs and OFLs are shown below.

Alternative apportionment scheme using "even-weighting."

Year	2007				2008		2009	
Region	OFL	ABC	TAC	Catch	OFL	ABC	OFL	ABC
BS	3,520	2,980	2,980	2,720	3,652	3,090	3,144	2,823
AI	3,320	2,810	2,810	1,050	2,897	2,451	2,494	2,240
GOA	16,909	14,310	14,310	12,280	14,761	12,489	12,708	11,413
W	--	2,470	2,470	2,070	--	1,869	--	1,869
C	--	6,190	6,190	5,470	--	5,295	--	4,838
WYAK	--	2,280	2,280	1,650	--	1,995	--	1,823
SEO	--	3,370	3,370	3,090	--	3,330	--	3,043
Total	23,749	20,100	20,100	16,050	21,310	18,030	18,345	16,476

Overfishing level (OFL)

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b results in a value of 21,310 t for the combined stock. The OFL is apportioned by region, Bering Sea (3,380 t), Aleutian Islands (2,890 t), and Gulf of Alaska (15,040 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 3.27). 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. Sufficient sampling of potential predators, 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. 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 sablefish predators are adult coho and chinook salmon, which prey on young-of-the-year sablefish during their pelagic stage. Sablefish were the fourth most commonly reported prey species in the salmon troll logbook program from 1977 to 1984 (Wing 1985), however the effect of salmon predation on sablefish survival is unknown. The only other fish species reported to prey on sablefish in the Gulf of Alaska is Pacific halibut; however, sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999). Juvenile sablefish may not be a prominent prey item because of their relatively low and sporadic abundance compared to other prey items.

Another predator of sablefish in Alaska is the sperm whale. 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.

Fishery effects on the ecosystem

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

The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of sablefish is minimal or temporary in the current fishery management regime based on the criteria that sablefish are currently above Minimum Stock Size Threshold (MSST), however caution is warranted 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."* Sablefish are substantially dependent on benthic prey (18% of diet by weight) which may be adversely affected by fishing. Little is known about sablefish spawning habitat and effects of fishing on that habitat as well as habitat requirements for growth to maturity are better understood, but are not complete. Although sablefish do not appear substantially dependent on physical structure, living structure and coral are reduced in much of the area where sablefish reside. Effects of fishing other than slope habitat destruction may reduce juvenile survivorship, such as fishing on the continental shelf and juvenile sablefish bycatch in other fisheries. These issues are a concern in areas of the Bering Sea and Gulf of Alaska where juvenile sablefish are concentrated and bottom trawl fishing intensity is high.

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

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

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

Biota	2003	2004	2005	2006	Average	Average Catch (t)
Birds	17.36%	10.69%	9.97%	20.15%	14.54%	0.13
Brittle Stars	0.60%	0.03%	0.70%	0.15%	0.37%	0.12
Corals	0.88%	1.73%	1.12%	2.98%	1.68%	0.69
Eelpouts	0.67%	1.09%	1.53%	2.14%	1.36%	1.11
Grenadier	65.01%	62.84%	66.79%	83.26%	69.47%	1,563.60
Sculpin	0.02%	0.05%	0.27%	0.08%	0.10%	5.34
Octopus	1.86%	0.04%	0.11%	0.14%	0.54%	2.0848
Anemone	0.16%	0.16%	0.09%	0.25%	0.17%	0.19
Sea Star	0.02%	0.06%	0.03%	0.15%	0.06%	1.87
Shark	4.96%	14.42%	24.27%	8.96%	13.15%	140.49
Sleeper	5.65%	1.37%	3.02%	4.22%	3.56%	17.42
Salmon	0.03%	0.85%	0.00%	0.00%	0.22%	0.09
Dogfish	7.21%	69.78%	72.90%	16.73%	41.65%	119.79
Skate	0.92%	0.26%	0.48%	0.89%	0.64%	120.57
Big	0.00%	0.04%	0.45%	0.71%	0.30%	2.80
Longnose	26.52%	1.00%	3.45%	3.87%	8.71%	13.36
Other	0.86%	0.26%	0.36%	0.84%	0.58%	104.42
Snails	1.47%	0.88%	3.48%	4.48%	2.58%	3.92
Sponge	0.15%	0.35%	0.39%	0.36%	0.31%	0.54

Data gaps and research priorities

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

Future sablefish research is going to focus on several directions:

1) Explore the utility of using environmental satellite information in determining recruitment estimates for sablefish.

2) Consider different ways to estimate selectivity, including varying selectivity over time.

3) Examine the effects of using relative population numbers and relative population weights in the model and the potential confounding effects of changes in growth on the way RPWs are calculated.
4) The sablefish migration model (Heifetz and Fujioka 1991) has been translated into an AD Model Builder program. We are now looking forward to assembling the entire data set which has expanded in size considerably since the 1991 analysis. Once we have revisited and updated these migration rates, we will evaluate the appropriateness of the current apportionment scheme.
5) Continue to monitor increased catch by pot gear in the Bering Sea and Aleutian Islands and compare selectivity differences in gear types and spatial differences in fishing locations.
6) Improve knowledge of sperm whale depredation during the longline survey and its effect on survey catch rates.
7) A sablefish maturity study has been initiated and will provide updated maturity estimates from visual and histological methods.
8) Initiate studies that will explore the comparability and standardization of auto-bait gear and hand-bait gear on the longline survey vessels.
9) Evaluate appropriateness of current variance assumptions about data components, including those used in the apportionment scheme.

Summary

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

Age at 50% selection for survey	3.9
Age at 50% selection for IFQ fishery	4.2
Natural mortality (M)	0.10
Tier	3b
Equilibrium unfished spawning biomass	306
Reference point spawning biomass, $B_{40\%}$	122
Reference point spawning biomass, $B_{35\%}$	107
Spawning biomass	112
Total (age-4+) biomass	268
Maximum permissible fishing level	
$F_{40\%}$	0.093
$F_{40\%}$ adjusted	0.084
$F_{40\%}$ adjusted Yield	18.0
Overfishing level	
$F_{35\%}$	0.111
$F_{35\%}$ adjusted	0.101
$F_{35\%}$ adjusted Yield	21.3
Authors' recommendation	
F	0.084
ABC	18.0

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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/ Soeast.	Un- known	Fixed	Trawl
1956	773	0	0	0	0	773			0	773	0
1957	2,059	0	0	0	0	2,059			0	2,059	0
1958	477	6	0	0	0	471			0	477	0
1959	910	289	0	0	0	621			0	910	0
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,433	668	2,080	739	11,971	9,975	4,619	5,356	0	22,912	2,521
1994	23,760	694	1,726	555	9,495	11,290	4,497	6,793	0	20,797	2,963
1995	20,954	990	1,333	1,747	7,673	9,211	3,866	5,345	0	18,342	2,612
1996	17,577	697	905	1,648	6,772	7,555	2,899	4,656	0	15,390	2,187
1997	14,922	728	929	1,374	6,237	5,653	1,928	3,725	0	13,287	1,635
1998	14,108	614	734	1,435	5,877	5,448	1,969	3,479	0	12,644	1,464
1999	13,575	677	671	1,487	5,873	4,867	1,709	3,158	0	11,590	1,985
2000	15,919	828	1,314	1,587	6,172	6,018	2,066	3,952	0	13,906	2,013
2001	14,097	878	1,092	1,589	5,518	5,020	1,737	3,283	0	10,863	1,783
2002	14,789	1,166	1,139	1,863	6,180	4,441	1,550	2,891	0	10,852	2,261
2003	16,432	1,006	1,081	2,110	7,090	5,145	1,822	3,323	0	14,370	2,062
2004	17,782	1,179	974	2,168	7,428	6,033	2,243	3,790	0	16,137	1,645
2005	16,537	1,064	1,147	1,923	6,688	5,385	1,823	3,562	0	14,981	1,556
2006	15,527	1,053	1,130	2,139	6,034	5,170	1,878	3,292	0	14,288	1,239

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	316	42	761	1,119
2004	384	32	543	959
2005	601	115	738	1,453
2006	456	60	614	1,130
Bering Sea				
1991-1999	5	189	539	733
2000	53	290	471	814
2001	131	357	419	907
2002	546	304	471	1,321
2003	354	231	413	999
2004	434	293	311	1,038
2005	582	273	218	1,073
2006	604	83	366	1,053

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

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

Table 3.2 cont.

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

Table 3.2 cont.

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

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

	LENGTH							AGE		
	U.S. NMFS trawl survey (GOA)	Japanese fishery		U.S. fishery		Cooperative longline survey	Domestic longline survey	Cooperative longline survey	Domestic longline survey	U.S. longline fishery
Year		Trawl	Longline	Trawl	Longline					
1963			30,562							
1964		3,337	11,377							
1965		6,267	9,631							
1966		27,459	13,802							
1967		31,868	12,700							
1968		17,727								
1969		3,843								
1970		3,456								
1971		5,848	19,653							
1972		1,560	8,217							
1973		1,678	16,332							
1974			3,330							
1975										
1976			7,704							
1977			1,079							
1978			9,985							
1979			1,292			19,349				
1980			1,944			40,949				
1981						34,699		1,146		
1982						65,092				
1983						66,517		889		
1984	16,222					100,029				
1985						125,129		1,294		
1986						128,718				
1987	13,032					102,639		1,057		
1988						114,239				
1989						115,067		655		
1990	4,124			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	7,121			468	23,884	80,596	94,699	1,178		
1994				89	13,614	74,153	70,431			
1995				87	18,174		80,826			
1996	4,650			239	15,213		72,247		1,175	
1997				0	20,311		82,783		1,211	
1998				35	8,900		57,773		1,183	
1999	5,588			1,268	26,662		79,451		1,188	1,145
2000				472	29,240		62,513		1,236	1,152
2001	* partial			473	30,362		83,726		1,214	1,023
2002				526	35,380		75,937		1,136	1,061
2003	5,680			503	37,386		77,678		1,198	1,128
2004				694	31,746		82,767		1,185	1,029
2005	6,265			2,306	33,914		74,433		1,187	1,040
2006				721	30,594		78,625		1,178	1,154
2007	5,665						73,480			

Table 3.4. Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. Relative population number equals catch per effort in numbers weighted by respective strata areas. Relative population weight equals catch per effort measured in weight multiplied by strata areas. Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands 1979, 1995, 1997, 1999, 2001, 2003, 2005, and 2007 and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004, and 2006. 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		111

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

Year	CPUE	SE	CV	Sets	Vessels
1990	0.53	0.10	0.10	193	8
1991	0.50	0.07	0.07	246	8
1992	0.40	0.12	0.15	131	8
1993	0.28	0.08	0.14	308	12
1994	0.29	0.11	0.18	138	13
1995	0.30	0.09	0.14	208	14
1996	0.23	0.06	0.12	204	17
1997	0.35	0.14	0.20	117	9
1998	0.29	0.10	0.17	75	12
1999	0.38	0.13	0.17	305	14
2000	0.29	0.06	0.11	313	15
2001	0.26	0.08	0.15	162	9
2002	0.32	0.07	0.11	245	10
2003	0.26	0.09	0.17	170	10
2004	0.21	0.09	0.21	138	7
2005	0.15	0.05	0.34	23	6
2006	0.23	0.04	0.16	205	11

Bering Sea-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.72	0.22	0.15	42	8
1991	0.28	0.11	0.20	30	7
1992	0.25	0.21	0.43	7	4
1993	0.09	0.07	0.36	4	3
1994	0.35	0.31	0.45	2	2
1995	0.41	0.14	0.17	38	10
1996	0.63	0.38	0.30	35	15
1997					0
1998	0.17	0.06	0.18	28	9
1999	0.29	0.18	0.32	27	10
2000	0.28	0.18	0.31	21	10
2001	0.31	0.05	0.07	18	10
2002	0.10	0.05	0.22	8	4
2003	0.16	0.09	0.29	8	2
2004	0.17	0.11	0.31	9	4
2005	0.23	0.07	0.16	9	6
2006	0.17	0.07	0.21	68	15

Western Gulf-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.64	0.28	0.22	178	7
1991	0.44	0.11	0.13	193	16
1992	0.38	0.10	0.14	260	12
1993	0.35	0.06	0.09	106	12
1994	0.32	0.07	0.10	52	5
1995	0.51	0.09	0.09	432	22
1996	0.57	0.11	0.10	269	20
1997	0.50	0.10	0.10	349	20
1998	0.50	0.07	0.07	351	18
1999	0.53	0.13	0.12	244	14
2000	0.49	0.13	0.13	185	12
2001	0.50	0.10	0.10	273	16
2002	0.51	0.10	0.09	348	15
2003	0.45	0.09	0.10	387	16
2004	0.47	0.16	0.17	162	10
2005	0.58	0.07	0.13	447	13
2006	0.42	0.04	0.13	306	15

Central Gulf-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.54	0.08	0.07	653	32
1991	0.62	0.11	0.09	303	24
1992	0.59	0.11	0.09	335	19
1993	0.60	0.08	0.07	647	32
1994	0.65	0.12	0.09	238	15
1995	0.90	0.14	0.08	457	41
1996	1.04	0.14	0.07	441	45
1997	1.07	0.17	0.08	377	41
1998	0.90	0.11	0.06	345	32
1999	0.87	0.17	0.10	269	28
2000	0.93	0.10	0.06	319	30
2001	0.70	0.08	0.06	347	31
2002	0.84	0.13	0.08	374	29
2003	0.99	0.14	0.07	363	34
2004	1.08	0.19	0.09	327	29
2005	0.89	0.06	0.07	518	32
2006	0.82	0.06	0.08	361	33

West Yakutat-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990	0.95	0.47	0.25	75	9
1991	0.65	0.14	0.10	164	12
1992	0.64	0.35	0.27	98	6
1993	0.71	0.15	0.10	241	12
1994	0.65	0.35	0.27	81	8
1995	1.02	0.20	0.10	158	21
1996	0.97	0.15	0.07	223	28
1997	1.16	0.22	0.09	126	20
1998	1.21	0.20	0.08	145	23
1999	1.20	0.31	0.13	110	19
2000	1.28	0.20	0.08	193	32
2001	1.03	0.14	0.07	184	26
2002	1.32	0.26	0.10	155	23
2003	1.36	0.20	0.07	216	27
2004	1.23	0.19	0.08	210	24
2005	1.32	0.09	0.07	352	24
2006	0.96	0.10	0.10	257	30

East Yakutat/SE-Observer

Year	CPUE	SE	CV	Sets	Vessels
1990					0
1991	0.52	0.37	0.71	17	2
1992	0.87			20	1
1993	1.02	0.19	0.19	26	2
1994	0.36			5	1
1995	1.45	0.20	0.14	101	19
1996	1.20	0.11	0.09	137	24
1997	1.10	0.14	0.13	84	17
1998	1.27	0.12	0.10	140	25
1999	0.94	0.12	0.13	85	11
2000	0.84	0.13	0.16	81	14
2001	0.84	0.08	0.09	110	14
2002	1.20	0.23	0.19	121	14
2003	1.29	0.13	0.10	113	19
2004	1.08	0.10	0.09	135	17
2005	1.18	0.13	0.11	181	16
2006	0.93	0.11	0.11	104	18

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

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

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

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

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

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

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	0	na	136,368	0	5

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

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 (lengths 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.

Year	Age 4+ biomass (kt)	Spawning biomass (SSB, kt)	SSB (LCI)	SSB (UCI)	Number (millions) at age 2	Catch	Catch / Age 4+ biomass
1960	391	157	145	180	61.81	3.1	0.008
1961	417	173	160	196	3.37	16.1	0.039
1962	487	179	166	204	27.64	26.4	0.054
1963	457	180	166	206	51.06	16.9	0.037
1964	470	188	173	214	44.73	7.3	0.016
1965	528	200	185	227	15.50	8.7	0.016
1966	578	213	198	241	23.78	15.6	0.027
1967	574	224	209	251	0.96	19.2	0.033
1968	572	232	218	259	0.33	31.0	0.054
1969	520	229	215	254	0.46	36.8	0.071
1970	457	214	202	237	30.44	37.8	0.083
1971	393	193	182	213	46.75	43.5	0.111
1972	372	167	156	184	2.51	53.0	0.143
1973	371	138	129	153	2.24	36.9	0.100
1974	326	122	114	136	2.45	34.6	0.106
1975	281	109	102	122	16.54	29.9	0.107
1976	240	97	91	109	13.68	31.7	0.132
1977	220	81	75	92	1.42	21.4	0.097
1978	210	71	66	81	2.45	10.4	0.050
1979	193	69	64	77	83.02	11.9	0.062
1980	176	67	62	75	46.04	10.4	0.059
1981	288	69	64	76	17.46	12.6	0.044
1982	352	76	71	84	48.38	12.0	0.034
1983	372	93	88	103	21.49	11.8	0.032
1984	435	116	110	127	37.30	14.1	0.032
1985	453	139	131	150	0.70	14.5	0.032
1986	489	157	149	169	29.21	28.9	0.059
1987	452	165	156	177	15.13	35.2	0.078
1988	446	164	156	176	9.46	38.4	0.086
1989	415	156	147	168	5.46	34.8	0.084
1990	379	146	138	158	10.44	32.1	0.085
1991	338	135	127	147	23.48	27.0	0.080
1992	310	125	118	136	2.68	24.9	0.080
1993	306	115	107	125	30.86	25.4	0.083
1994	273	105	98	115	0.90	23.8	0.087
1995	284	98	91	107	9.50	20.9	0.073
1996	256	94	87	103	10.17	17.6	0.069
1997	242	93	86	101	19.11	14.9	0.061
1998	233	92	85	100	4.26	14.1	0.061
1999	239	90	83	98	33.36	13.6	0.057
2000	223	89	82	97	18.13	15.9	0.071
2001	251	88	81	96	13.07	14.1	0.056
2002	260	89	82	98	38.39	14.8	0.057
2003	260	93	86	102	13.31	16.5	0.063
2004	297	98	90	107	2.47	17.0	0.057
2005	297	104	95	113	10.58	16.5	0.056
2006	278	109	100	119	1.02	16.1	0.058
2007	268	113	103	123	11.92	16.1	0.060

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

Year	Maximum permissible F	Author's F (prespecified catch 2008-9)*	Half maximum F	5-year average F	No fishing	Overfished?	Approaching overfished?
Spawning biomass (kt)							
2007	112.4	112.4	112.4	112.4	112.4	112.4	112.4
2008	111.6	111.6	111.6	111.6	111.6	111.6	111.6
2009	106.4	108.0	110.8	107.7	115.5	104.7	106.4
2010	100.8	103.9	108.9	102.9	118.0	98.0	100.8
2011	97.3	99.9	108.1	99.6	121.4	93.7	96.0
2012	97.0	99.2	110.3	99.3	127.6	92.8	94.6
2013	99.4	101.1	115.0	101.7	136.7	94.5	96.0
2014	102.9	104.3	121.1	105.4	147.4	97.4	98.6
2015	106.7	107.8	127.4	109.5	158.7	100.6	101.4
2016	110.1	111.0	133.5	113.6	169.8	103.4	104.1
2017	113.2	113.9	139.2	117.3	180.5	105.9	106.4
2018	115.8	116.3	144.3	120.6	190.6	108.0	108.3
2019	118.2	118.6	149.0	123.8	200.2	109.8	110.0
2020	120.3	120.6	153.4	126.7	209.3	111.5	111.6
Fishing mortality							
2007	0.071	0.071	0.071	0.071	0.071	0.071	0.071
2008	0.084	0.068	0.042	0.071	-	0.101	0.101
2009	0.080	0.064	0.042	0.071	-	0.094	0.094
2010	0.076	0.078	0.041	0.071	-	0.088	0.088
2011	0.073	0.075	0.040	0.071	-	0.083	0.083
2012	0.072	0.074	0.040	0.071	-	0.082	0.082
2013	0.072	0.074	0.041	0.071	-	0.082	0.082
2014	0.073	0.074	0.042	0.071	-	0.083	0.083
2015	0.074	0.075	0.043	0.071	-	0.085	0.085
2016	0.075	0.076	0.046	0.071	-	0.086	0.086
2017	0.077	0.077	0.046	0.071	-	0.087	0.087
2018	0.078	0.078	0.046	0.071	-	0.089	0.089
2019	0.079	0.079	0.046	0.071	-	0.090	0.090
2020	0.080	0.080	0.046	0.071	-	0.091	0.091
Yield (kt)							
2007	16.20	16.20	16.20	16.20	16.20	16.20	16.20
2008	18.03	18.03	9.19	15.36	-	21.32	18.03
2009	15.98	16.48	8.82	14.47	-	18.34	15.98
2010	14.98	15.88	8.83	14.37	-	16.81	17.73
2011	15.17	15.90	9.31	14.96	-	16.79	17.52
2012	15.94	16.52	10.00	15.64	-	17.51	18.07
2013	16.86	17.29	10.67	16.23	-	18.48	18.90
2014	17.77	18.09	11.32	16.82	-	19.44	19.74
2015	18.57	18.81	11.89	17.32	-	20.27	20.49
2016	19.25	19.44	12.42	17.76	-	20.98	21.13
2017	19.88	20.02	12.88	18.17	-	21.61	21.72
2018	20.47	20.57	13.36	18.60	-	22.19	22.27
2019	21.08	21.15	13.83	19.01	-	22.80	22.85
2020	21.66	21.71	14.27	19.39	-	23.36	23.40

* Projections in Author's F (Alternative 2) are based on an estimated catch of 14,720 t and 13,020 t used in place of maximum permissible ABC for 2008 and 2009. This was done in response to management requests for a more accurate one-year projection.

Table 3.11. Regional estimates of sablefish age 4+ biomass (kt). Age 4+ biomass was estimated by year and region by applying only survey-based weights, similar to the method used to apportion the ABC (except that the ABC allocation also used fishery data).

Year	Bering Sea	Aleutian Islands	Western Gulf of Alaska	Central Gulf of Alaska	West Yakutat	East Yakutat/ Southeast	Alaska
1960							391
1961							417
1962							487
1963							457
1964							470
1965							528
1966							578
1967							574
1968							572
1969							520
1970							457
1971							393
1972							372
1973							371
1974							326
1975							281
1976							240
1977							220
1978							210
1979	37	40	18	57	17	25	193
1980	32	44	17	45	15	24	176
1981	52	69	30	66	27	44	288
1982	64	75	44	87	33	49	352
1983	67	81	55	91	30	47	372
1984	81	101	65	105	34	50	435
1985	91	101	65	112	35	48	453
1986	102	103	68	120	42	54	489
1987	69	102	63	122	43	54	452
1988	59	88	60	138	44	57	446
1989	60	86	49	125	43	52	415
1990	54	67	44	120	41	53	379
1991	35	56	37	108	44	59	338
1992	26	44	30	107	45	57	310
1993	17	42	36	103	49	59	306
1994	20	38	35	88	42	51	273
1995	23	36	33	92	42	58	284
1996	23	28	29	92	35	50	256
1997	21	25	26	90	32	49	242
1998	21	30	27	79	28	48	233
1999	20	35	26	83	26	48	239
2000	18	34	29	74	24	44	223
2001	27	39	37	81	22	45	251
2002	32	41	37	85	23	42	260
2003	33	41	37	87	22	39	260
2004	38	47	37	104	27	44	297
2005	43	45	43	93	25	48	297
2006	42	40	37	88	26	45	278
2007	42	37	28	82	29	50	268

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

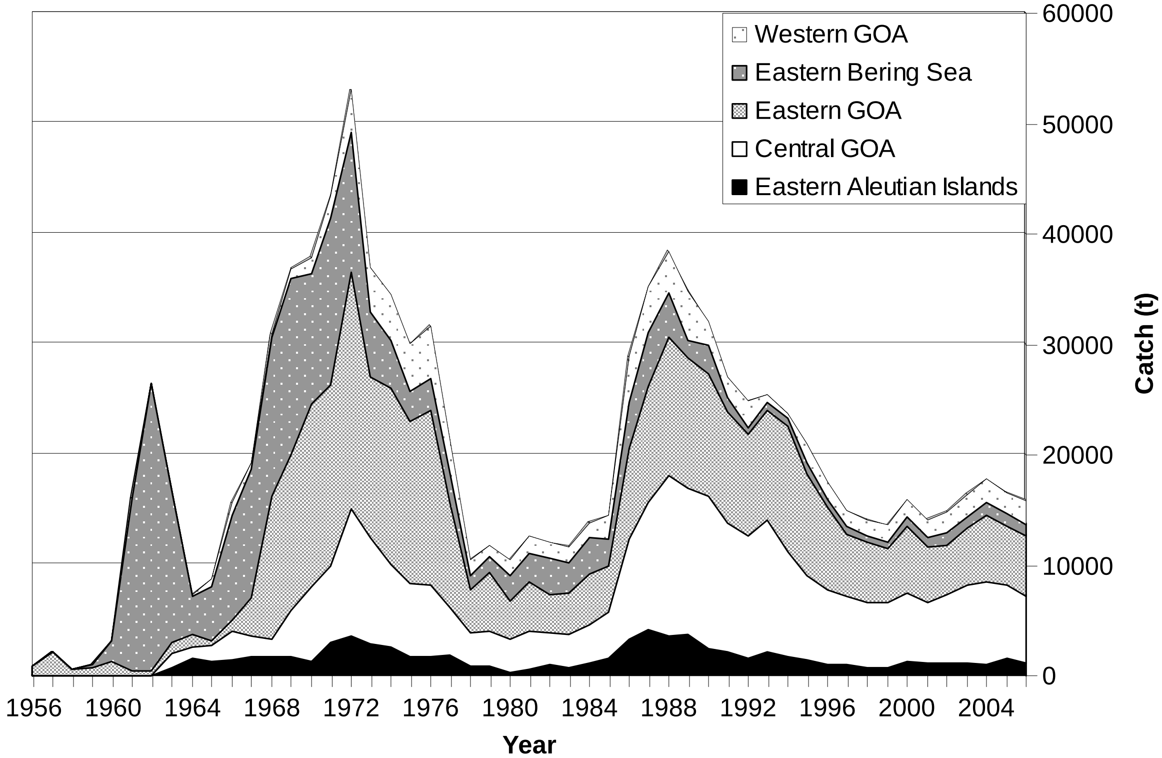


Figure 3.1. Sablefish fishery total reported catch (t) by North Pacific Fishery Management Council area and year.

