# 3. Assessment of the Sablefish stock in Alaska

by
Dana H. Hanselman, Chris R. Lunsford, and Cara J. Rodgveller

## Executive Summary

### *Summary of major changes*

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

*Input data:* We added relative abundance and length data from the 2011 longline survey, relative abundance and length data from the 2010 longline and trawl fisheries, relative abundance and length data from the 2011 GOA trawl survey, age data from the 2010 longline survey and 2010 longline fishery, updated 2010 catch and estimated 2011 catch to the assessment model.

*Model changes:* There are no model changes. Key results for the recommended model compared to last year's recommendations are shown below.

| | As estimated or specified *last* year for: | | As estimated or recommended *this* year for: | |
|---|---|---|---|---|
| **Quantity/Status** | 2011 | 2012 | **2012** | 2013* |
| *M* (natural mortality) | 0.10 | 0.10 | 0.10 | 0.10 |
| Specified/recommended Tier | 3b | 3b | 3b | 3b |
| Projected biomass (ages 2+, t) | 251,141 | 256,761 | 262,522 | 268,992 |
| Female spawning biomass (t) | | | | |
| Projected | 102,139 | 97,307 | 101,325 | 98,983 |
| $B_{100\%}$ | 275,270 | 275,270 | 271,436 | 271,436 |
| $B_{40\%}$ | 110,108 | 110,108 | 108,574 | 108,574 |
| $B_{35\%}$ | 96,345 | 96,345 | 95,003 | 95,003 |
| $F_{OFL}$ | 0.106 | 0.106 | 0.106 | 0.106 |
| $maxF_{ABC}$ | 0.089 | 0.089 | 0.089 | 0.089 |
| $F_{ABC}$ | 0.089 | 0.089 | 0.089 | 0.089 |
| OFL (t) | 18,950 | 17,377 | 20,400 | 20,132 |
| max ABC (t) | 16,040 | 14,697 | 17,240 | 17,019 |
| ABC (t) | 16,040 | 14,697 | 17,240 | 17,019 |
| | As determined *last* year for: | | As determined *this* year for: | |
| **Status** | 2009 | 2010 | 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

* Projections are based on estimated catches of 13,539 t and 12,896 t used in place of maximum permissible ABC for 2012 and 2013. This was done in response to management requests for a more accurate two-year projection.

*Assessment results:* The fishery abundance index was down 9% from 2009 to 2010 (the 2011 data are not available yet). The survey abundance index increased 3% from 2010 to 2011 following a 10% increase from 2009 to 2010. Spawning biomass is projected to decrease from 2011 to 2016, and then stabilize. Sablefish are managed under Tier 3 of NPFMC harvest rules. Reference points are calculated using recruitments from 1979-2009. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 108,574 t (combined across the EBS, AI, and GOA), 0.096, and 0.114, respectively. Projected female spawning biomass (combined areas) for 2012 is 101,325 t (93% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of $F_{ABC}$ under Tier 3b is 0.089, which translates into a 2012 ABC (combined areas) of 17,240 t. The OFL fishing mortality rate is 0.106 which translates into a 2012 OFL (combined areas) of 20,400 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

**We recommend a 2012 ABC of 17,240 t.** The maximum permissible ABC for 2012 from an adjusted $F_{40\%}$ strategy is 17,240 t. The maximum permissible ABC for 2012 is a 7% increase from the 2011 ABC of 16,040 t. This increase is supported by a substantial increase in the domestic longline survey index in the past two years that offset the prior year's decrease in the fishery abundance index and a low Gulf of Alaska trawl survey biomass estimate. There was also a slight increase in estimates of incoming recruitment year classes. Spawning biomass is projected to decline through 2016, and then is expected to increase assuming average recruitment is achieved. Because of the indications of recent slightly stronger year classes, the maximum permissible ABC is projected to stabilize at 17,019 t in 2013 and 16,769 in 2014 (using estimated catches, instead of maximum permissible, see Table 3.17).

**Projected 2012 spawning biomass is 37% of unfished spawning biomass.** Spawning biomass has increased from a low of 30% of unfished biomass in 2002 to 37% projected for 2012. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 10% of the 2012 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now mature and should comprise 23% of the spawning biomass in 2012. The 2002 year class is beginning to show signs of strength and will comprise 10% of spawning biomass in 2012 and is 92% mature.

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 2012 ABC and OFL.

| **Apportionments are based on survey and fishery information** | **2011 ABC Percent** | **2011 Survey RPW** | **2010 Fishery RPW** | **2012 ABC Percent** | **2011 ABC** | **2012 ABC** | **Change** |
|---|---|---|---|---|---|---|---|
| Total | | | | | 16,040 | **17,240** | 7% |
| Bering Sea | 18% | 6% | 13% | 13% | 2,850 | **2,230** | -22% |
| Aleutians | 12% | 11% | 14% | 12% | 1,900 | **2,050** | 8% |
| Gulf of Alaska | 70% | 83% | 73% | 75% | 11,290 | **12,960** | 15% |
| Western | 14% | 14% | 12% | 14% | 1,620 | **1,780** | 9% |
| Central | 42% | 51% | 38% | 44% | 4,740 | **5,760** | 22% |
| W. Yakutat | 16% | 15% | 18% | 16% | 1,830 | **2,080*** | 14% |
| E. Yakutat / Southeast | 28% | 20% | 32% | 26% | 3,100 | **3,350** | 8% |

*After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the 2012 ABC for West Yakutat is 2,247 t and for East Yakutat/Southeast is 3,173 t. This adjustment projected to 2013 is 2,218 t for W. Yakutat and 3,132 t for E. Yakutat.

| **Adjusted for 95:5 hook-and-line: trawl split in EGOA** | Year | W. Yakutat | E. Yakutat/Southeast |
|---|---|---|---|
| | 2012 | 2,247 t | 3,173 t |
| | 2013 | 2,218 t | 3,132 t |

### *Plan team summaries*

| Area | Year | Biomass (4+) | OFL | ABC | TAC | Catch |
|---|---|---|---|---|---|---|
| GOA | 2010 | 140,000 | 12,270 | 10,370 | 10,370 | 10,086 |
| | 2011 | 149,000 | 13,340 | 11,290 | 11,290 | 10,683 |
| | 2012 | 180,000 | 15,330 | 12,960 | | |
| | 2013 | 169,000 | 15,129 | 12,794 | | |
| BS | 2010 | 38,000 | 3,310 | 2,790 | 2,790 | 754 |
| | 2011 | 37,000 | 3,360 | 2,850 | 2,850 | 617 |
| | 2012 | 30,000 | 2,640 | 2,230 | | |
| | 2013 | 28,000 | 2,605 | 2,201 | | |
| AI | 2010 | 27,000 | 2,450 | 2,070 | 2,070 | 1,076 |
| | 2011 | 25,000 | 2,250 | 1,