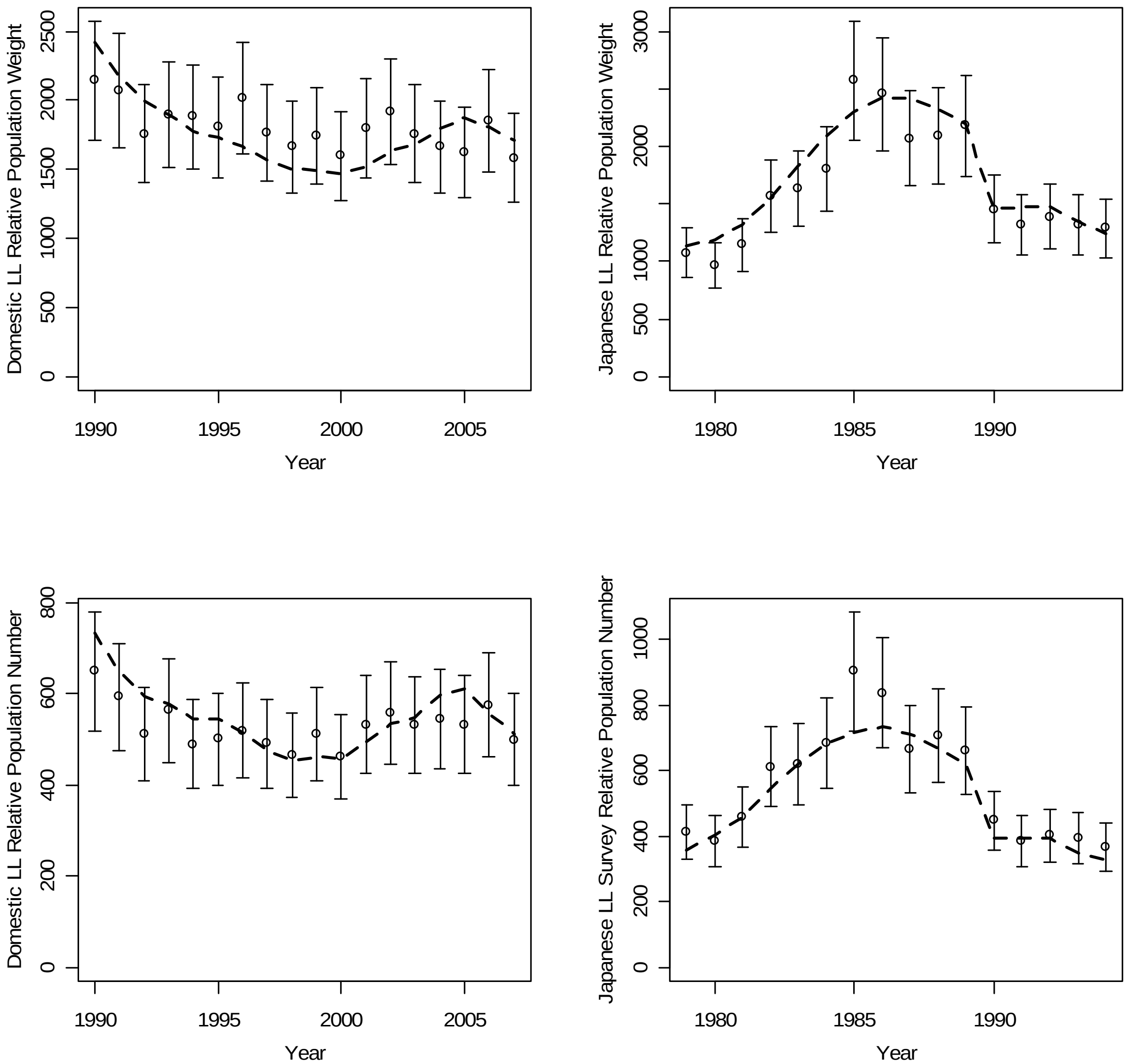


Figure 3.2. Observed and predicted sablefish relative population weight and numbers versus year. Points are observed estimates with approximate 95% confidence intervals, dashed line is model 3 fit.

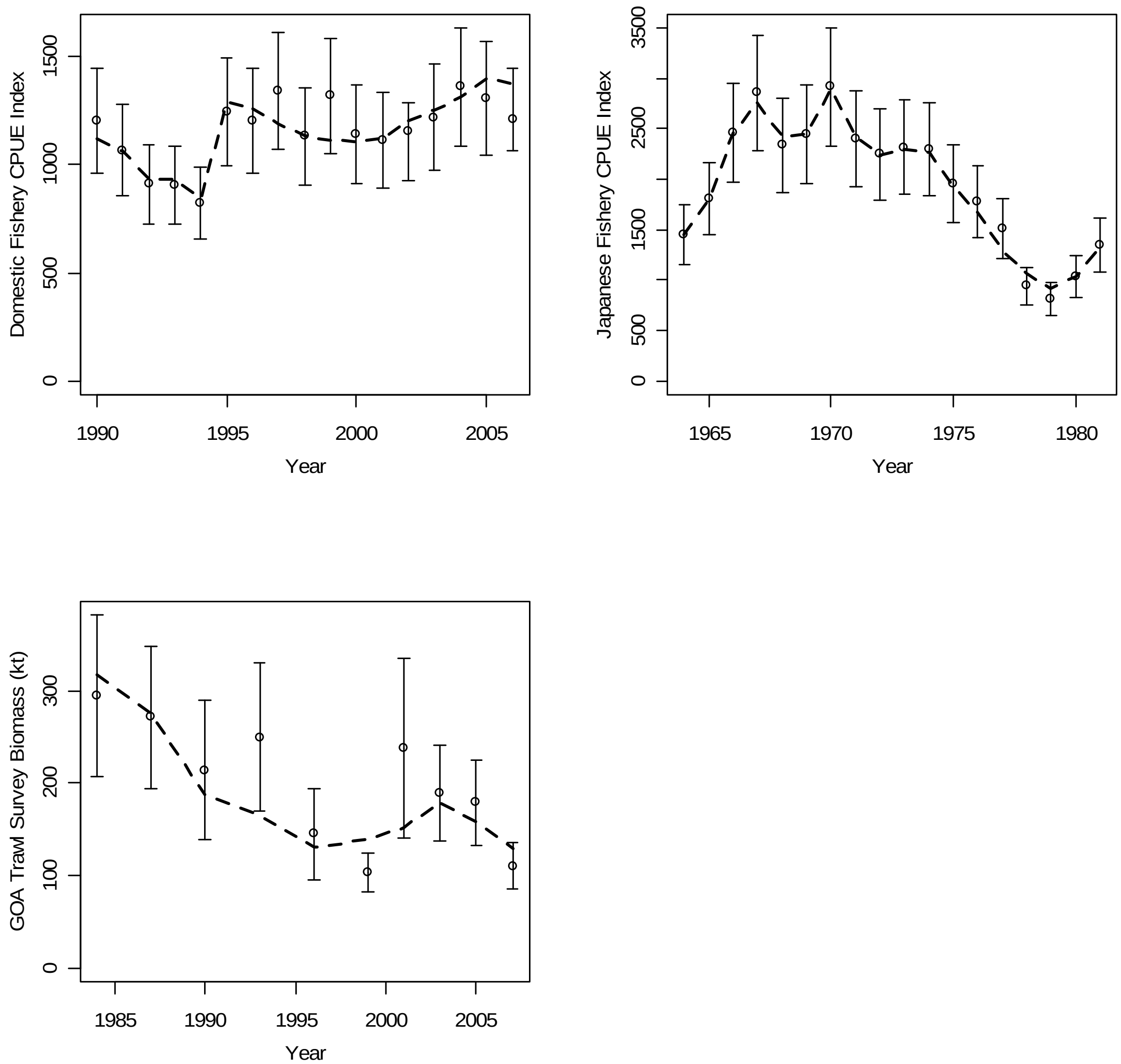


Figure 3.3. Observed and predicted sablefish abundance indices. Fishery indices are on top two panels, GOA trawl survey is on the bottom left panel. Points are observed estimates with approximate 95% confidence intervals while dashed lines are fits from Model 3.

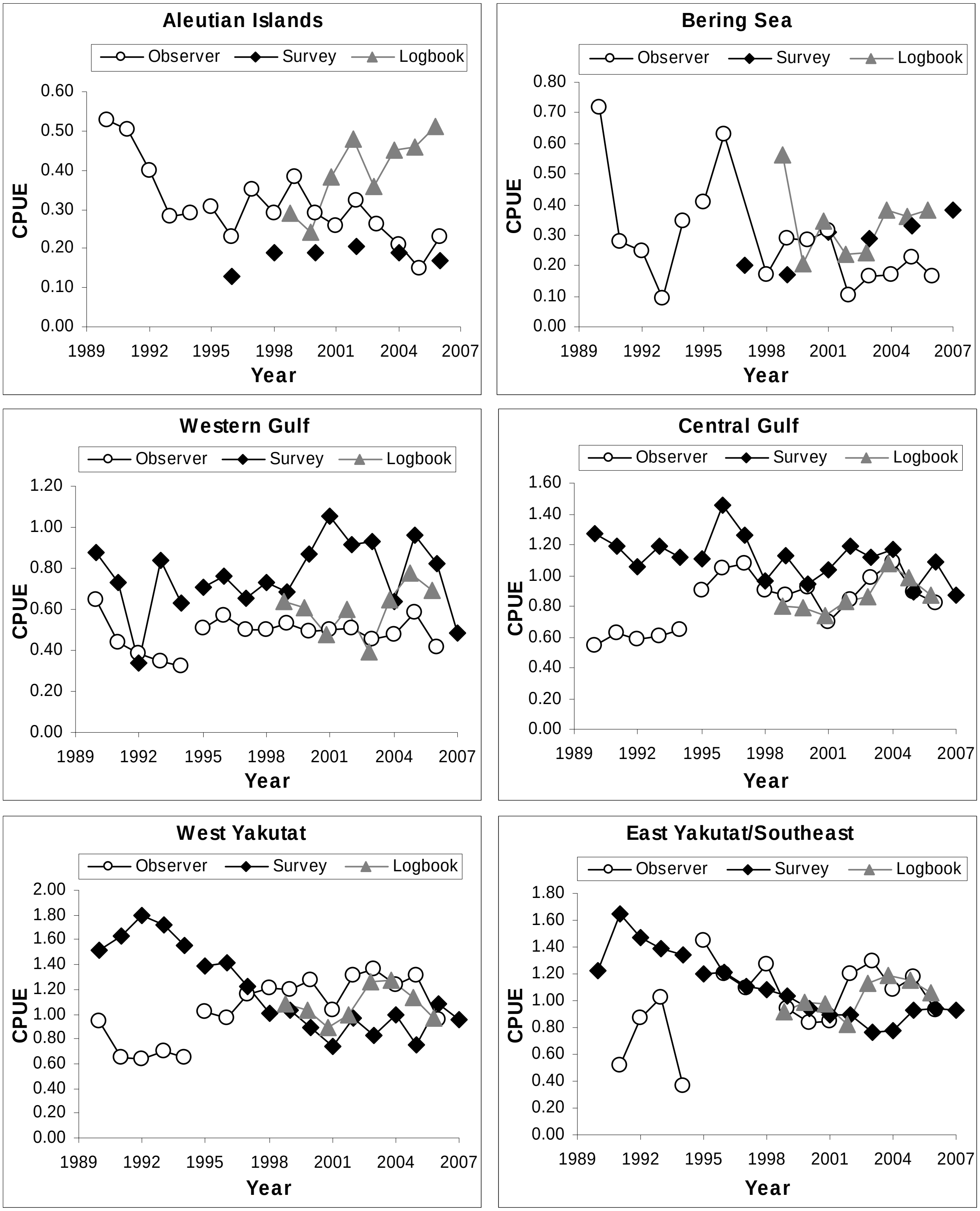


Figure 3.4. Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

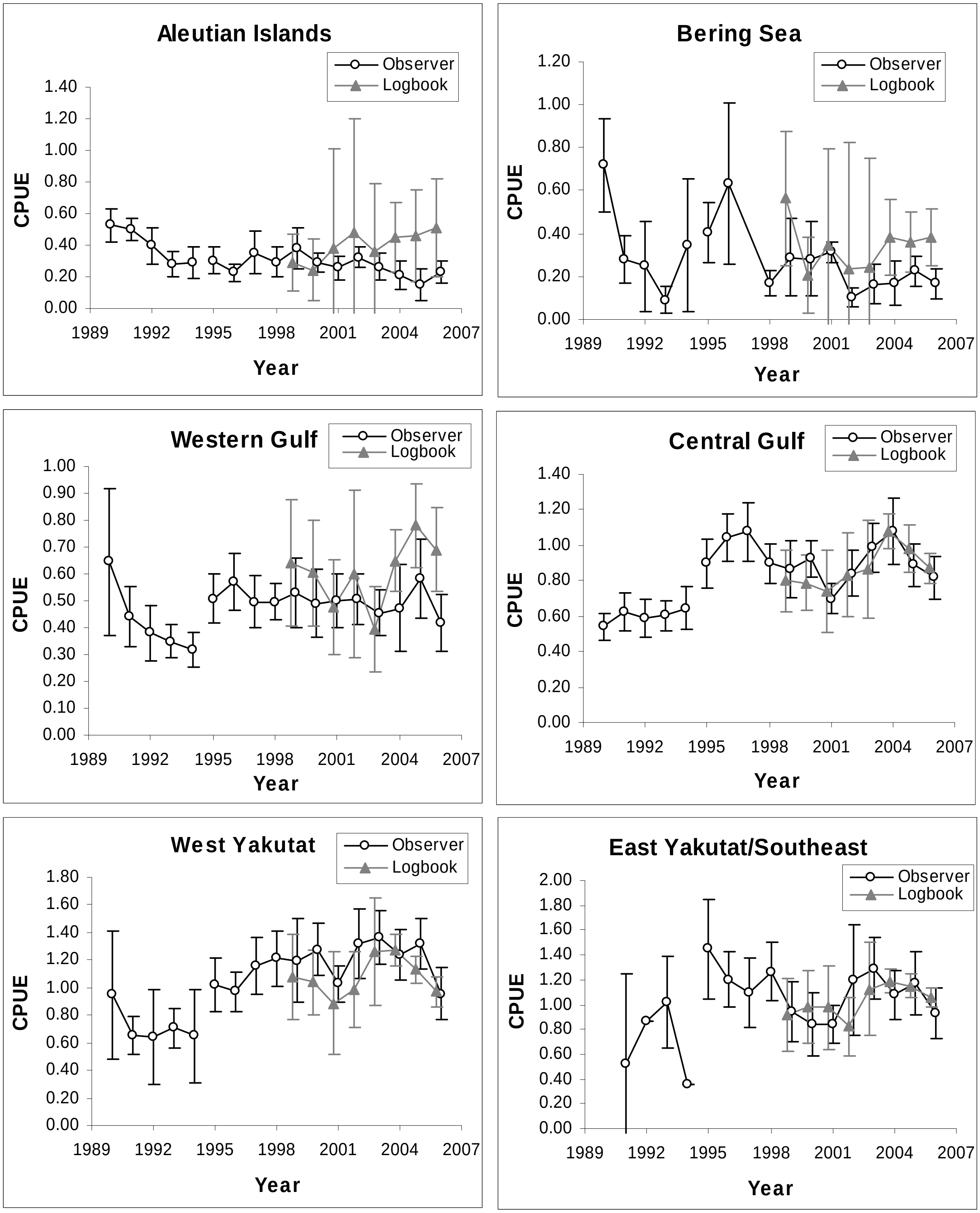


Figure 3.5. Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

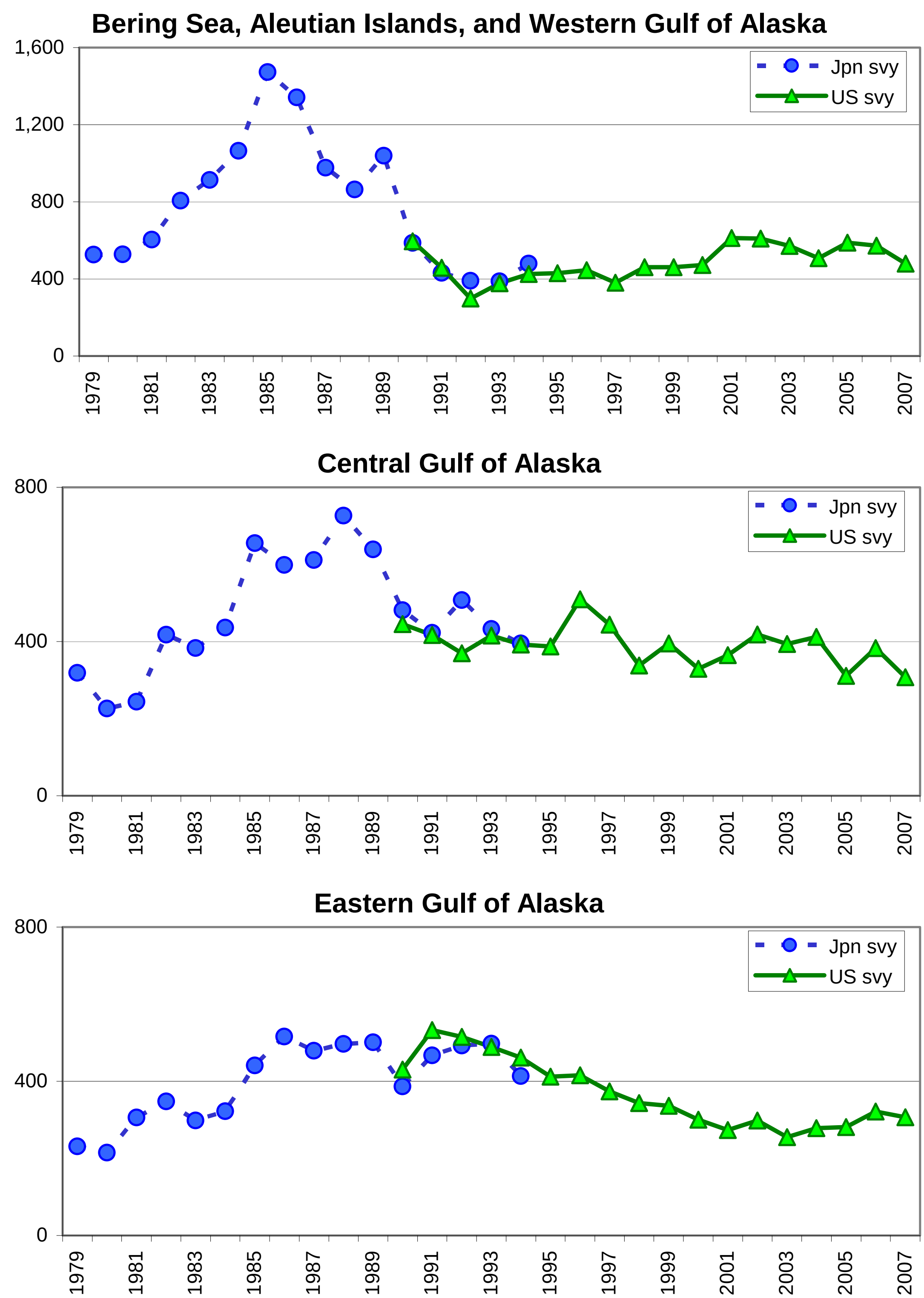


Figure 3.6. Relative abundance (weight) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the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

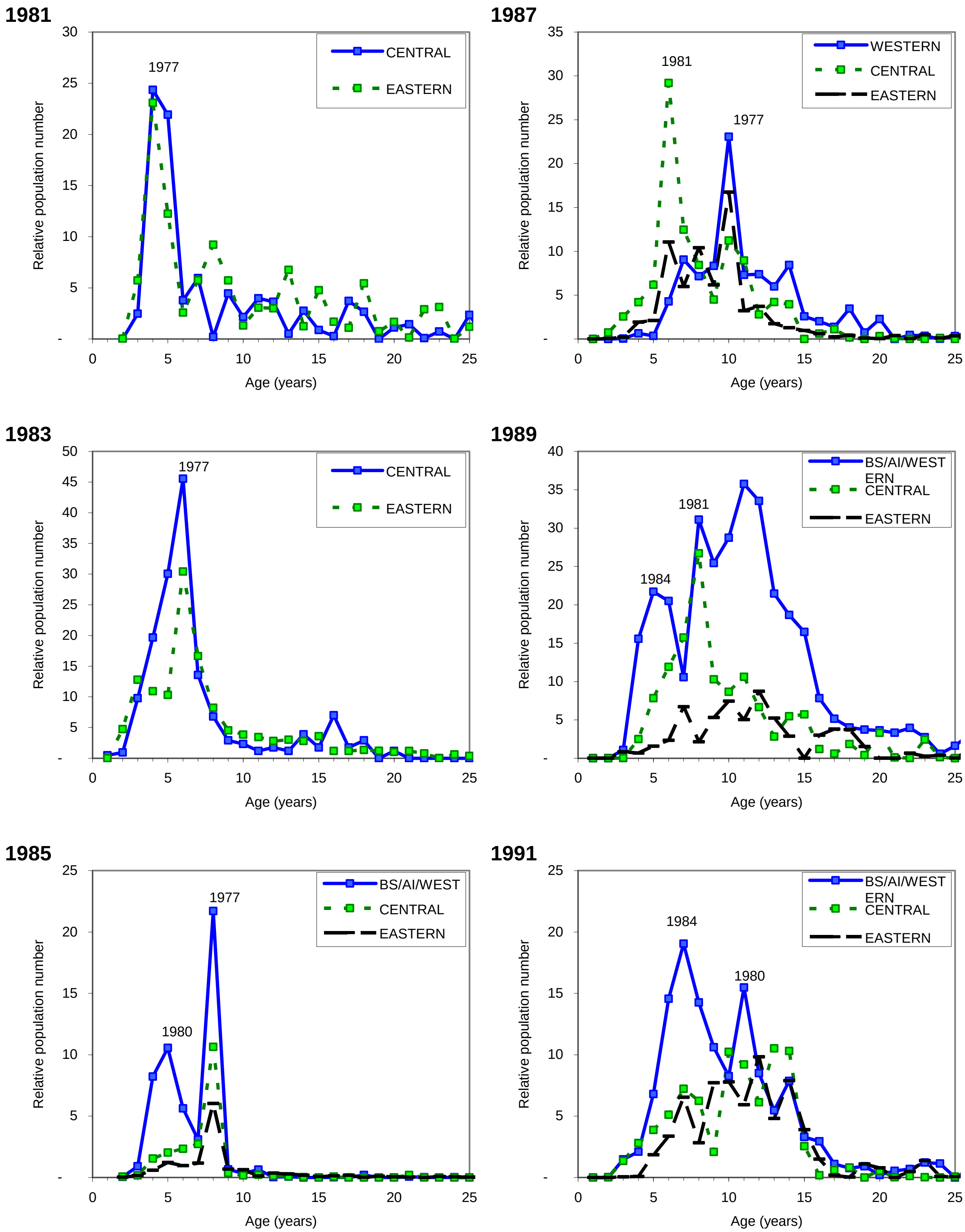


Figure 3.7. Relative abundance (number in thousands) by age and region from two surveys, the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

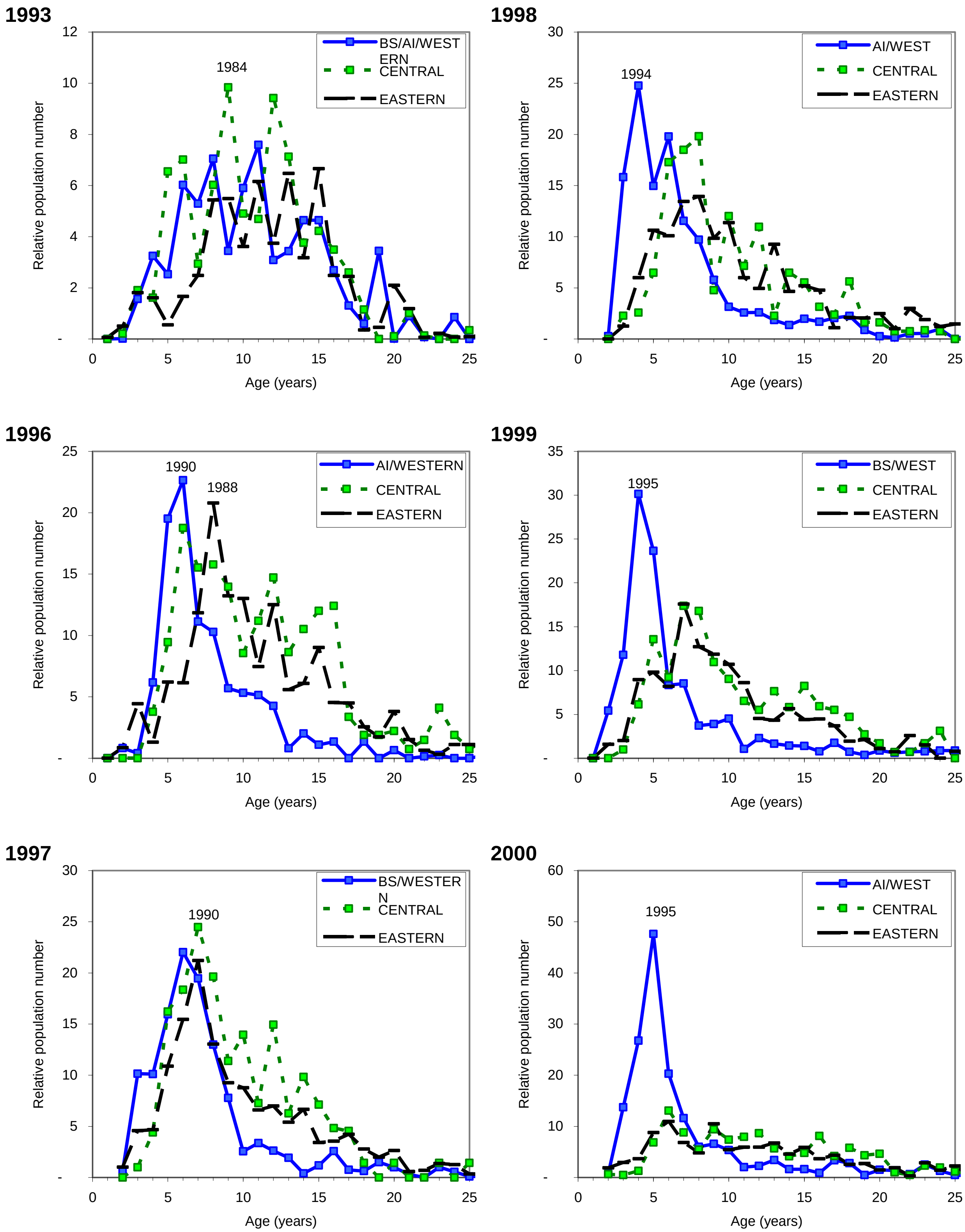


Figure 3.7 cont.

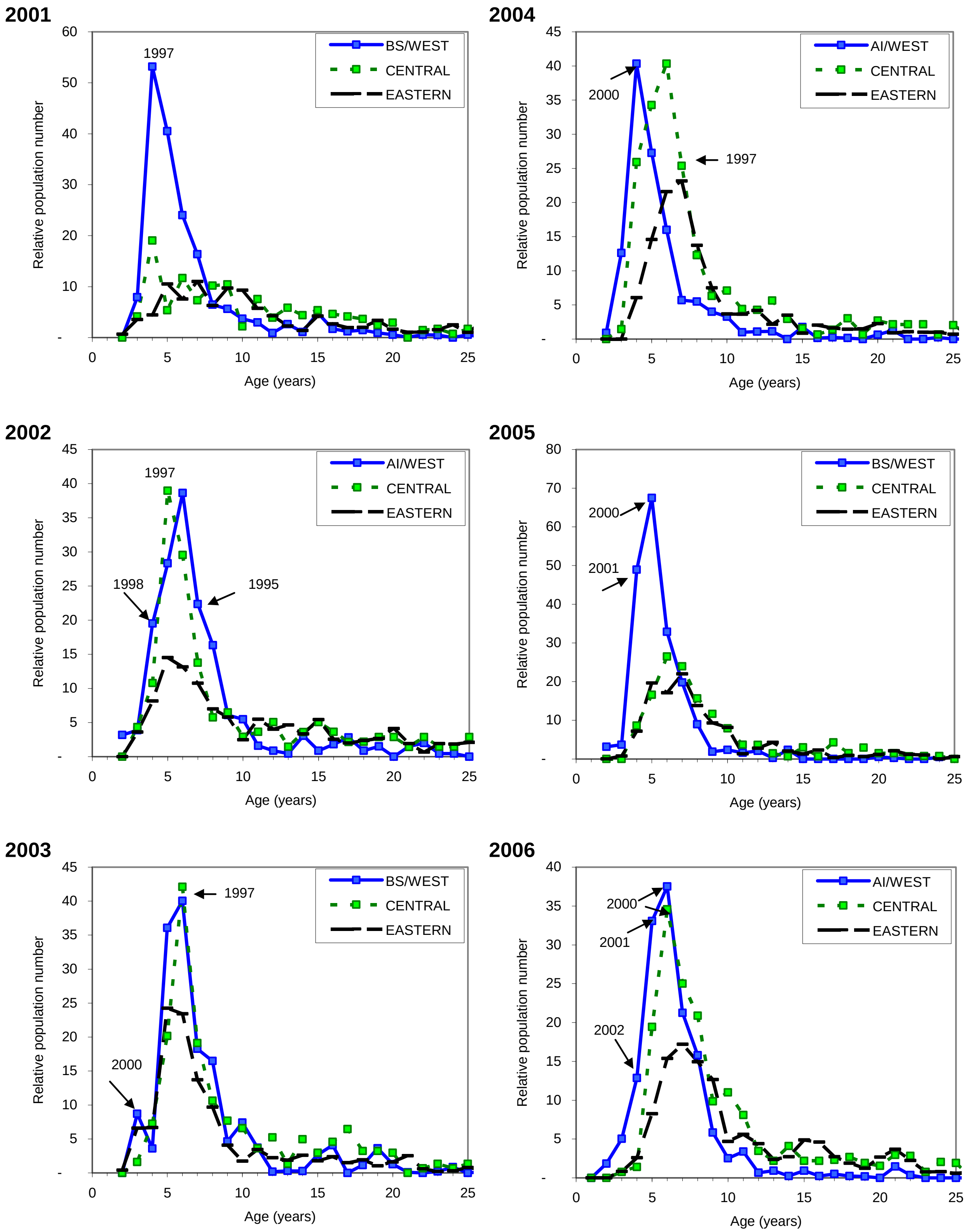


Figure 3.7. cont.

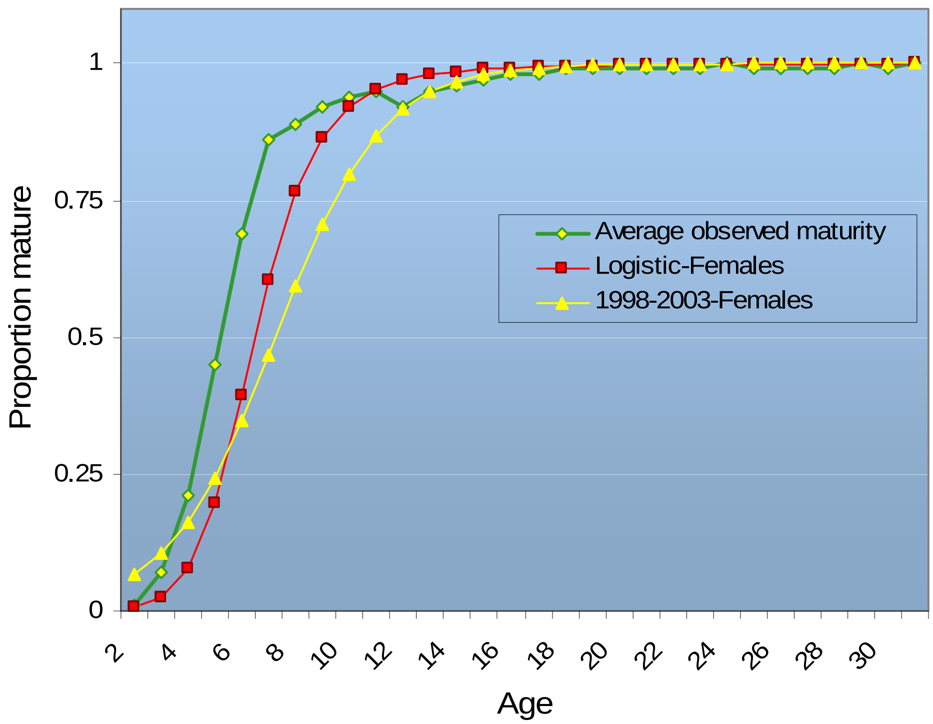


Figure 3.8. Estimated maturity curves for sablefish. Green line with diamonds is average male and female maturity from Sasaki (1985), Red line with squares are logistic fit to female maturity from Sasaki.

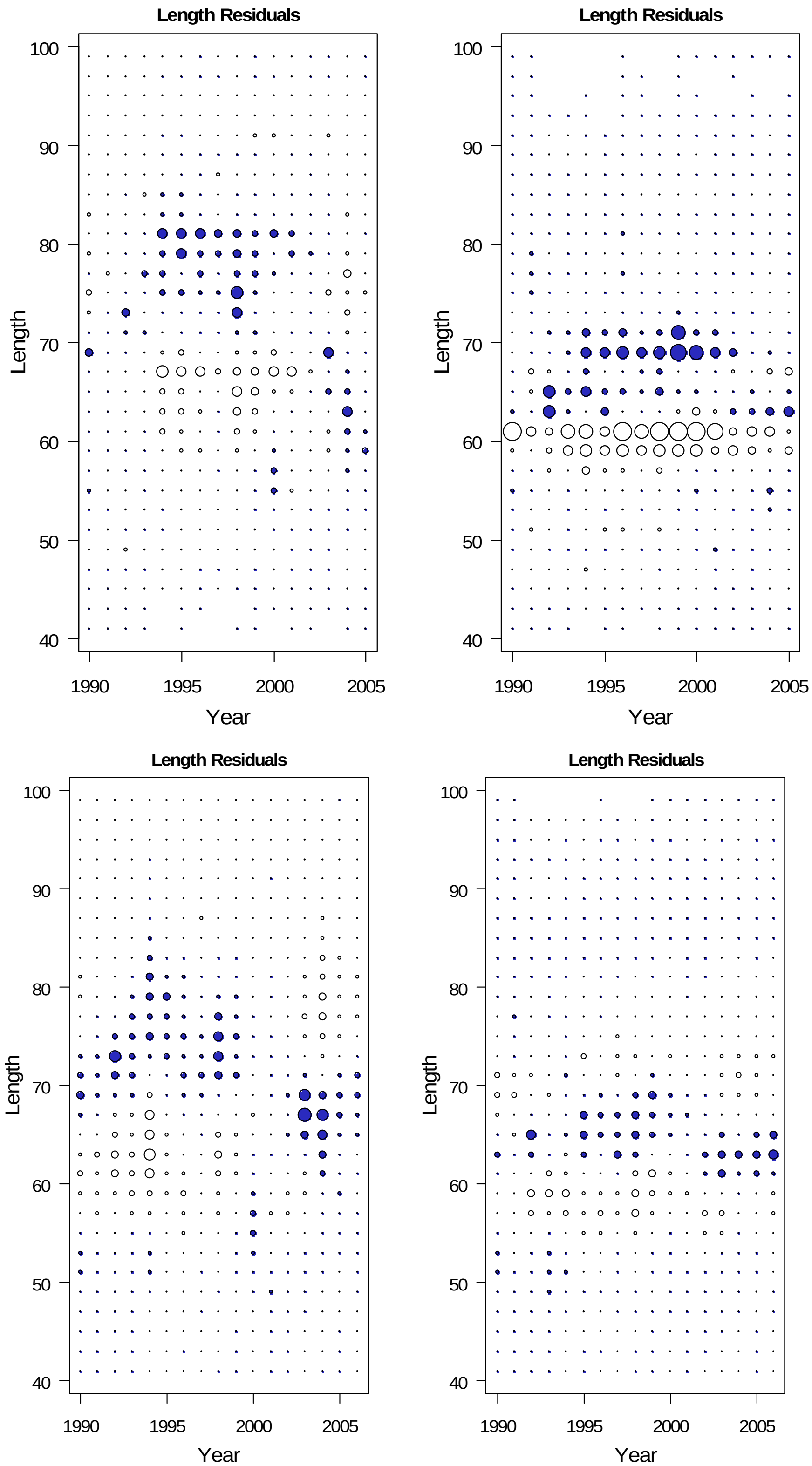


Figure 3.9. Residuals from the U.S. longline fishery length compositions for 2006 Model (top) and Model 3 (bottom). Left is females, right is males. Dark bubbles are positive residuals, while open bubbles are negative residuals.

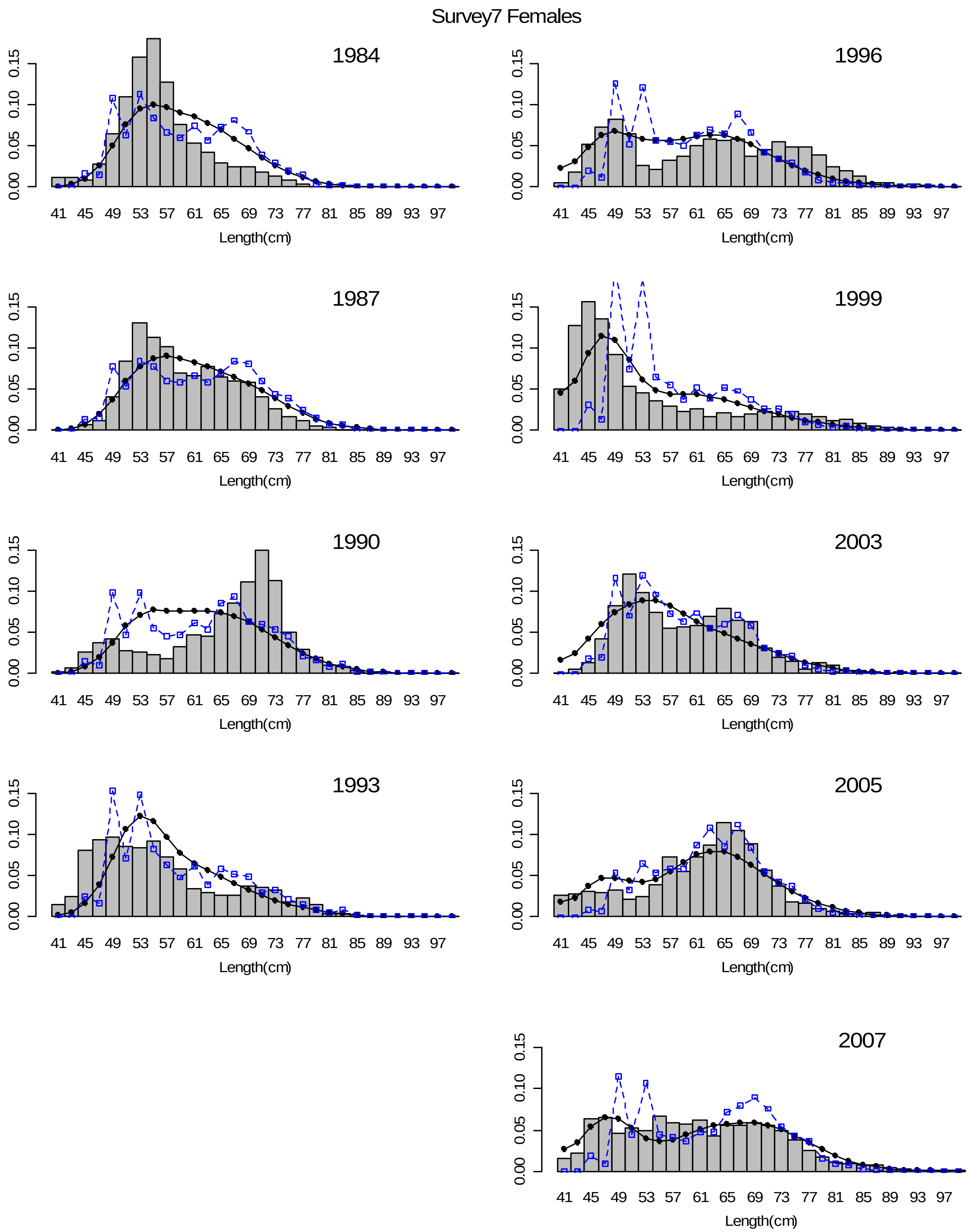


Figure 3.10a. Gulf of Alaska bottom trawl survey lengths for female sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

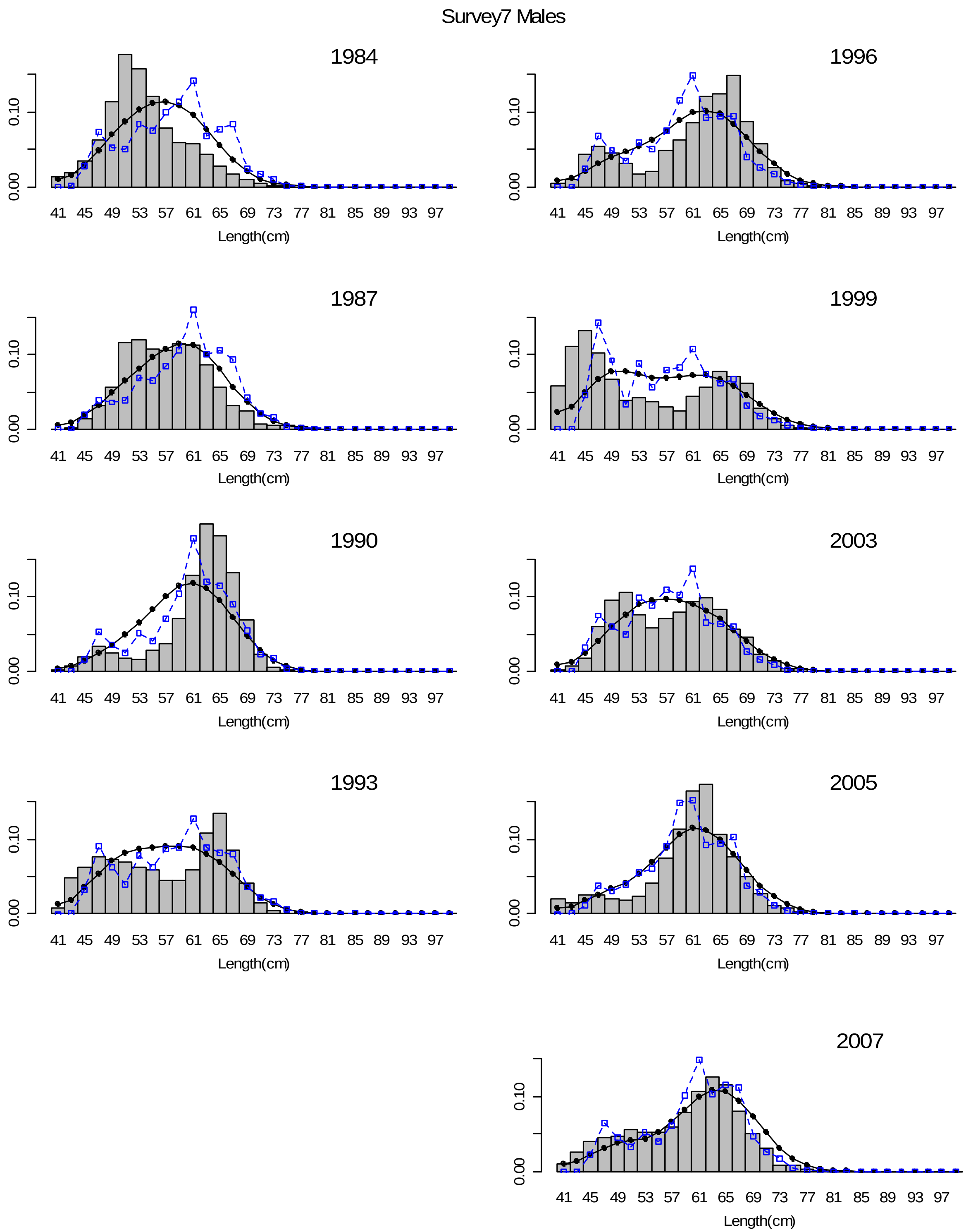


Figure 3.10b. Gulf of Alaska bottom trawl survey lengths for male sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

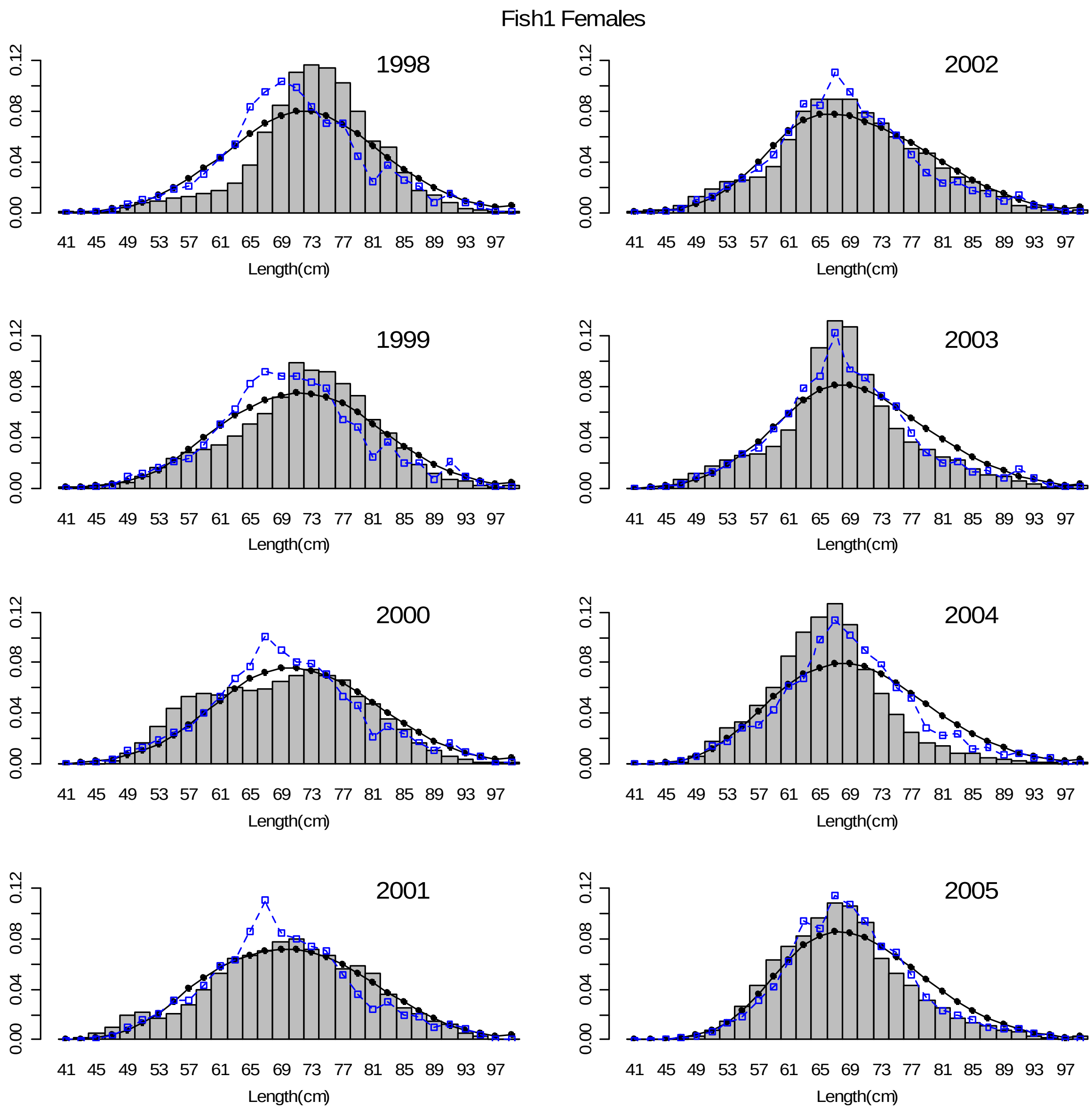


Figure 3.11a. Domestic fixed gear fishery lengths compositions for females. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

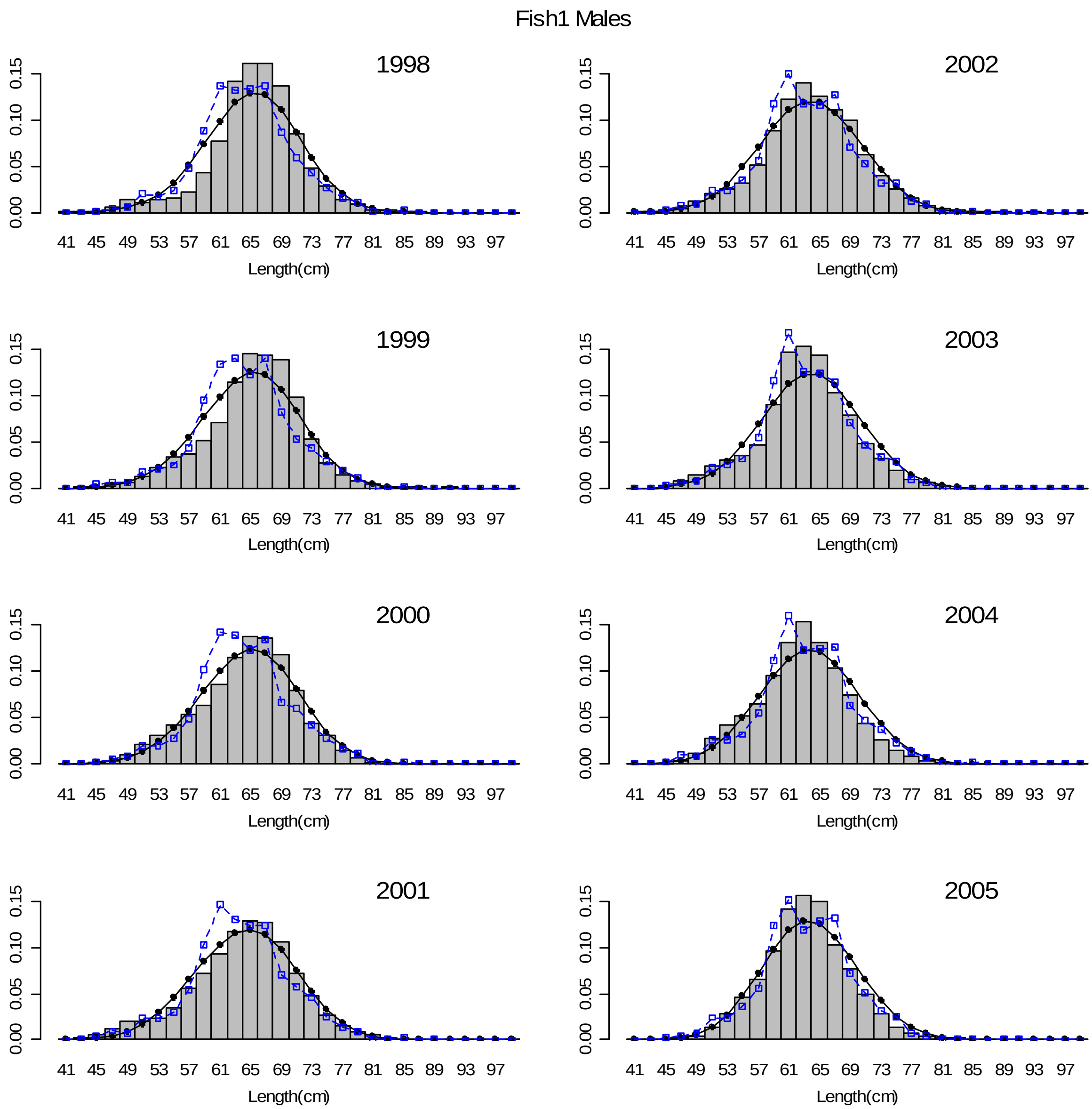


Figure 3.11b. Domestic fixed gear fishery lengths compositions for males. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

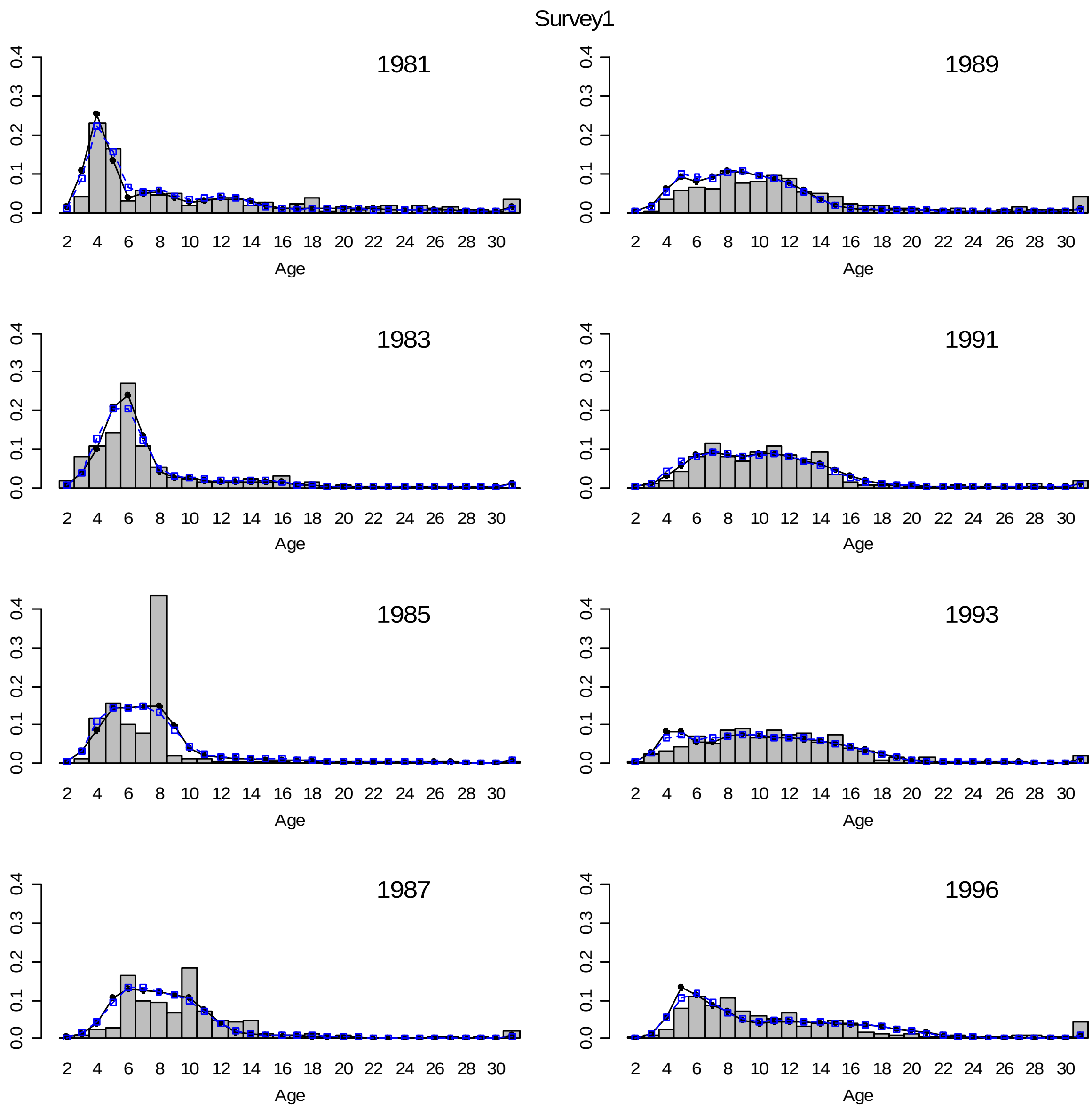


Figure 3.12. Longline survey age compositions. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

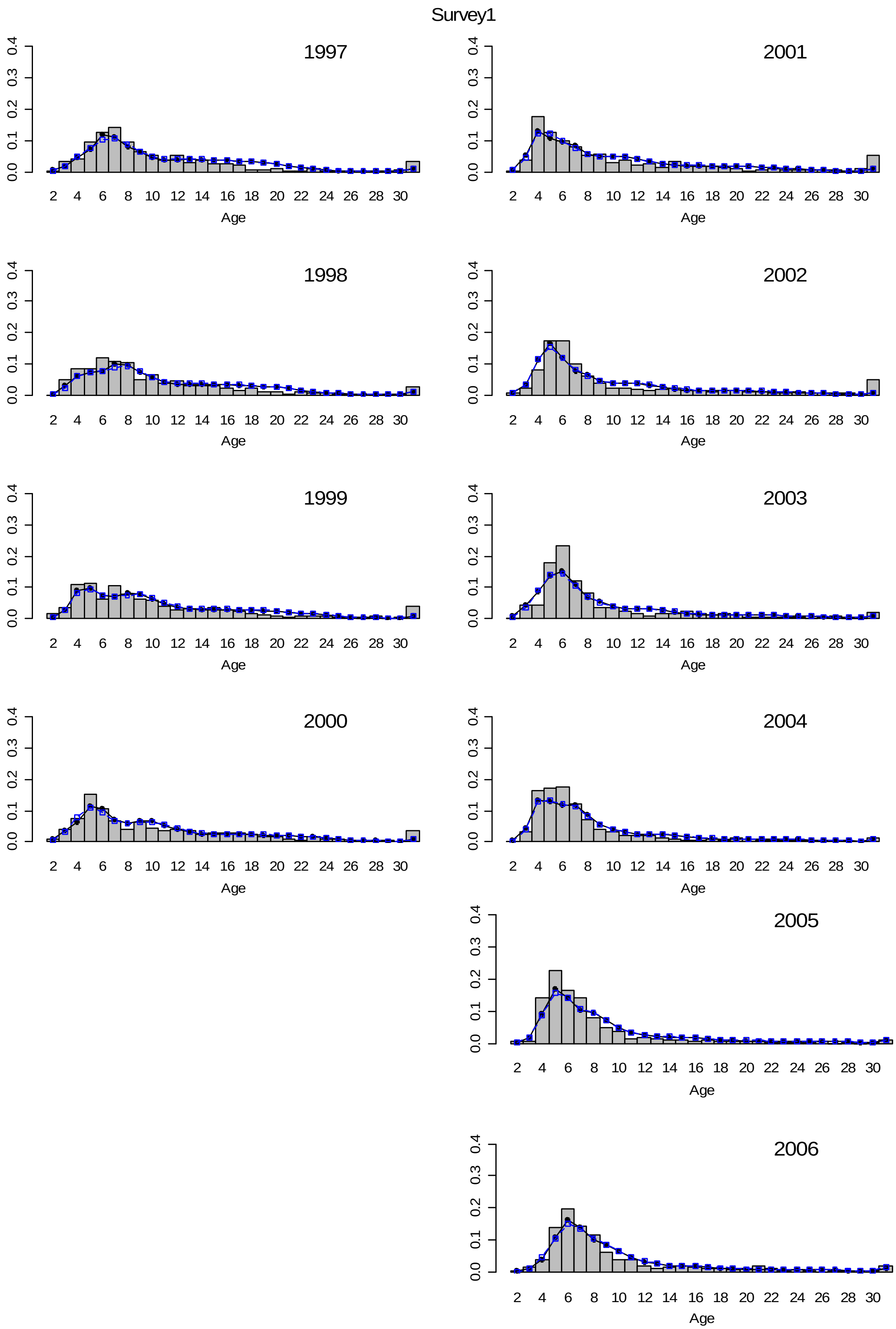


Figure 3.12. (continued).

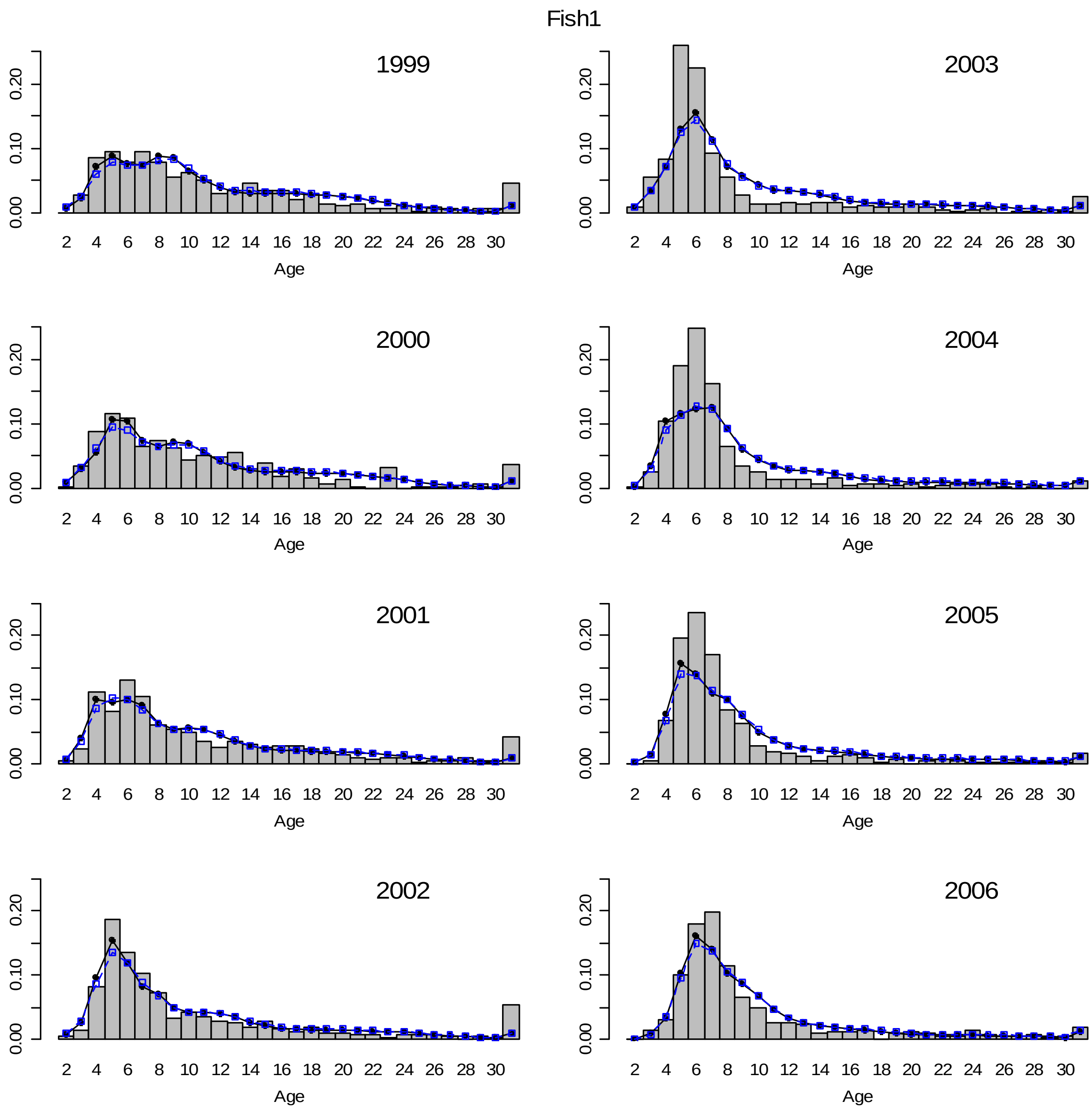


Figure 3.13. Domestic fishery age compositions. Bars are observed frequencies and line is predicted frequencies. Blue dashed line with empty squares is Model 1. Solid black line with filled circles is Model 3.

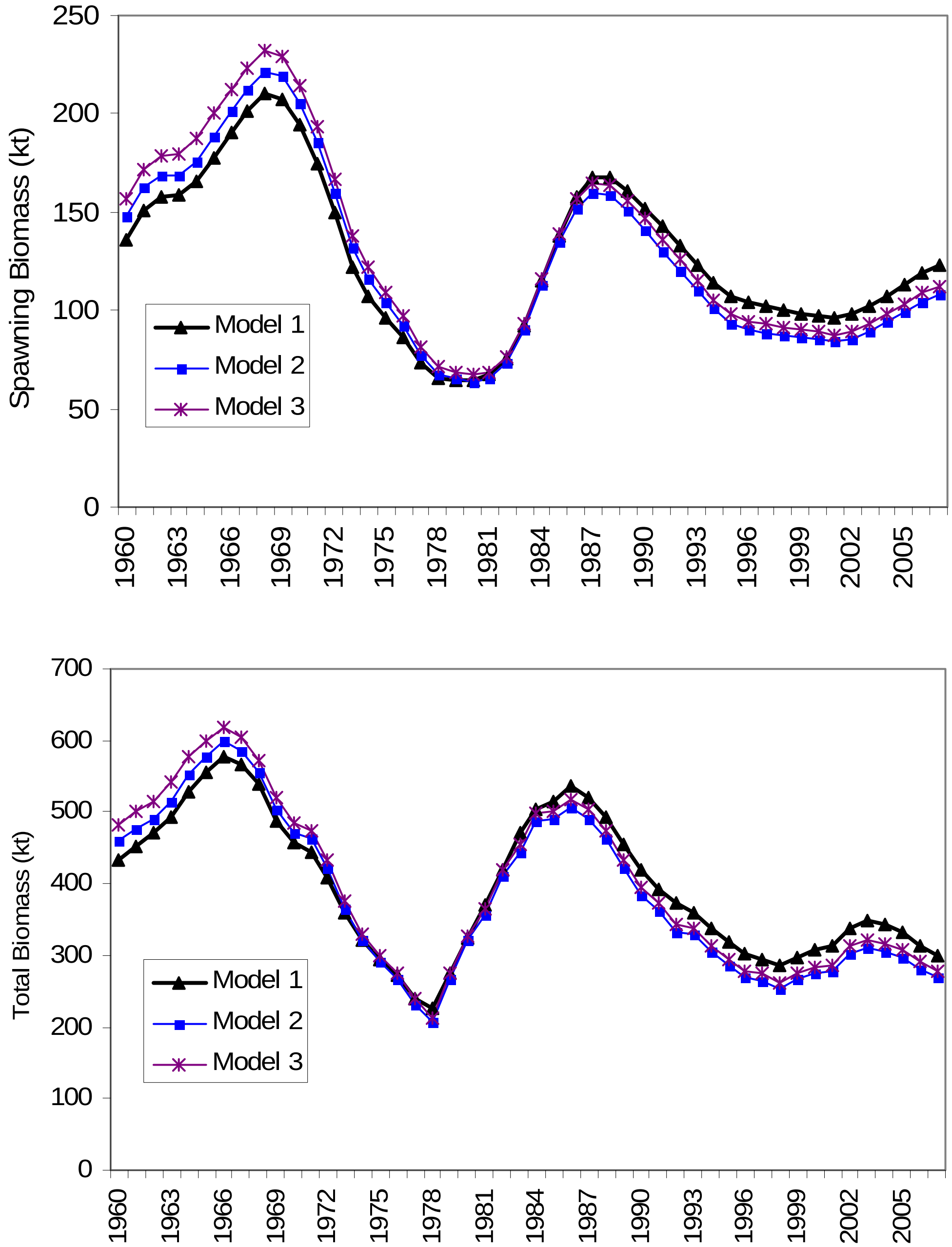


Figure 3.14.--Estimated sablefish female spawning biomass (top) (thousands t) and total biomass (bottom) versus year by assessment model. The recommended model is Model 3.

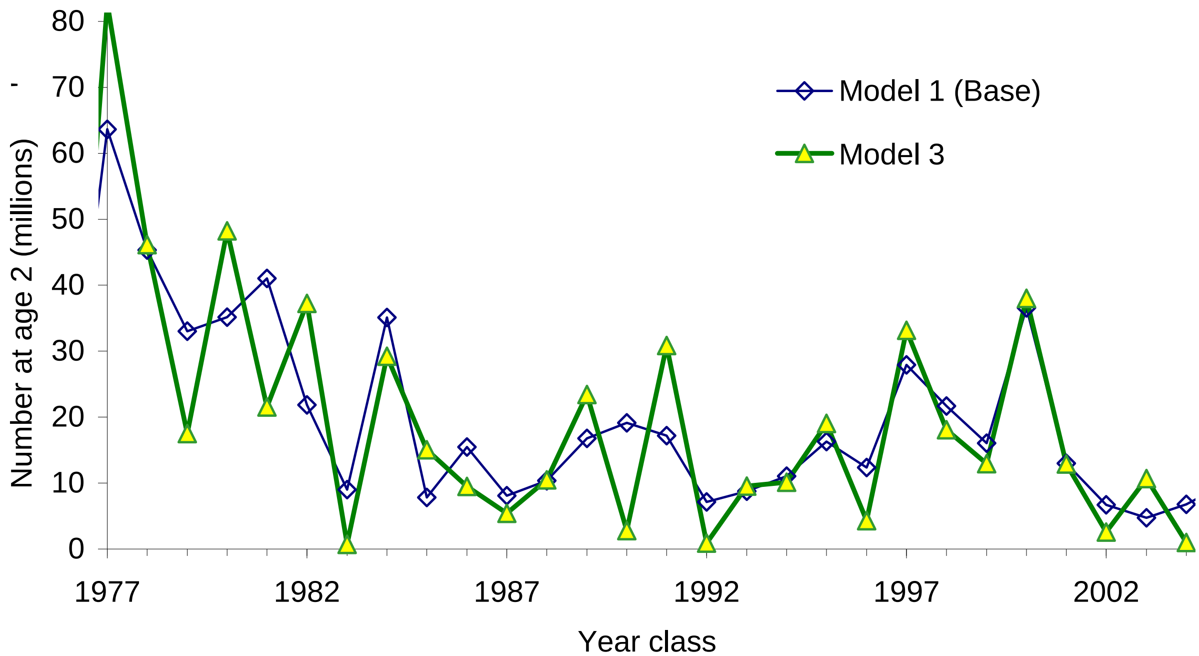


Figure 3.15a.Estimated recruitment (number at age 2, millions) versus year for Models 1 and 3.

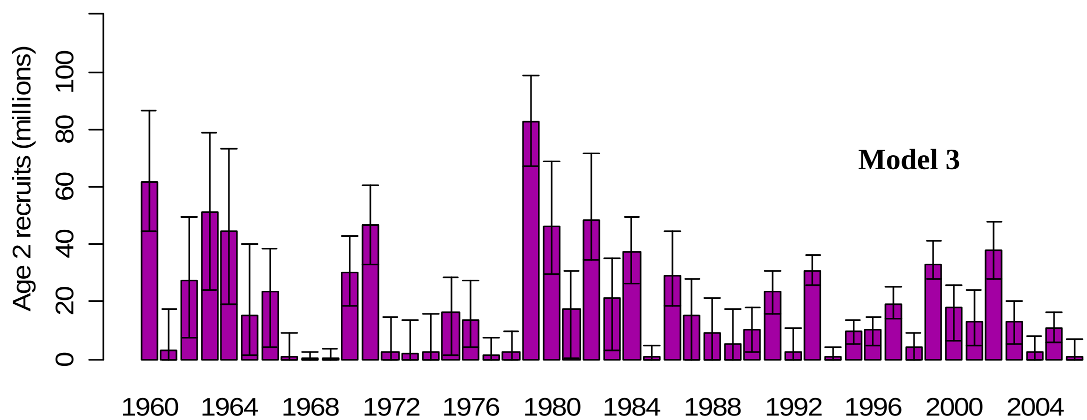


Figure 3.15b. Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on 5,000,000 MCMC runs. Year on bottom is year when fish recruited as age 2 sablefish, so year class is 2 years prior.

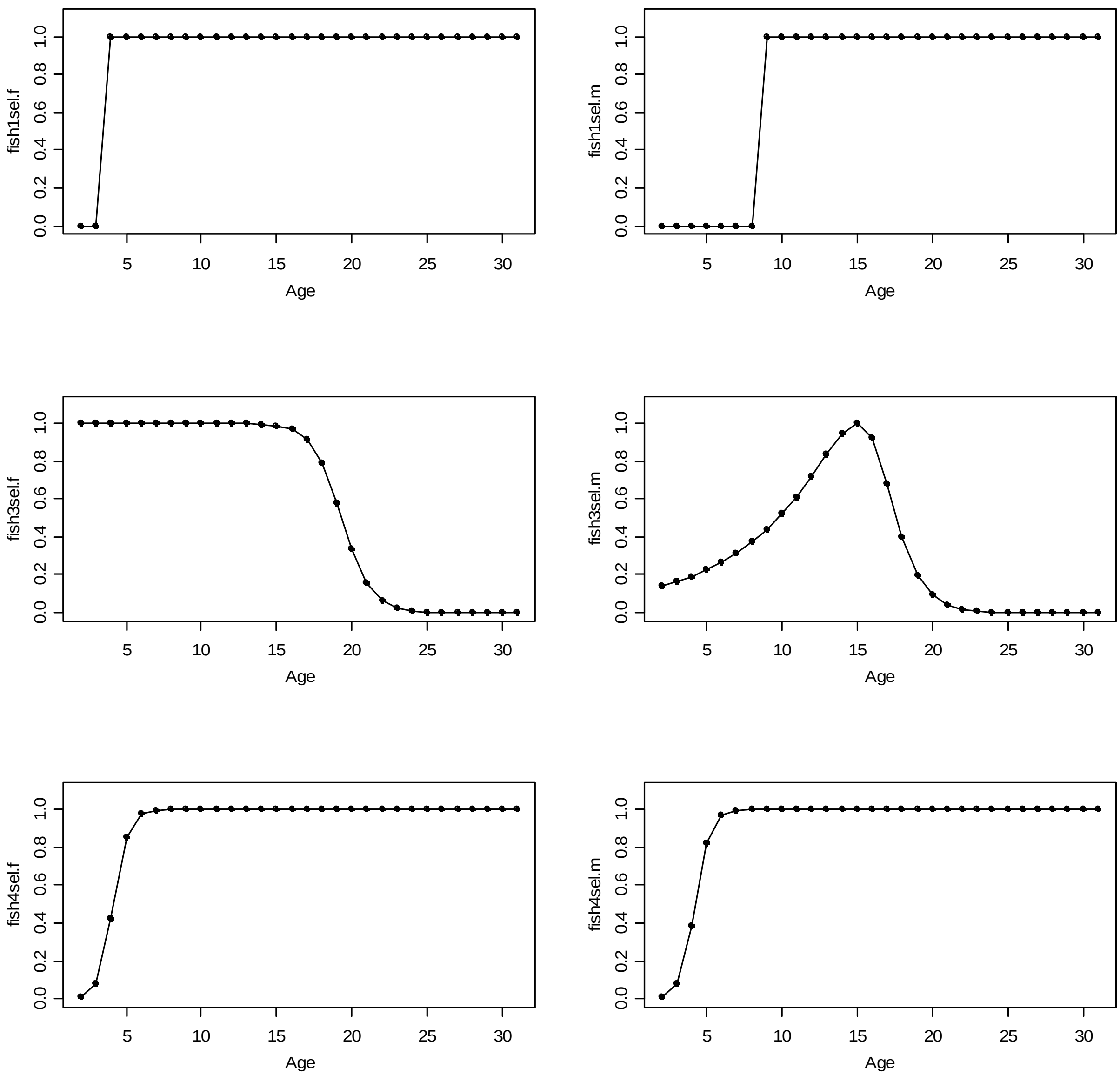


Figure 3.16a. Sablefish selectivities from Model 3. Top panel is fishery selectivities where fish1=Dom LL fishery-derby, fish3=Domestic trawl fishery, fish4=Dom LL fishery IFQ. Sexes are represented by .f=female and .m=male.

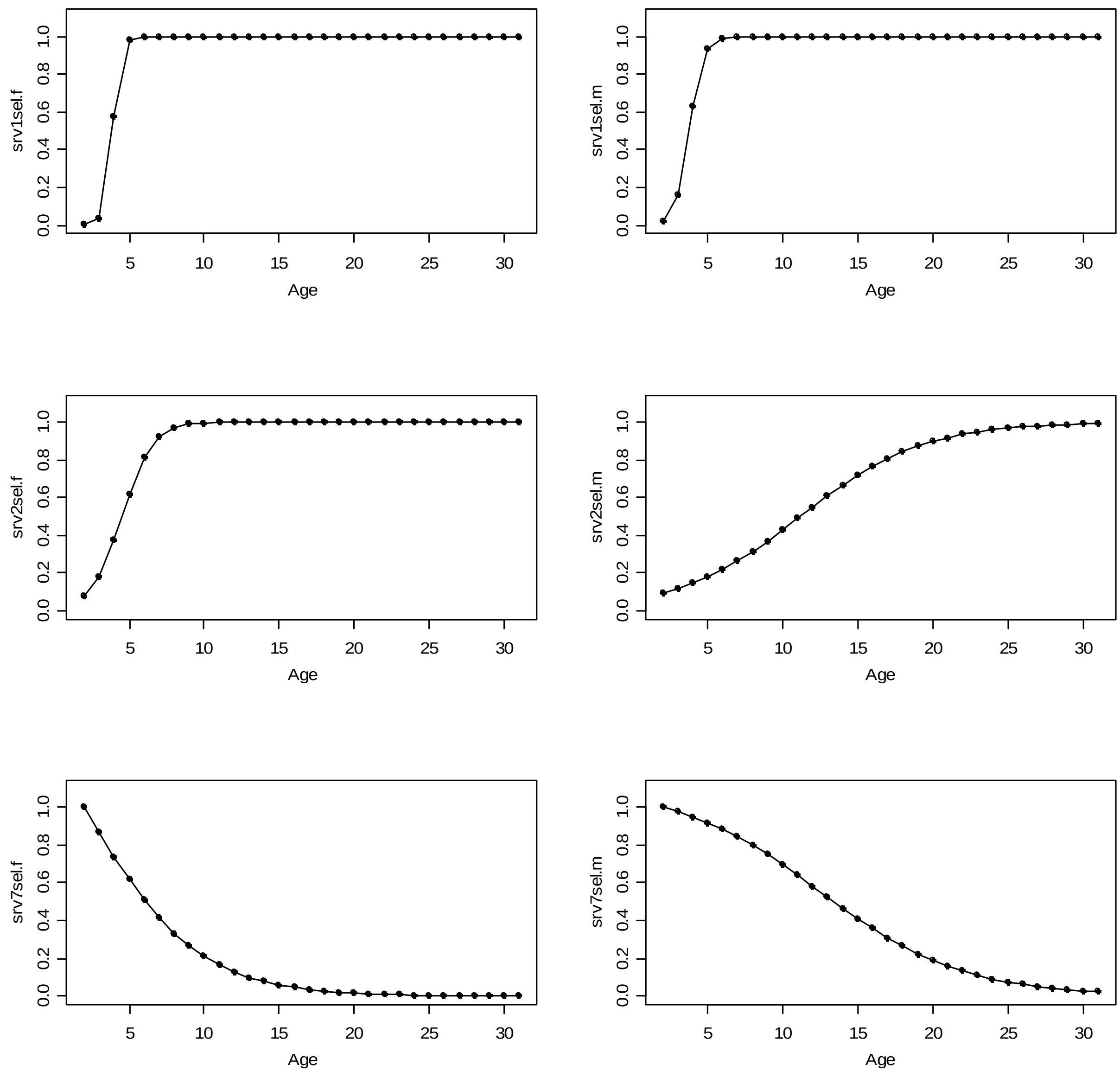


Figure 3.16b. Sablefish selectivities from Model 3. Survey selectivities srv1= Dom. LL survey, srv2 = Japanese LL survey, srv7 = NMFS GOA trawl survey. Sexes are represented by .f=female and .m=male.

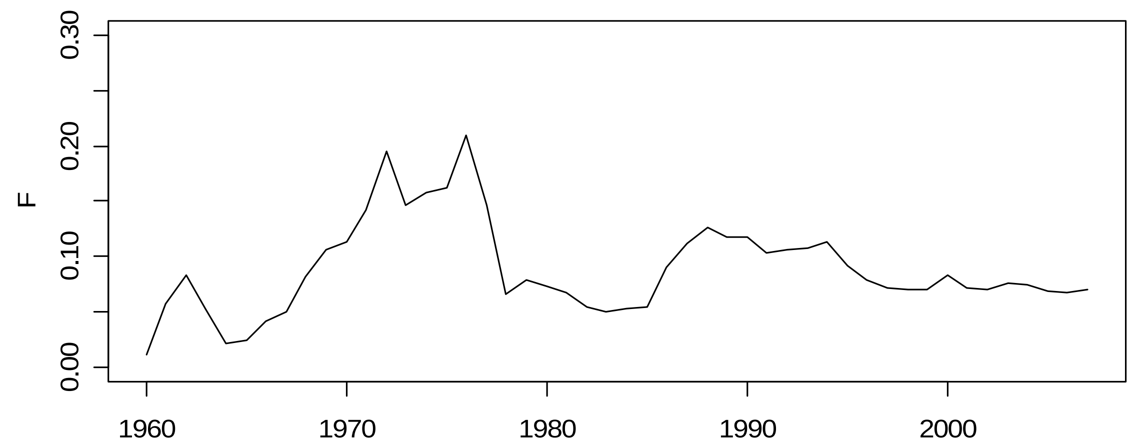


Figure 3.17. Time series of combined fully-selected fishing mortality for fixed and trawl gear for sablefish.

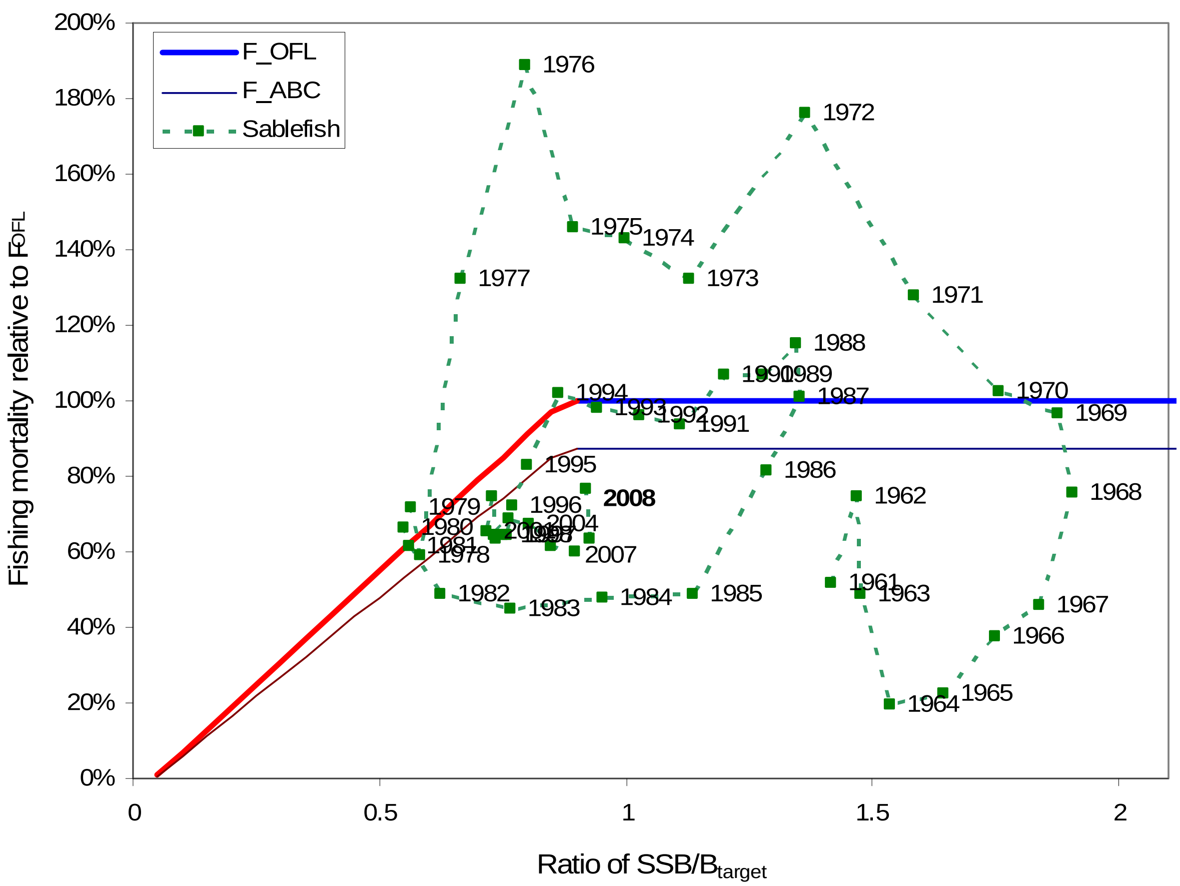


Figure 3.18. Phase-plane diagram of time series of sablefish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

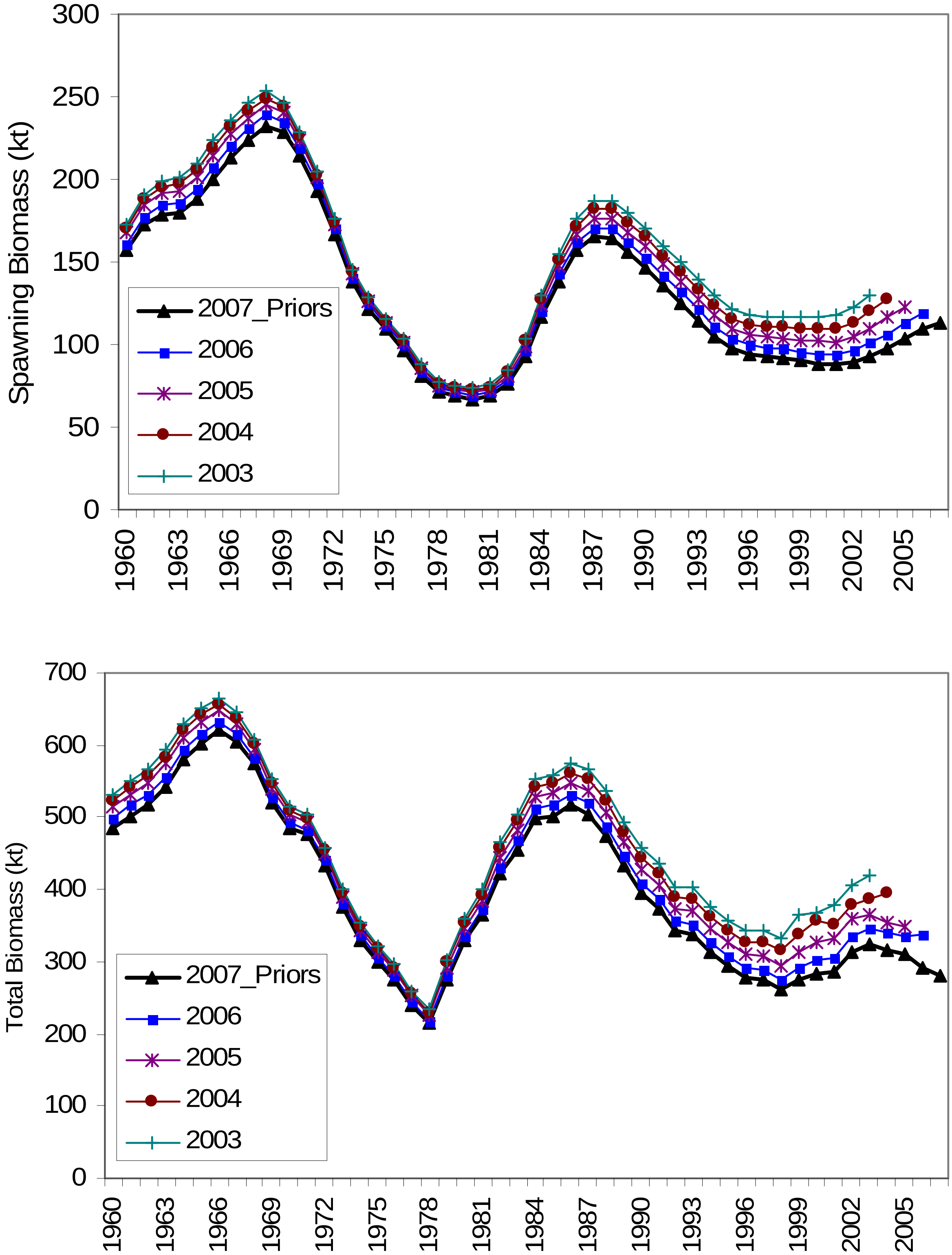


Figure 3.19. Retrospective trends for Model 3 (2007_Priors) for spawning biomass (top) and total biomass (bottom) from 2003-2007.

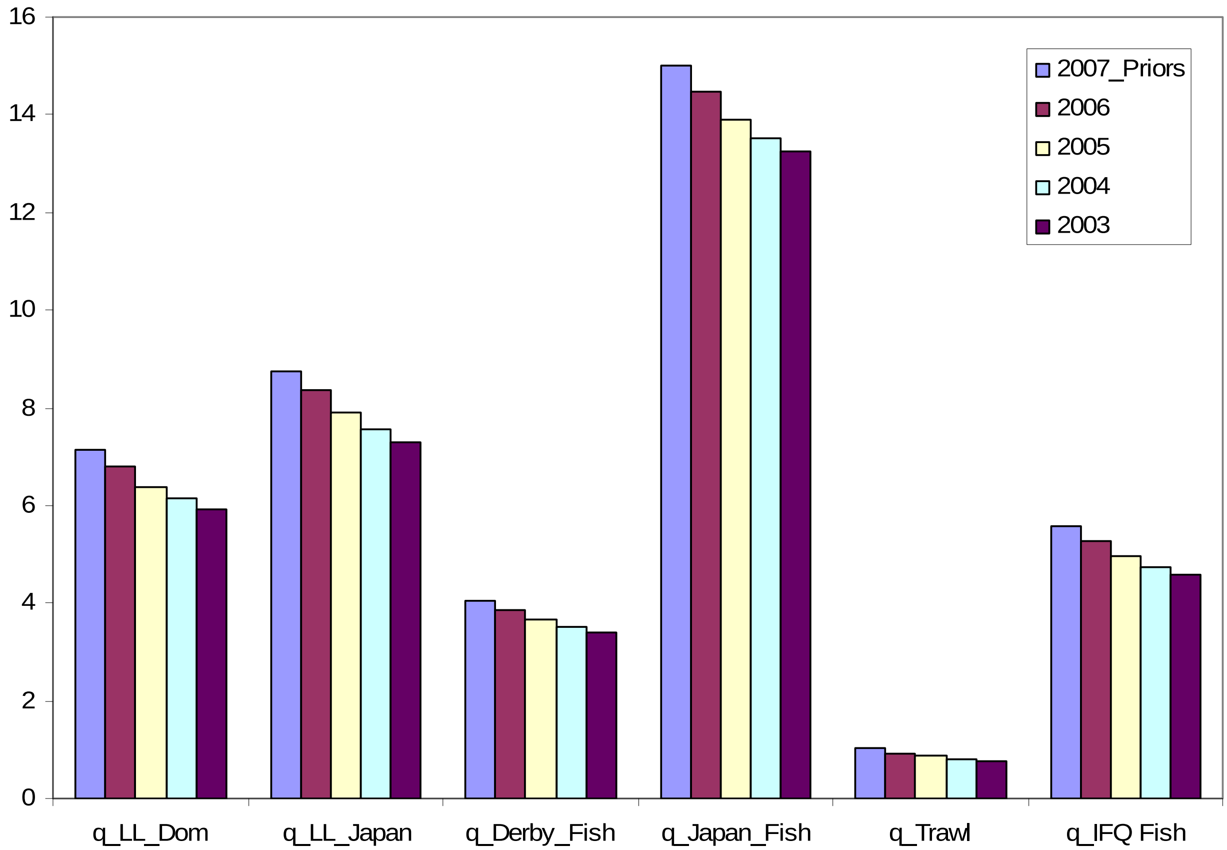


Figure 3.20. Retrospective trends for Model 3 (2007_Priors) for six catchability parameters from 2007 back to 2003.

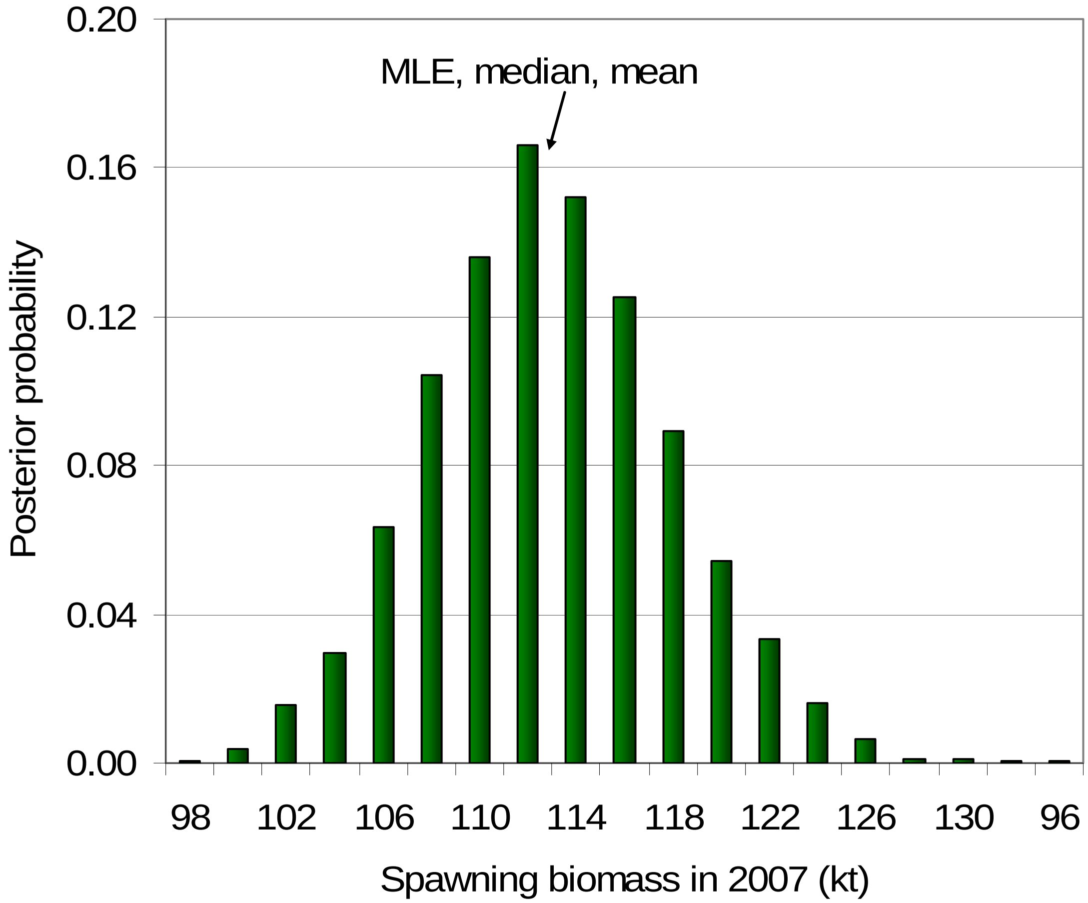


Figure 3.21. Posterior probability distribution for spawning biomass (thousands t) in 2007.

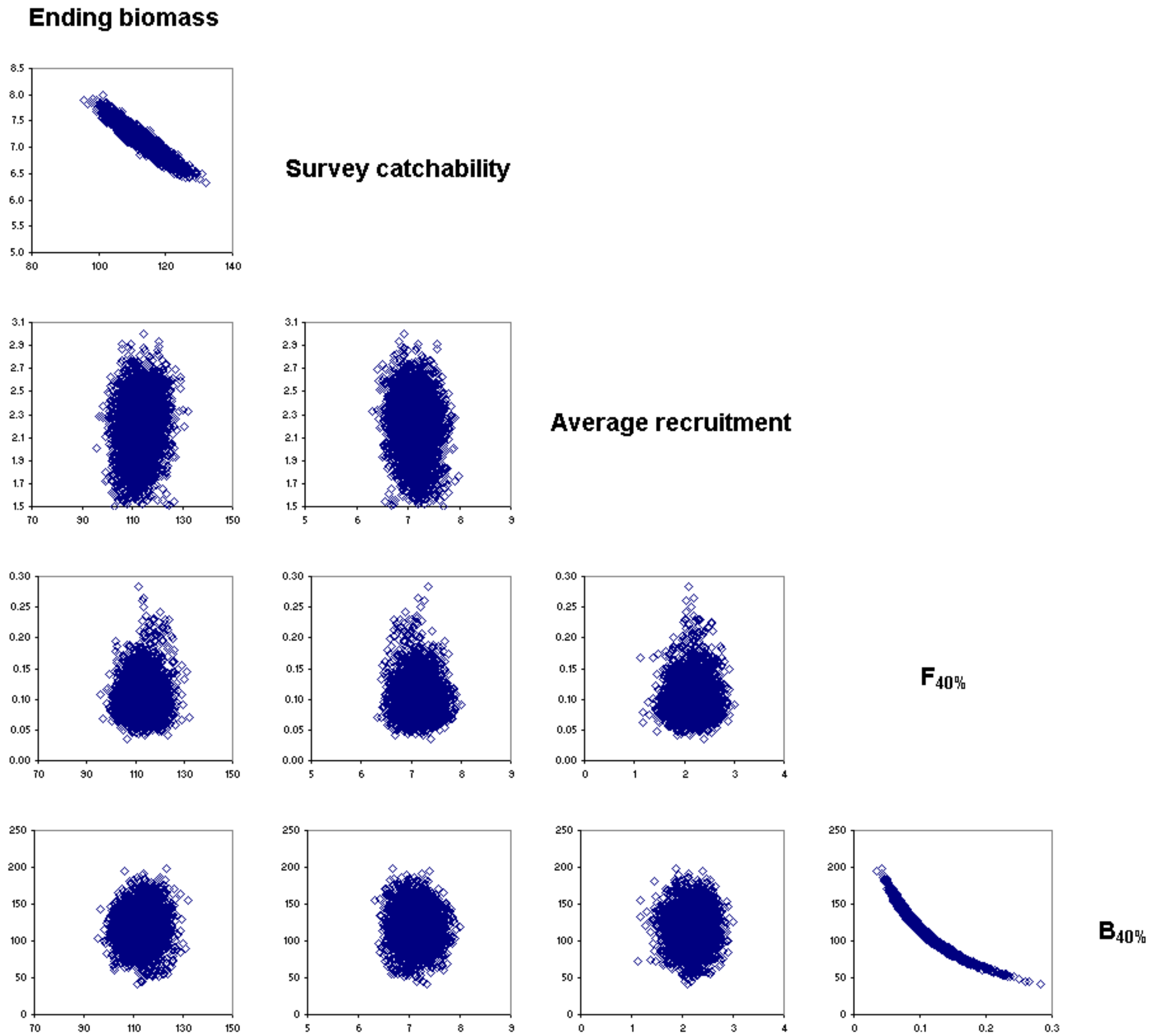
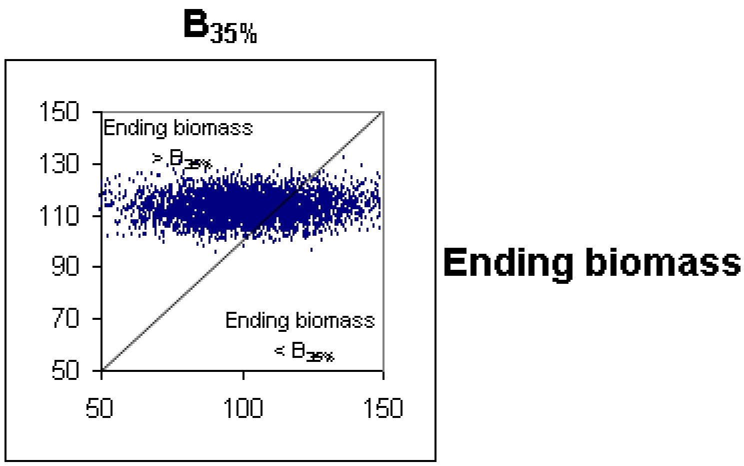


Figure 3.22. Pairwise scatterplots of key parameter MCMC runs.

a.



b.

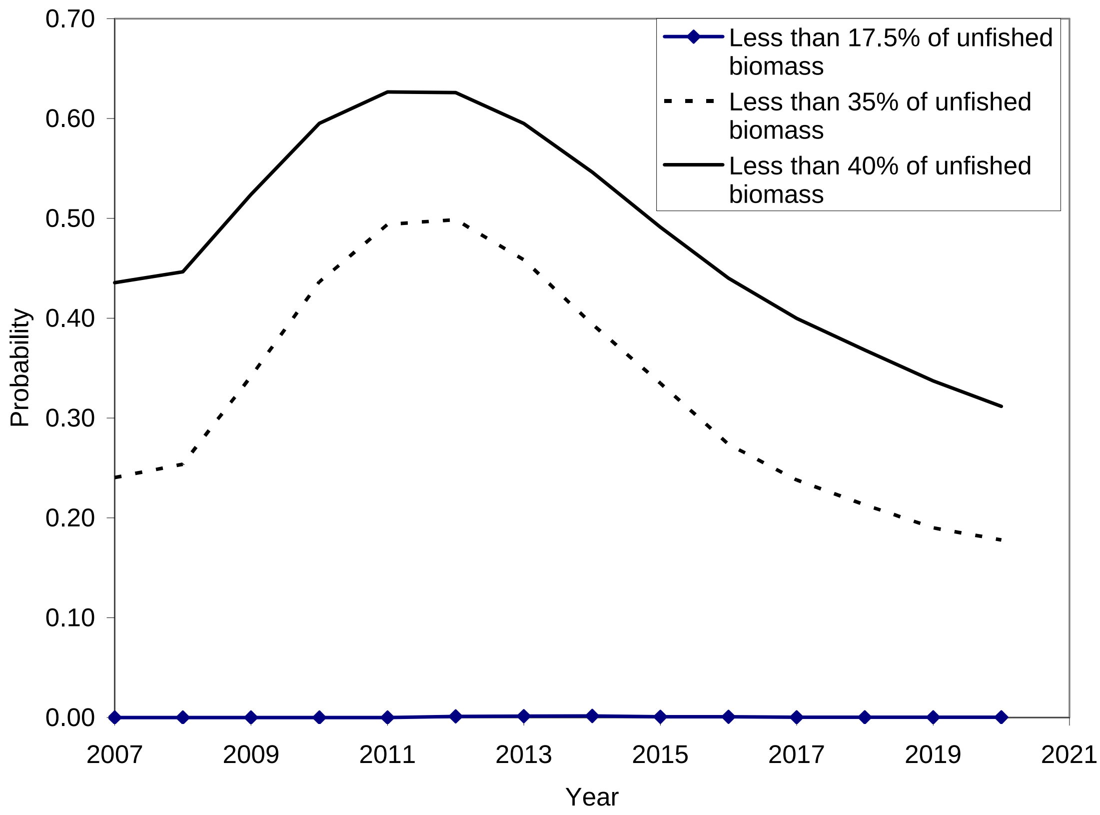


Figure 3.23a. Ending biomass was compared to $B_{35\%}$ for each MCMC run and the probability that ending biomass falls below $B_{35\%}$ was estimated (0.30). 3.23b. Probability that projected spawning biomass will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

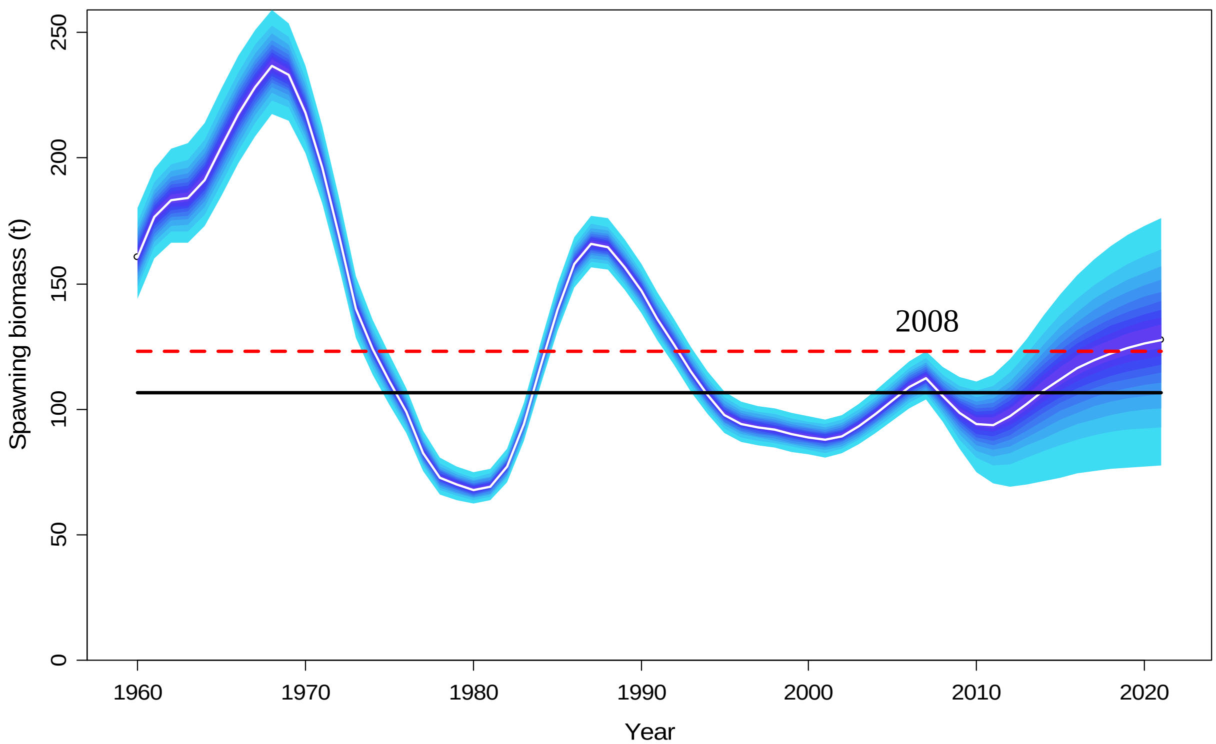


Figure 3.24. Estimates of female spawning biomass (thousands t) and their uncertainty. White line is the median and shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 5,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval.

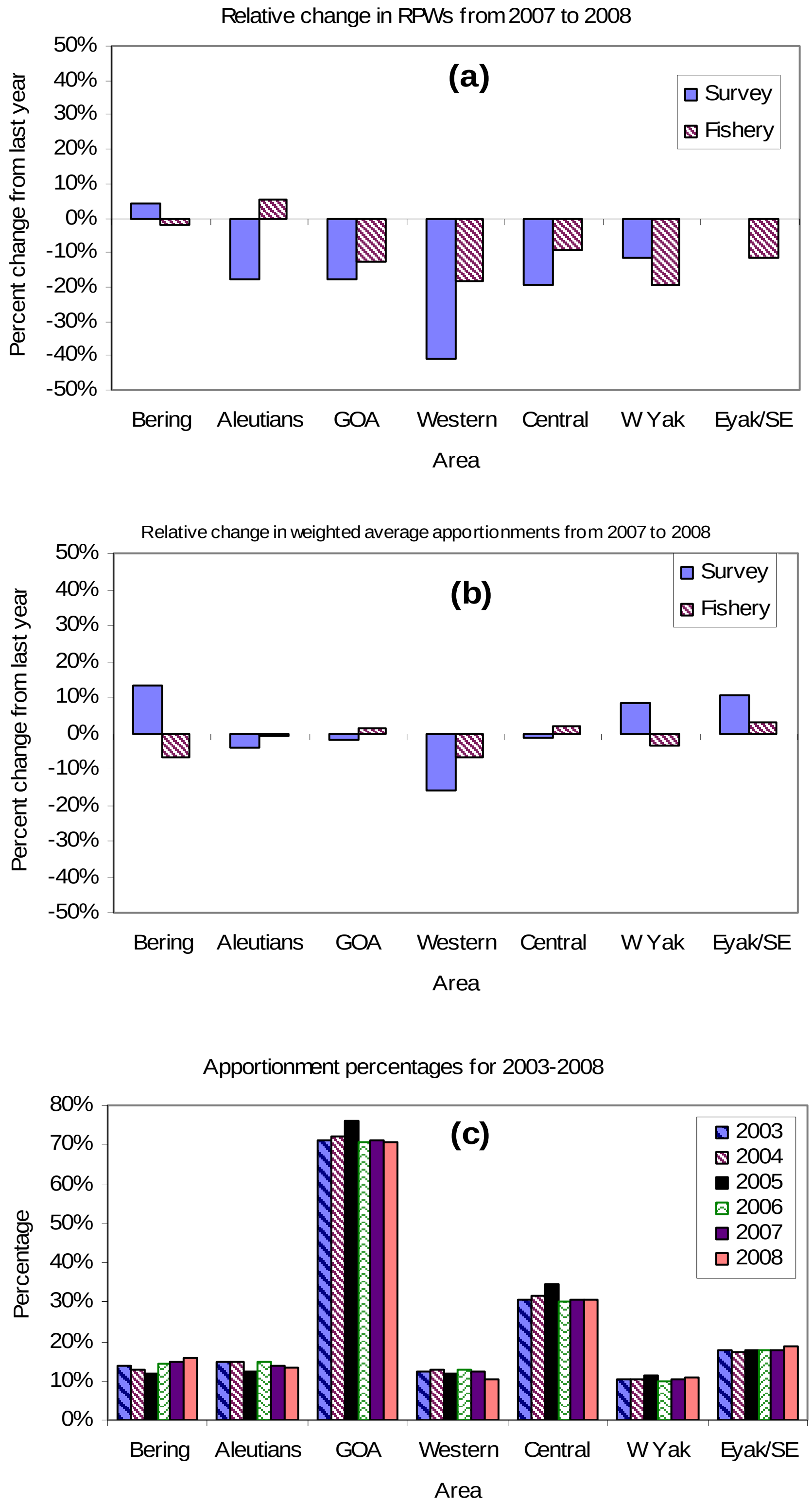
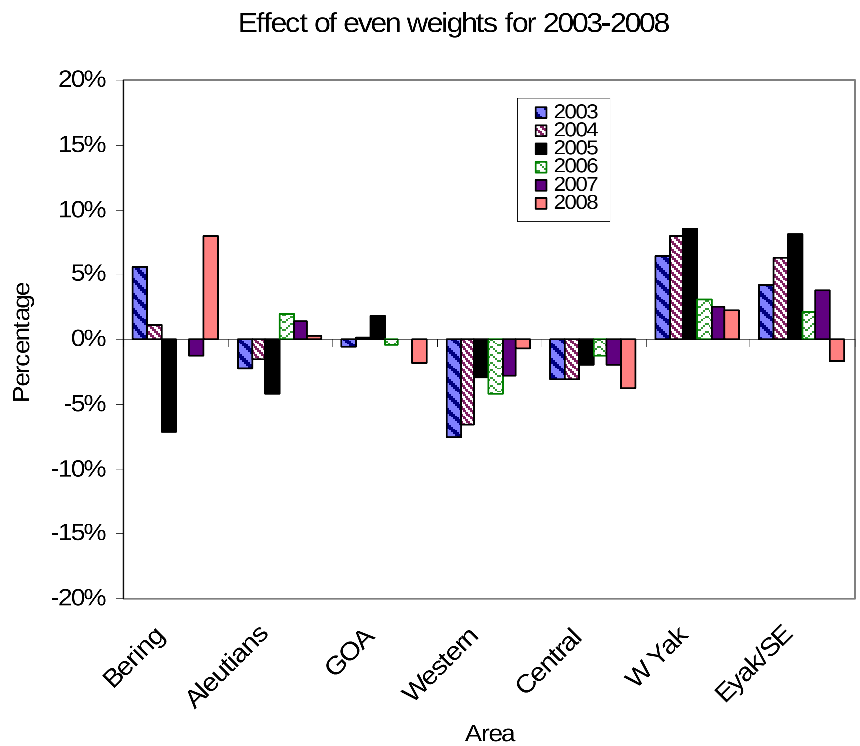


Figure 3.25. (a) The percentage change of each Relative Population Weight (RPW) index by area from 2007 assessment to the 2008 assessment. (b) The percentage change of the weighted average of apportionment by area. (c) The apportionment percentages by area of ABCs for 2003-2008.



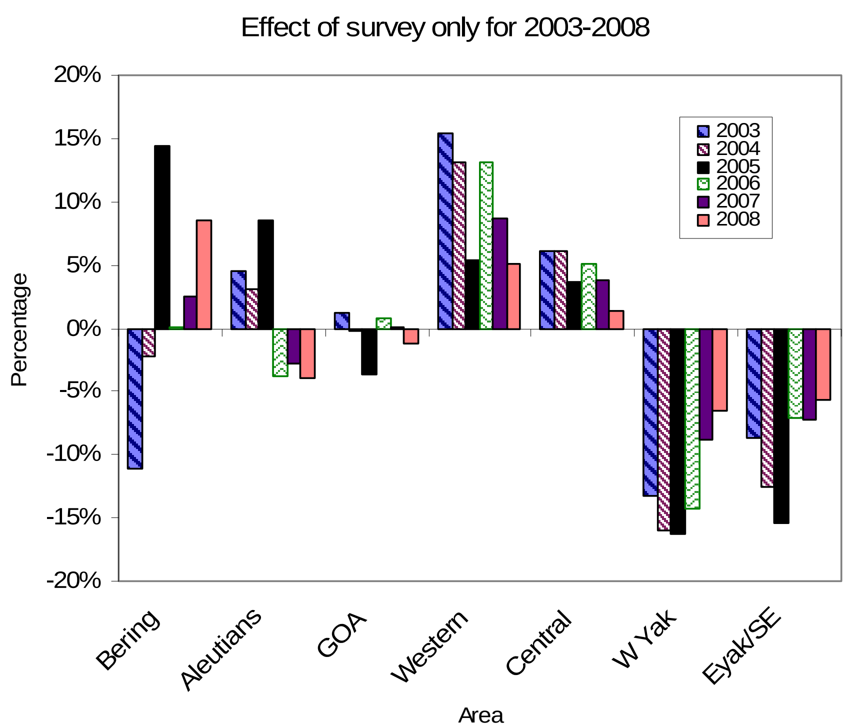


Figure 3.26. The relative change in apportionment for each area in each of the last six assessment cycles. Top panel shows the effect by area of using equal fishery and survey weighting. The bottom panel shows using only the survey to apportion.

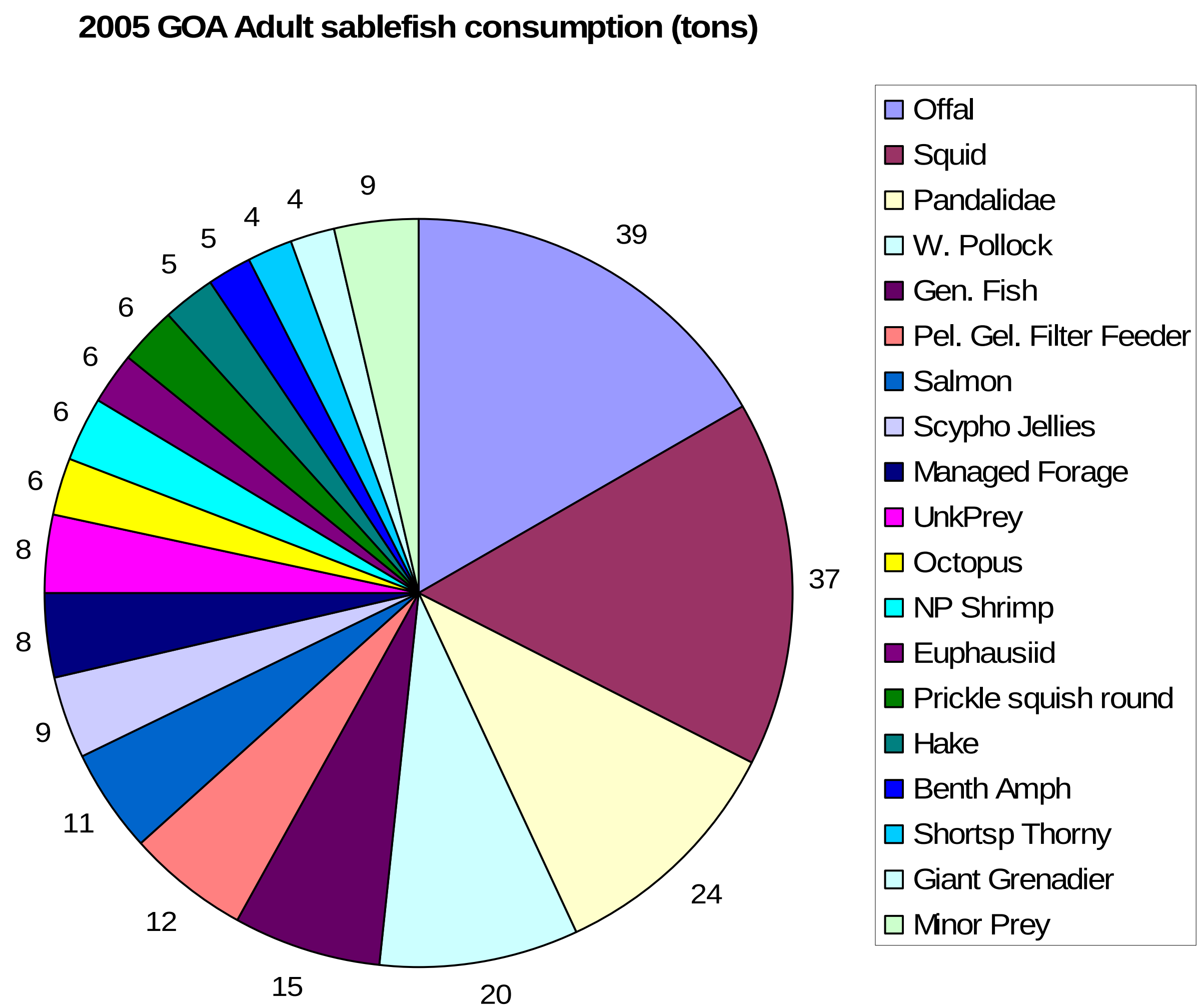


Figure 3.27. Consumption of prey in tons by sablefish in the Gulf of Alaska in 2005. Minor prey category are prey that totaled less than 4 tons of consumption.

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 trawl fishery interactions. Distribution of the survey schedule to all IFQ permit holders, radio announcements from the survey vessel, and the threat of a regulatory rolling closure have had intermittent success at reducing the annual number of longline fishery interactions.

From 2000-2005, the number of vessels fishing near survey stations has remained relatively low. In 2006 and 2007, however, the number of vessels found fishing near stations has increased to eight in each year. During the past several surveys, many fishing vessels were contacted by the survey vessel and in most cases fishermen were aware of the survey or willing to help out by fishing other grounds.

LONGLINE SURVEY - FISHERY INTERACTIONS

	Longline		Trawl		Pot		Total	
Year	**Stations**	**Vessels**	**Stations**	**Vessels**	**Stations**	**Vessels**	**Stations**	**Vessels**
1995	8	7	9	15	0	0	17	22
1996	11	18	15	17	0	0	26	35
1997	8	8	8	7	0	0	16	15
1998	10	9	0	0	0	0	10	9
1999	4	4	2	6	0	0	6	10
2000	10	10	0	0	0	0	10	10
2001	1	1	1	1	0	0	2	2
2002	3	3	0	0	0	0	3	3
2003	4	4	2	2	0	0	6	6
2004	5	5	0	0	1	1	6	6
2005	1	1	1	1	0	0	2	2
2006	6	6	1	2	0	0	7	8
2007	8	6	2	2	0	0	10	8

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions decreased in 1999 and 2001-2005. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance. We are concerned about potential survey/fishery interactions with the trawl fleet during the Rockfish Pilot Project. This management action lengthens the rockfish trawl fishery in the Central Gulf area which will likely cause an overlap between the trawl fishery and longline survey operations. In 2007 two trawl vessels in the Central Gulf were fishing within 5 miles of survey stations but we are uncertain if their fishing locations overlapped the stations. This is not atypical from what has been recorded in the past but we will continue to monitor survey/fishery interactions in this area.

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

Year	Echo integration trawl	Trawl	Japan US longline survey	Domestic longline survey	Total
1977		3,126			3,126
1978	23	14,302			14,325
1979		27,274	103,839		131,113
1980		69,738	114,055		183,793
1981	813	87,268	150,372		238,452
1982		107,898	239,696		347,595
1983	44	45,780	235,983		281,807
1984		127,432	284,431		411,864
1985		185,692	390,202		575,894
1986	80	123,419	395,851		519,350
1987		116,821	349,424		466,245
1988		14,570	389,382	302,670	706,622
1989		3,711	392,624	367,156	763,491
1990	94	25,835	272,274	366,236	664,439
1991		3,307	255,057	386,212	644,576
1992	168	10	281,380	392,607	674,165
1993	34	39,275	280,939	407,839	728,088
1994	65	852	270,793	395,443	667,153
1995				386,169	386,169
1996	0	12,686		430,447	439,165
1997	0	1,080		395,579	397,347
1998	5	25,528		324,957	336,096
1999	0	43,224		311,358	293,149
2000	0	2,316		289,966	271,654
2001	2	11,411		326,274	315,538
2002	154	2,607		309,098	295,617
2003	141	15,737		279,687	295,565
2004	53	1,826		287,732	289,611
2005	244	17,915		254,762	272,921
2006	19	1,816		286,518	288,353
2007	8	16,670		266,477	283,155

Appendix 3C.

Updated growth analysis for Alaska sablefish

Dana Hanselman[1] and Katy Howard[2]

[1]NOAA Fisheries

[1]University of Alaska-Fairbanks, Fisheries Division

1.0 EXECUTIVE SUMMARY

Growth parameters for Alaskan sablefish have not been updated for stock assessment purposes since Sasaki (1985). Meanwhile, many more sablefish have been aged with better geographic coverage. In this study we updated and corrected for bias in the older length-stratified data (1981-1993), analyzed newer randomly collected samples (1996-2004), and estimated new length-at-age and weight-at-age parameters. We then applied the updated growth data to the current stock assessment model. Our analyses showed that both male and female sablefish growth has changed significantly. Recently, sablefish are growing to a moderately larger maximum size. For use in the 2008 sablefish stock assessment, we recommend using the updated growth information divided into the two time periods (1981-1993 and 1996-2004). This new information provides the best fit to the data when applied in the stock assessment model and also provides results that are biologically reasonable.

1.1 INTRODUCTION

Growth parameters for Alaskan sablefish have not been updated since Sasaki (1985). When age-length conversion matrices were first added to the stock assessment in 1995, they were constructed from data (1987-1993) that were collected under a length-stratified sampling scheme. These data were randomized by using the method of Kimura and Chikuni (1987), but these data were from limited areas and years and were aggregated in a way that put too much weight on large fish. Meanwhile, many more sablefish have been aged with better geographic coverage. Since the last update of sablefish growth, significant changes in length-at-age have been discovered for other species and have caused substantial changes in stock assessment results, such as with Pacific halibut (Clark et al. 1999).To evaluate whether changes to sablefish growth have occurred, we examined all the length-at-age data that has been collected on the longline survey since 1981. We then examined the sensitivity of the current stock assessment model to utilizing this new growth information by showing the effects of different growth scenarios on biomass trajectories.

1.2 METHODS

1.2.1 Length-at-age analysis

Length, weight, and maturity of sablefish specimens have been collected from the inception of the Japanese longline survey in 1978 and continues in the current NMFS domestic longline survey that started in 1987. These data were collected under two different sampling designs.

From 1981-1993, ages were sampled under a length-stratified design (a pre-determined number of otolith pairs were collected for each length). Estimates produced from length-stratified data create biased estimates of mean length at age for the population. This bias is caused by ageing smaller and larger specimens more often than would be aged under a random sampling design. This results in the mean size-at-age for early age groups to be too small, while the mean-size-at-age for the oldest age-groups is too large (Goodyear 1995, Sigler et al. 1997, Bettoli and Miranda 2001).

Fish aged 31 years and older were pooled together into a 31+ age category (Hanselman et al. 2006). In order to correct this bias in the length-stratified data (1981-1993), we considered the length data for all years to be a random sample from the longline survey and used the samples to create bias corrected age-length samples of the 1981 – 1993 data, using the following method (Bettoli and Miranda 2001):

$$\overline{L}_i = \frac{\sum N_j (n_{ij}/n_j) l_i}{N_i}$$

where $\overline{L}_i$ is the mean length-at-age, l_i is the length-at-age in subsamble j, N_j is the number of fish in the jth length-group, n_j is the number of fish subsampled in the jth length-group, n_{ij} is the number of fish in the ith age group and the jth length group, and N_i is the number of fish in the ith age group over all j length-groups. The von Bertalanffy (LVB) age-length model was fitted to bias corrected mean length at age data from 1981 – 1993 and to randomly collected age-length data from 1996 – 2004 by nonlinear least squares (Figures 3 and 4),

$$\overline{L}_a = L_\infty (1 - e^{-\mathrm{K}(a - t_0)}) + \varepsilon_a$$

where ε_a is an additive error term, and L_∞, κ, and t_o are model parameters. L_∞ represents the average maximum length, κ describes the mean growth rate, and t_o describes the mean theoretical age a fish would have been zero length (McDevitt 1990, Quinn & Deriso 1999). LVB growth curves were further fit to data by area and sex to look for differences in growth within the two time periods among different areas. The results by area are presented, but not discussed in this document; because the stock assessment is not subdivided into small areas.

Standard errors, correlation estimates, and 95% confidence intervals for each LVB growth curve parameter were estimated using the Hessian method. Individual parameters of growth models were compared between different data sets using the univariate Fisher-Behrens test, in which variance is not assumed to be constant (Quinn & Deriso 1999).

Hotelling T^2 multiparameter tests, analogues to the one-parameter, two-sample Fisher-Behrens test described above, were carried out to compare growth curves from different data sets. The Cerrato approach (Quinn & Deriso 1999) was used because the assumption of common variance-covariance matrices did not need to be made (Quinn & Deriso 1999), as the difference of sample size between most data sets being tested is large. The variance-covariance matrix of $\Delta\hat{\theta}$ is now $\hat{\mathbf{V}}_3 = \hat{\mathbf{S}}_1 + \hat{\mathbf{S}}_2$ and the Hotelling T^2 test statistic is

$$T_3^{\,2} = (\Delta\theta)' \hat{\mathbf{V}}_3^{\,-1} (\Delta\hat{\theta}) .$$

The residual degrees of freedom for each data set is f = n – p for a growth model with p parameters. The effective overall degrees of freedom, f, is

$$f^{-1} = \frac{1}{f_1}\left(\frac{(\Delta\hat{\theta})'\hat{V}_3^{\,-1}\hat{S}_1\hat{V}_3(\Delta\hat{\theta})}{T_3^{\,2}}\right)^2 + \frac{1}{f_2}\left(\frac{(\Delta\hat{\theta})'\hat{V}_3^{\,-1}\hat{S}_2\hat{V}_3(\Delta\hat{\theta})}{T_3^{\,2}}\right)^2 .$$

The test statistic $T_3^{\,2}$ is then compared against the critical value

$$T_{1-\alpha}^{\;*2} = \frac{fp}{f - p + 1} F(p, f - p + 1)_{1-\alpha} ,$$

where $f = n - 2p$ and $F(p, f\text{-}p+1)_{1-\alpha}$ at $\alpha = 0.05$ is the appropriate tabled F critical value. The null hypothesis is rejected if $T_3^{\;2} > T_{1-\alpha}^{\;*2}$.

1.2.2 Weight-at-age

Weight-at-age data from the domestic longline survey was available from 1996-2004. This data was collected randomly and could be used directly without bias correction. To determine weight-at-age for the stock assessment model, first the length-weight relationship was determined using the typical nonlinear allometric relationship:

$$\hat{W} = \alpha L^{\beta} + \varepsilon$$

A common method to fit weight-at-age data is with the four-parameter LVB model. However, due to high parameter correlation with only one dependent variable, it is usually difficult to fit all four parameters at once, so a convenient method is to fix the allometric parameter β, determined from the length-weight relationship as a fixed parameter (Quinn and Deriso 1999). For this data set, there was a multiplicative error structure (Figure 1), so we log-transform the LVB model to:

$$\ln \hat{W}_a = \ln W_\infty + \beta \ln(1 - e^{-\kappa(a-t_0)}) + \varepsilon_a$$

where ε_a is a multiplicative error term, and $\ln W_\infty$ is exponentiated to obtain the estimate of W_∞. Nonlinear least squares was used to determine the best estimates of W_∞, κ, and t_0, while β is fixed. These estimates of weight-at-age were then applied to the stock assessment model.

To obtain weight-at-age estimates for the older growth regime, we applied the newly estimated length-weight relationship to the bias-corrected length-at-age relationship. This was preferable to the observed average weight-at-age previously used. Also, the length-weight relationship would be expected to change much less than the length-at-age relationship.

1.2.3 Application to stock assessment

Length-at-age information is used in the Alaskan sablefish stock assessment through age-length conversion matrices. These matrices are used to take estimated numbers-at-age in the model and predict lengths to compare with observed length compositions. If these matrices are developed with growth data that does not correspond with the true growth regime, then this can bias the model.

Data previously used in the model to populate the age-length conversion matrices were raw, but randomized lengths-at-ages from 1981-1993 (Figure 2). A smooth growth curve based on more years and geographic coverage for the historical growth and a new growth curve for recent length-at-age should better describe the underlying population dynamics.

The age-length conversion matrix is a matrix describing the probability of a fish of a given age to be a certain length. To develop this matrix, we use the estimated growth curve as the highest probability range of the matrix, but gave it normal error to account for the variability in length-at-age. The amount of error added to the growth curve is determined by fitting a nonlinear model to the observed standard deviations of each corresponding growth data set. This model takes the form:

$$\hat{s}_a = \alpha \ln(a) + \beta$$

where $\hat{s}_a$ is the estimated standard deviation of length-at-age at age a, α is a scalar parameter, a is the age of fish, and β is the intercept. Each age-group is weighted by its sample size in the nonlinear least squares procedure.

The resulting age-length conversion matrices were then applied to the current stock assessment model. Preliminary results are briefly compared for four new model runs with the accepted assessment model from last year. The base model from 2006 (**0**), updated weight-at-age data (**1**), updated 1981-1993 data (**2**), only 1996-2004 data (**3**), or updated growth information for both time periods (**4**).

We attempted to separate the weight-at-age relationships into the same two time periods as above. In all cases, the model fit was worse than simply using the new weight-at-age data. Therefore, we only show model results using the 1996-2004 weight-at-age data.

1.3 RESULTS

1.3.1 Length at Age Analysis:

Results from the comparison of LVB growth curves fit to updated 1981 – 1993 data against 1996 – 2004 data for all Alaskan waters show similar results for both male and female sablefish (Figure 3, Tables 1 and 2): older (1981 – 1993) data fish display smaller asymptotic lengths (L_∞), slower growth rates (κ), and smaller t_o estimates. Results of the univariate Fisher-Behrens test on the male data show that only the L_∞ parameter is significantly different ($p < 0.01$) between the old (1981 – 1993) and new (1996 – 2004) data, but according to the multiparameter Hotelling T^2 statistical test, the two growth curves are significantly different ($p < 0.01$). Test results on the female data show that the L_∞ ($p = 0.00$) and t_o ($p < 0.01$) parameter estimates are significantly different, and that the two growth curves ($p < 0.01$) are significantly different as well.

Current average maximum length estimates used in the 2007 Alaska Sablefish Stock Assessment are 69 cm for males and 83 cm for females (Hanselman et al. 2006). Improving the estimates of the 1981-1993 data resulted in lower maximum size at age than that currently used in the stock assessment model. However, the newer data shows larger lengths-at-age then the updated older data. Parameter estimates by region and time period are shown in Tables 3 and 4.

1.3.2 Weight at Age Analysis:

Results of the length-weight and weight-at-age analysis are shown in Table 5. Average maximum weight was 3.16 kg for males and 5.47 kg for females. These estimates of maximum weight are smaller than the observed average values currently used in the stock assessment.

1.3.3 Stock assessment application

The model fitted the standard deviation of length-at-age data well (Figure 4). Using these relationships, we constructed new age-length conversion matrices for the two time periods using the new growth curves described above. The resulting matrices (Figure 5) are smooth and more realistic than the rough matrices used in Hanselman et al. (2006, Figure 2).

When the updated weight-at-age data was applied to the model (**1**), the effect was a slight downward shift of the entire spawning biomass curve (Figure 6). This result is expected as the overall weight-at-age curve is slightly below the historic observed weight-at-age data previously in the model. When we exchanged the older observed length-at-age data with the bias-corrected LVB fit (**2**) the curve generally shifted up slightly from the base model (**0**) mainly at the peak biomasses, and substantially from Model **1**. When we apply only the new growth curve (1996-2004) to the model (**3**), this results in a dramatic downward revision of estimated spawning biomass (Figure 6).

Finally, when we choose two growth regimes and apply both growth data sets (**4**), the estimated spawning biomass series returned to similar magnitudes as the base model (**0**) (Figure 6). The principal difference between model **4** and the base model (**0**) was that the lows in estimated spawning biomass were lower, and the initial biomass in 1960 was quite a bit higher. This result of model **4** is logical because it would be expected that initial biomass should be high because fishing mortality was low prior to 1960. Another pertinent difference between model **4** and the base model is that although the estimated spawning biomass in recent years is slightly lower in model **4**, the upward slope of the recent trajectory is steeper than in the base model. Therefore, Model **4** will likely yield similar harvest recommendations to the base model in the near future.

Updating the growth data in general improved the fit to the data (Figure 7). Changing the weight-at-age data improved the fit to the data slightly, but adding the bias-corrected age-length matrices only from the older data (**2**) yielded a fit similar to the base model (**0**). Using the newer growth data (**3** and **4**), yielded substantially better fits than the base model (**0**), and splitting the growth into two time periods (**4**) yielded the best fit to the data.

1.4 DISCUSSION

Our analyses show that there has been some change in the growth of both male and female sablefish. While these changes were not severe, they were significantly different. It appears that recently sablefish are growing to a larger maximum size.

For use in the 2008 sablefish stock assessment, we recommend using the updated growth information divided into the two time periods. Not only does it provide the best fit to the data, it provides results that are biologically reasonable. The choice of where to split growth regimes was not based on a visible shift in growth at that time, but on a change in sampling design on the longline survey. Separating these data periods buffers the model from any other unforeseen effects that the sampling design change may have had on the data besides the bias expected on the tails of the distribution. The addition of the newest data will be more biologically realistic, while only having nominal effects on harvest rates.

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Table 1. Male sablefish length-at-Age LVB parameter estimates and test results.

	1981 - 1993		1996 - 2004					Univariate Tests	
	MLE	SE	MLE	SE	$\Delta\theta$	*z*	*f_e*	P-value	Conclusion
L_∞	65.269	0.341	67.774	0.127	-2.50	6.882	35	0.000	Reject null
k	0.227	0.029	0.290	0.009	-0.06	2.033	32	0.051	Fail to reject
t_o	-4.092	0.936	-2.273	0.171	-1.81	1.911	29	0.066	Fail to reject
RSS	34		91,089						
n	30		4,889						

Multivariate Test

T_3^2	183.071
P-value	0.000
f_e	36.41
num df	3
den df	34
Fcrit	2.883
T^{*2}	9.150
Conclusion:	Reject null

Table 2. Female sablefish length-at-Age LVB parameter estimates and test results.

	1981 - 1993		1996 - 2004					Univariate Tests	
	MLE	SE	MLE	SE	$\Delta\theta$	*z*	*f_e*	P-value	Conclusion
L_∞	75.568	0.460	80.220	0.221	-4.65	9.116	42	0.000	Reject null
k	0.208	0.018	0.222	0.005	-0.01	0.758	33	0.454	Fail to reject
t_o	-3.629	0.523	-1.949	0.119	-1.67	3.131	31	0.004	Reject null
RSS	73		191,866						
n	31		5767						

Multivariate Test

T_3^2	164.595
P-value	0.000
f_e	40.18
num df	3
den df	38
Fcrit	2.852
T^{*2}	9.003
Conclusion:	Reject null

Table 3. Estimated LVB growth curve parameters for male sablefish stratified by region and time period in Alaskan waters.

Area	Time Frame	L_∞	κ	t_0	RSS	n
Chirikof Slope	1981 – 1993	70.863	0.226	-2.587	318.449	26
	1996 - 2004	67.272	0.335	-1.617	4430.503	294
Aleutian Slope	1981 - 1993	67.536	0.170	-6.255	105.491	30
	1996 - 2004	67.723	0.237	-3.323	4650.722	285
Kodiak Slope	1981 - 1993	69.615	0.138	-7.413	529.277	29
	1996 - 2004	66.595	0.357	-2.052	9195.078	542
Shumagin Slope	1981 - 1993	65.699	0.328	-1.658	207.361	30
	1996 - 2004	70.076	0.193	-4.501	529384.2	267
Bering Slope	1981 - 1993	66.108	0.149	-8.648	116.423	30
	1996 - 2004	69.269	0.237	-3.479	6052.073	363
Southeast Slope	1981 - 1993	70.818	0.097	-11.369	203.389	30
	1996 - 2004	68.343	0.307	-1.714	13227.5	605

Table 4. Estimated LVB growth curve parameters for female sablefish stratified by region and time period in Alaskan waters.

Area	Time Frame	L_∞	κ	t_0	RSS	n
Chirikof Slope	1981 - 1993	78.151	0.197	-2.659	551.287	26
	1996 - 2004	77.247	0.296	-0.798	13303.94	485
Aleutian Slope	1981 - 1993	74.679	0.185	-3.800	440.07	30
	1996 - 2004	77.804	0.216	-2.267	25557.06	795
Kodiak Slope	1981 - 1993	75.163	0.243	-2.719	896.831	30
	1996 - 2004	78.605	0.314	-0.483	19207.57	602
Shumagin Slope	1981 - 1993	75.379	0.225	-2.552	431.381	28
	1996 - 2004	81.298	0.183	-2.813	1453269	563
Bering Slope	1981 - 1993	69.468	0.241	-3.977	462.229	30
	1996 - 2004	76.380	0.224	-2.692	12149.44	533
Southeast Slope	1981 - 1993	78.854	0.153	-5.348	361.443	31
	1996 - 2004	80.919	0.268	-0.854	19999.35	515

Table 5. Estimated length-weight and weight-at-age relationships for 1996-2004 sablefish specimen data.

	Males	Females
n	4889	5767
	Length-weight	
α	1.24E-05	1.01E-05
β	2.960	3.015
RSS	447.3593054	1044.259777
	Weight-at-age	
W_∞	3.162	5.471
κ	0.356	0.238
t_0	-1.129	-1.387
β	2.960	3.015
RSS	288.874	486.526

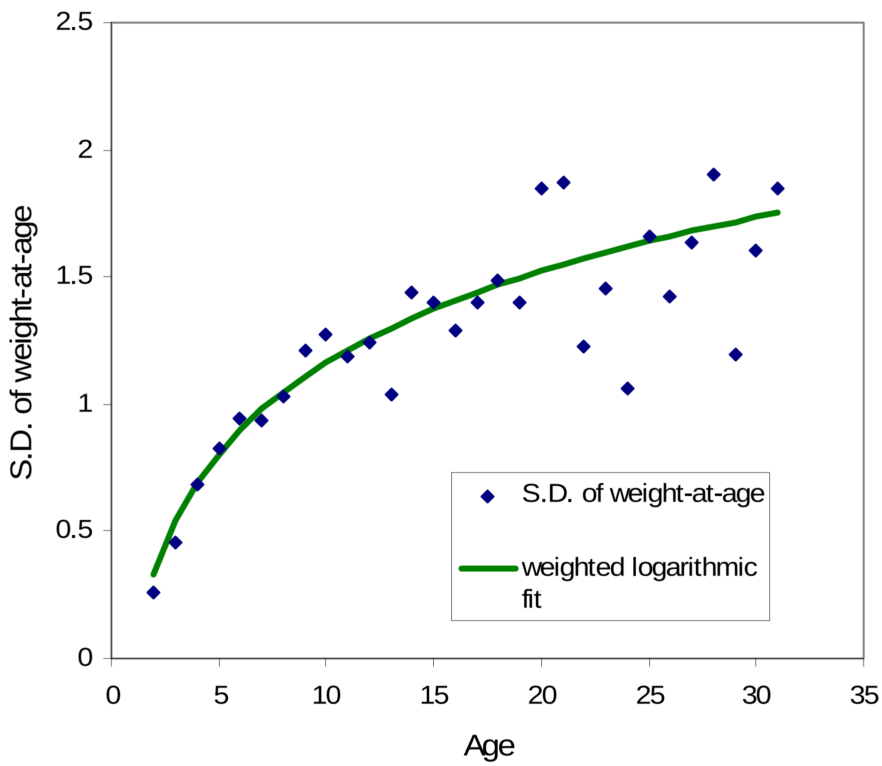

Figure 1. Standard deviation (S.D.) by age of weight for female sablefish.

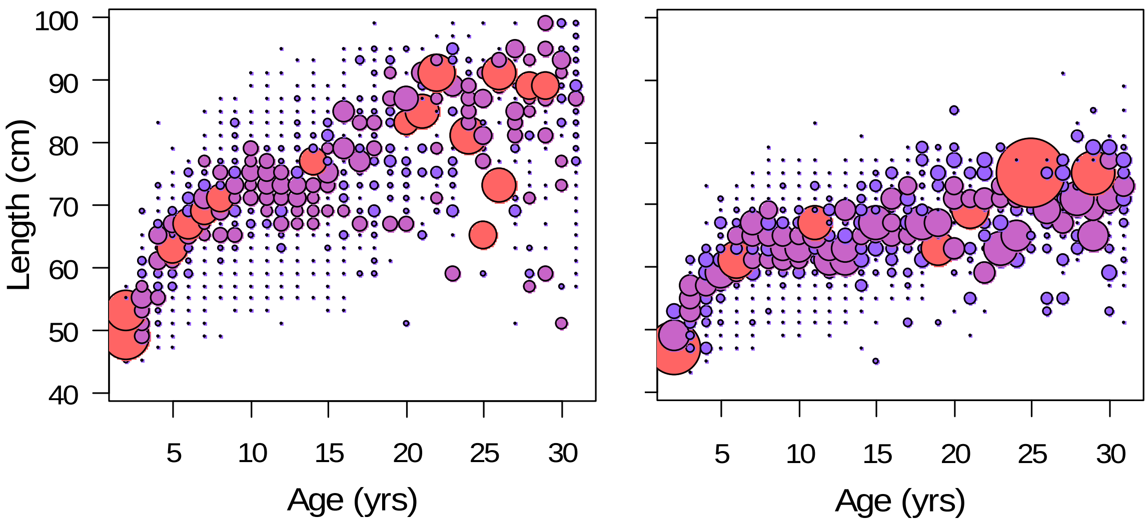

Figure 2. Age length conversion matrices using observed lengths-at-age from 1981-1993 for females on left and males on right.

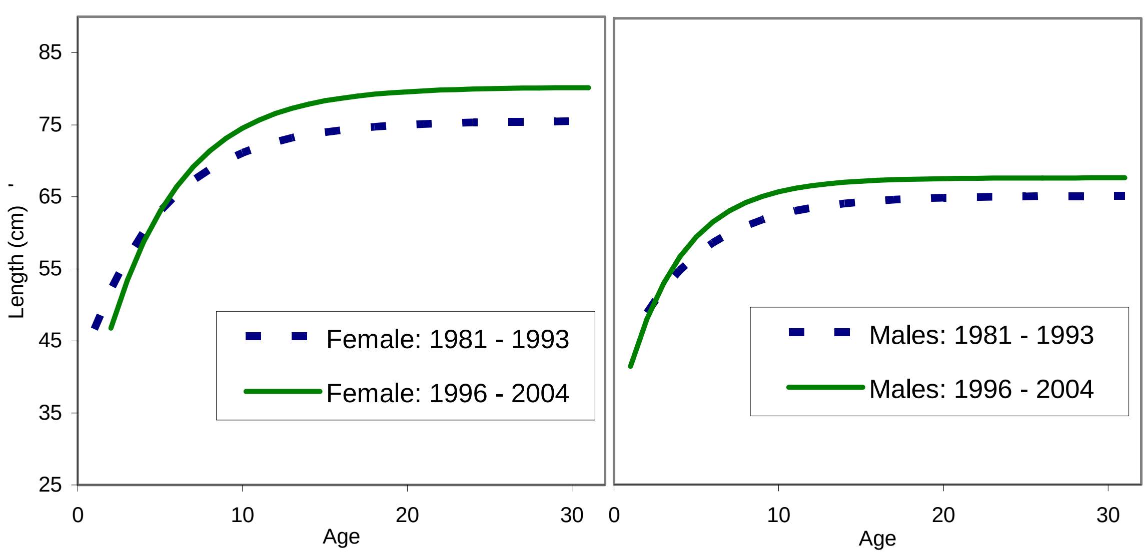

Figure 3: Comparison of sablefish LVB fit to length-at-age from 1981 to 1993 bias-corrected data (blue dashes) and 1996 to 2004 raw data (green solid line). Female left panel, males on right.

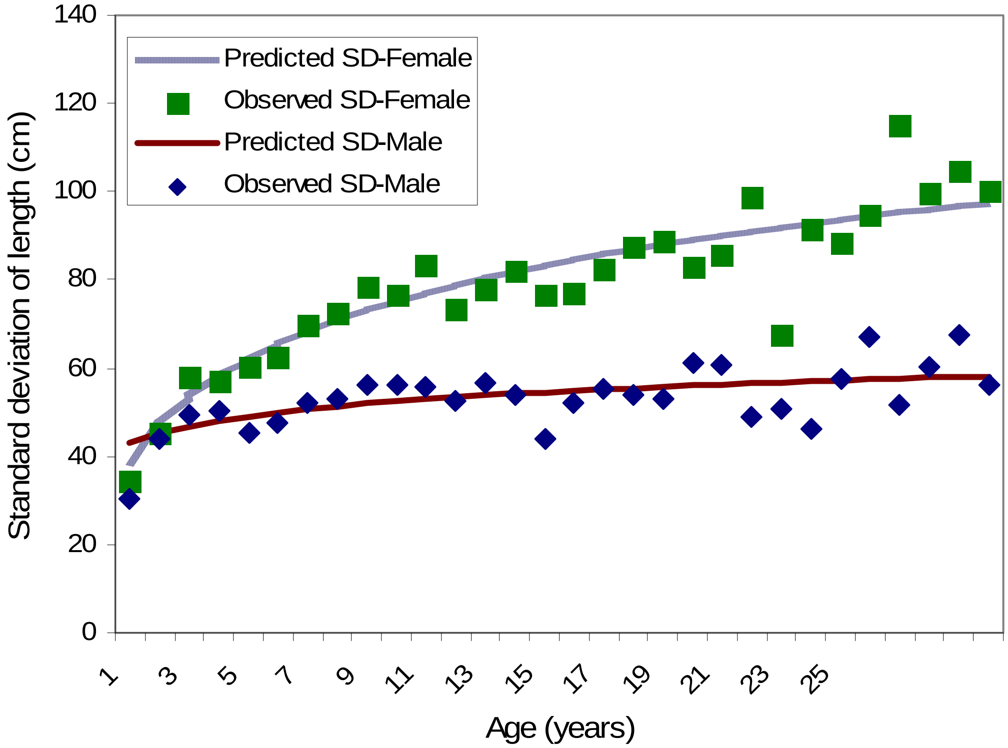

Figure 4. Standard deviations used for normal error in age-length conversion matrices.

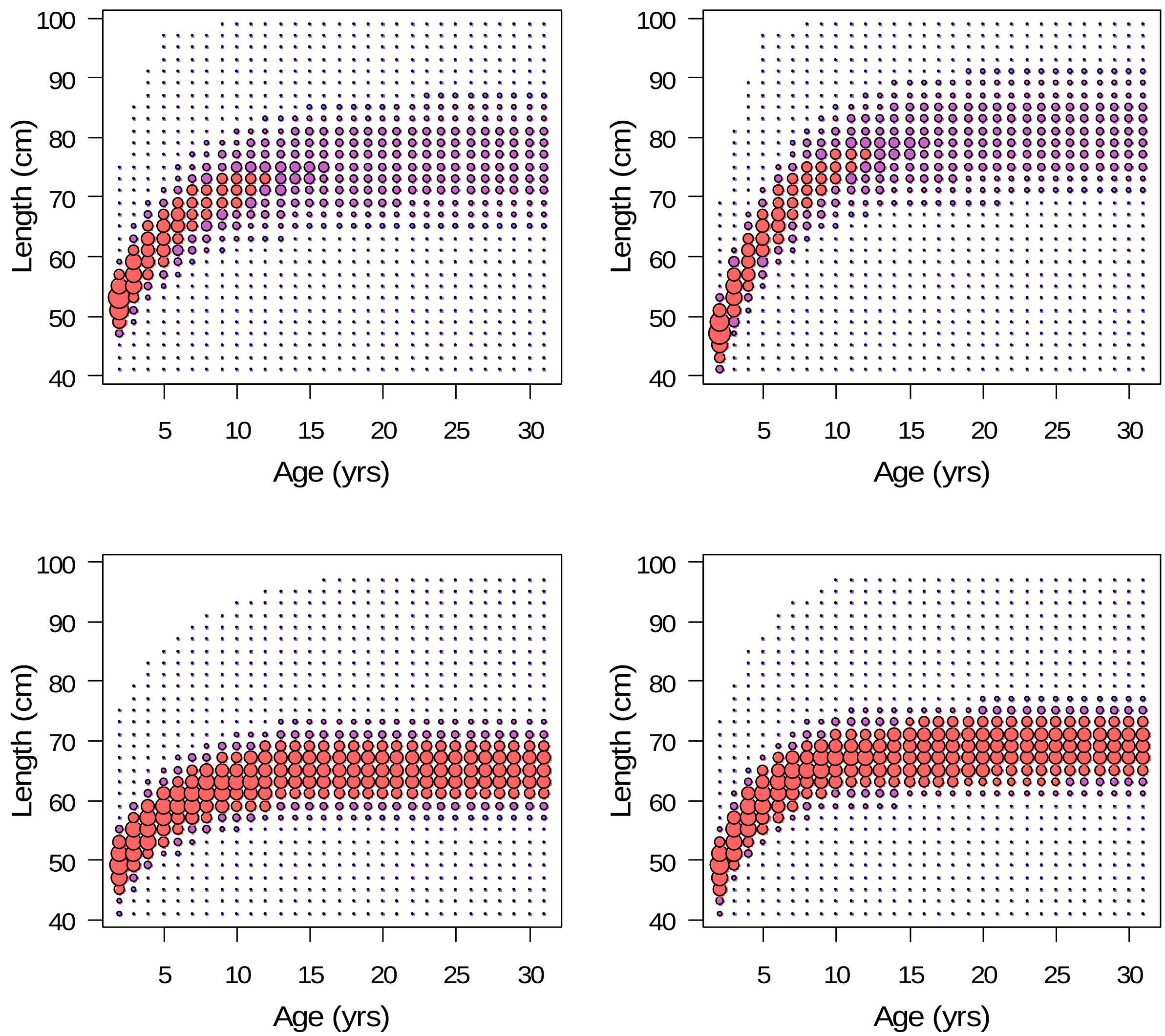

Figure 5. New age-length conversion matrices created from new growth analysis for sablefish. Top panels are female, bottom panel are males, left is 1981-1993, right is 1996-2004.

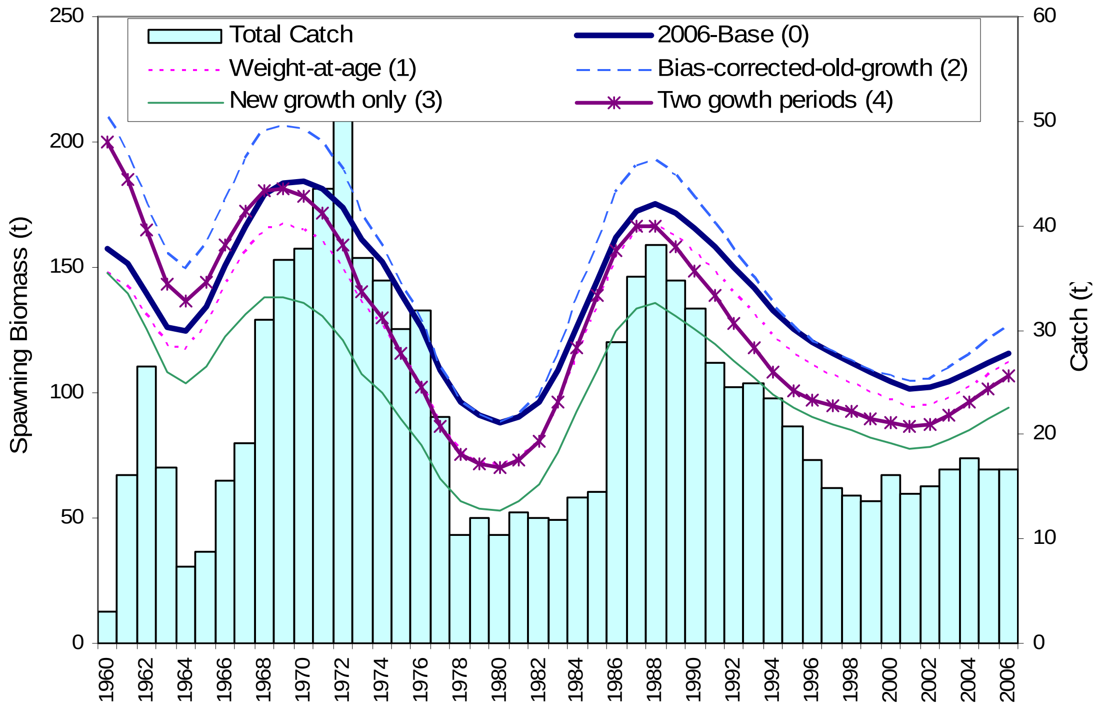

Figure 6. Spawning biomass trajectories for different growth scenarios compared to the 2006 sablefish model. Bars are catch.

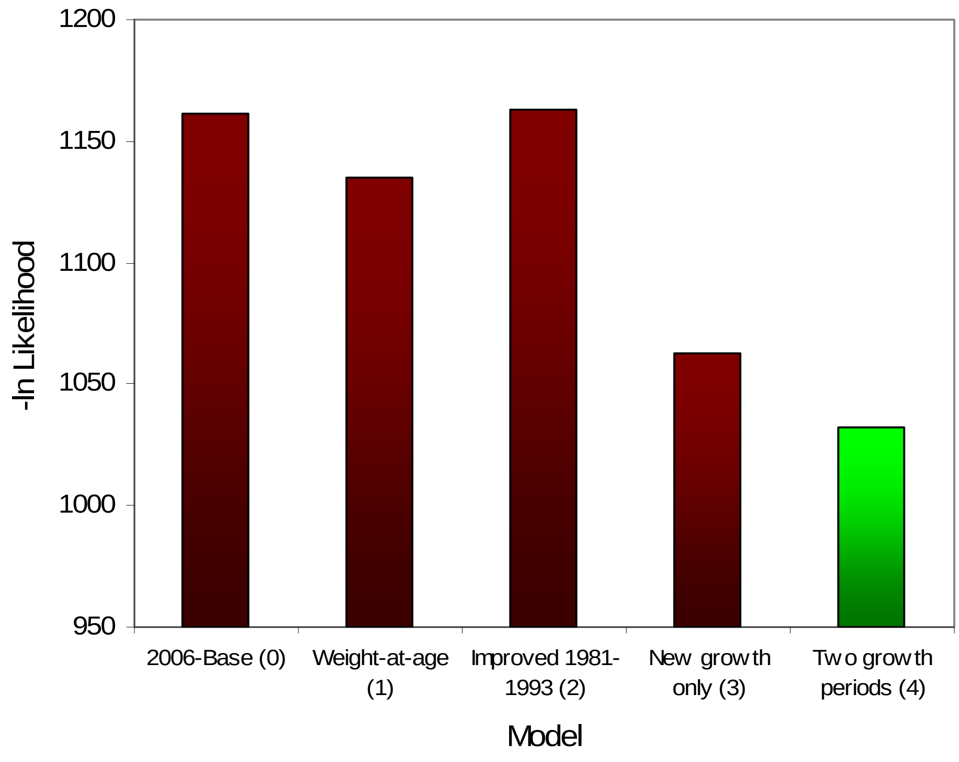

Figure 7. Comparison of fits for different growth scenarios in terms of objective function total of data component fits (-ln Likelihood).

Appendix 3D
Development of prior distributions for sablefish catchability

Dana Hanselman

Introduction

In the Alaska sablefish stock assessment, prior distributions are used to apply knowledge from outside of the model to assist in determining parameters that are difficult to estimate. Catchability (*q*) is one of these key parameters that has large consequences to the model as it is directly related to resultant biomass estimates. Currently, the prior distributions in the model are based on previous model estimates of catchability with an imprecise distribution (CV=500%). In this analysis, we use NMFS trawl survey biomass estimates to estimate longline survey and fishery catchability and to estimate the relative catchability of the GOA trawl survey (<500 meters in depth) to total trawl estimated biomass. These values can then be translated into the model as prior distributions for estimating catchability of each abundance index.

Methods

NMFS has bottom trawl sablefish biomass estimates for the Gulf of Alaska and the Aleutian Islands since 1980 on a triennial, then biennial basis. We use a combination of these two surveys biomass estimates, in addition to an average adjustment for biomass contained on the Bering Sea slope as an estimate of true biomass. This adjustment is used in lieu of a consistent trawl survey of the Bering Sea slope. We then use the ratio of each abundance index in the model to these estimates as an estimate of catchability. The formula for each yearly catchability index is:

$$\hat{q}_{iy} = \frac{\hat{B}_{iy}}{\hat{B}_{trawl,y}\left(1+p(BS)\right)}$$

where $\hat{q}_{iy}$ is the estimate of catchability for the *i*th index in year *y*, $\hat{B}_{iy}$ is the estimated biomass for the *i*th index in year *y*, $\hat{B}_{trawl,y}\left(1+p(BS)\right)$, is the estimated trawl biomass for Gulf of Alaska, Aleutian Islands, adjusted upward by the average additional biomass in the Bering Sea, $p(BS)$, estimated by the longline survey.

The variance of the annual catchability is estimated with the delta method (Shou 2002).

$$\mathrm{var}(\hat{q}_{iy}) = \frac{\hat{B}_{iy}^{\;2}}{\left(1+p(BS)\right)^2 \hat{B}_{trawl,y}^{\;2}}\left[\frac{\mathrm{var}\left(\hat{B}_{iy}\right)}{\hat{B}_{iy}^{\;2}} + \frac{\left(1+p(BS)\right)^2 \mathrm{var}\left(\hat{B}_{trawl,y}\right)}{\left(1+p(BS)\right)^2 \hat{B}_{trawl,y}^{\;2}}\right]$$

The formula for the overall catchability prior mean is:

$$\hat{q}_i = \frac{\sum \hat{q}_{iy}}{n}$$

and then the coefficient of variation for the prior mean is found from the variance of two stage sampling (Cochran 1977), ignoring the finite population correction is approximated by:

$$CV(\hat{q}_i) = \frac{\sqrt{\mathrm{var}(\hat{q}_i)/n + \mathrm{var}(\hat{q}_{iy})/m}}{\hat{q}}$$

where $\mathrm{var}(\hat{q}_i)$ is the variance among means, and $\mathrm{var}(\hat{q}_{iy})$ is the variance within means shown above.

These results are then used as the prior mean and coefficient of variation for lognormal prior distributions to be applied in the sablefish stock assessment as an alternative to the current diffuse prior distributions being used.

Results

Catchability estimates were computed for each abundance index used in the stock assessment model (Table 1). Lognormal priors were constructed with the means and CVs derived from the analysis. These distributions are shown in Figure 1. The catchability mean for the domestic longline survey is higher than the Japanese longline survey index and domestic fishery index which corroborates previous estimates in Kimura and Zenger (1997). The mean value for the NMFS GOA trawl survey index is higher (0.7) than the mean value previously used for the diffuse prior used in the 2007 sablefish assessment (0.3).

Discussion

New prior distributions for catchability appear to be reasonable values, and are within range of previous values used in the sablefish stock assessment. The most important assumption in this analysis that may be violated is that the trawl survey catchability is equal to one. It is more likely that the true catchability of the trawl survey is less than, rather than more than one, both because sablefish are fast swimmers and because the trawl survey has limited coverage of the full depth distribution of sablefish. If this is true, then assuming a trawl catchability of one is a precautionary assumption. However, there is enough uncertainty in the derived prior distributions for the data to provide substantial influence on the final estimate, yet there is enough precision to guide the model on how each catchability value is related between indices.

Applying these distributions to the model should result in greater model stability, and more precise estimates of biomass. The effect on harvest recommendations will likely be small, but directionality is not obvious due to interaction among the catchabilities and between other parameters such as selectivity.

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Table 1. Values and results used in catchability estimation for each index.

NMFS Domestic LL survey

Year	$\hat{B}_{iy}{}^2$	$\sqrt{\text{var}\left(\hat{B}_{iy}\right)}$	$\hat{B}_{trawl,y}$	$\hat{q}_{iy}$	$\text{var}(\hat{q}_{iy})$	$\sqrt{\text{var}(\hat{q}_{iy})}$	CV
1990	2141	214.1	222.563	9.620	3.673	1.916	20%
1993	1894	189.4	253.168	7.481	1.957	1.399	19%
1996	2017	201.7	151.562	13.308	6.560	2.561	19%
1999	1740	174	180.328	9.649	1.536	1.239	13%
2001	1798	179.8	195.054	9.218	6.001	2.450	27%
2003	1759	175.9	247.355	7.111	1.094	1.046	15%
2005	1695	169.5	278.618	6.084	0.675	0.822	14%

$\left(1+p(BS)\right)$	1.136		
$\hat{q}_{iy}$	8.924	Grand Variance	8.696
$\sqrt{\text{var}(\hat{q}_i)}$	2.372	Grand Stdev	2.949
CV	27%		
$\hat{q}_i$	**7.857**	Grand CV	**33%**

Table 1 (continued). Values and results used in catchability estimation for each index.

Japanese LL survey

Year	$\hat{B}_{iy}{}^2$	$\sqrt{\mathrm{var}\left(\hat{B}_{iy}\right)}$	$\hat{B}_{trawl,y}$	$\hat{q}_{iy}$	$\mathrm{var}(\hat{q}_{iy})$	$\sqrt{\mathrm{var}(\hat{q}_{iy})}$	CV
1984	1804	180.4	402.221	4.485	0.457	0.676	15%
1987	2068	206.8	405.620	5.098	0.576	0.759	15%
1990	1454	145.4	222.563	6.533	1.694	1.301	20%
1993	1318	131.8	253.168	5.206	0.947	0.973	19%

$\left(1+p(BS)\right)$	1.136		
$\hat{q}_{iy}$	5.331	Grand Variance	1.662
$\sqrt{\mathrm{var}(\hat{q}_i)}$	0.862	Grand Stdev	1.289
CV	16%		
$\hat{q}_i$	**4.693**	Grand CV	**24%**

NMFS Domestic Fishery CPUE

Year	$\hat{B}_{iy}{}^2$	$\sqrt{\mathrm{var}\left(\hat{B}_{iy}\right)}$	$\hat{B}_{trawl,y}$	$\hat{q}_{iy}$	$\mathrm{var}(\hat{q}_{iy})$	$\sqrt{\mathrm{var}(\hat{q}_{iy})}$	CV
1990	1201	120.1	222.563	5.396	1.156	1.075	20%
1993	904	90.4	253.168	3.571	0.446	0.668	19%
1996	1201	120.1	151.562	7.924	2.326	1.525	19%
1999	1316	131.5729	180.328	7.296	0.878	0.937	13%
2001	1110	111.0479	195.054	5.693	2.289	1.513	27%
2003	1218	121.765	247.355	4.923	0.524	0.724	15%
2005	1307	130.69	278.618	4.691	0.401	0.634	14%

$\left(1+p(BS)\right)$	1.136		
$\hat{q}_{iy}$	5.642	Grand Variance	3.433
$\sqrt{\mathrm{var}(\hat{q}_i)}$	1.512	Grand Stdev	1.853
CV	27%		
$\hat{q}_i$	**4.967**	Grand CV	**33%**

Table 1 (continued). Values and results used in catchability estimation for each index.

NMFS GOA Trawl survey (<500m)

Year	$\hat{B}_{iy}{}^{2}$	$\sqrt{\mathrm{var}\left(\hat{B}_{iy}\right)}$	$\hat{B}_{trawl,y}$	$\hat{q}_{iy}$	$\mathrm{var}(\hat{q}_{iy})$	$\sqrt{\mathrm{var}(\hat{q}_{iy})}$	CV
1984	294.429	43.53	402.221	0.732	0.019	0.136	19%
1987	271.099	38.17	405.620	0.668	0.014	0.120	18%
1990	213.882	37.57	222.563	0.961	0.056	0.236	25%
1993	249.516	39.98	253.168	0.986	0.049	0.222	23%
1996	144.808	24.83	151.562	0.955	0.052	0.227	24%
1999	103.766	10.68	180.328	0.575	0.006	0.075	13%
2003	189.184	25.67	247.355	0.765	0.018	0.133	17%
2005	178.884	23.25	278.618	0.642	0.010	0.102	16%

$\left(1+p(BS)\right)$	1.136		
$\hat{q}_{iy}$	0.786	Grand Variance	0.054
$\sqrt{\mathrm{var}(\hat{q}_{i})}$	0.161	Grand Stdev	0.232
CV	20%		
$\hat{q}_{i}$	**0.692**	Grand CV	**30%**

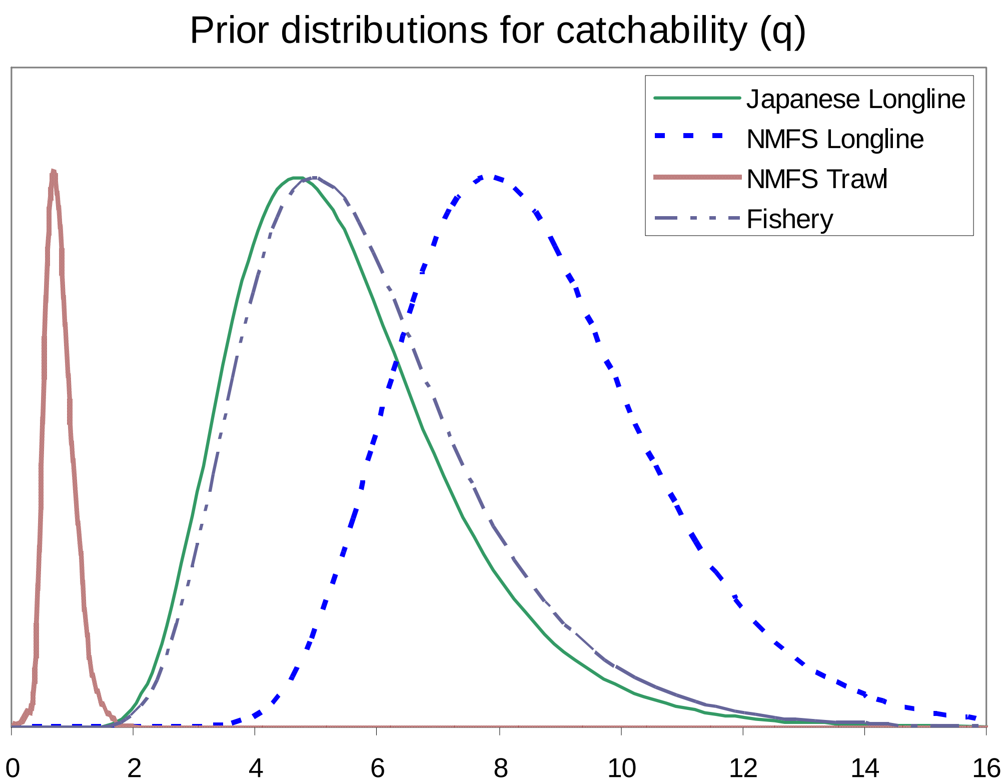

Figure 1. Prior distributions for catchability for four sablefish abundance indices.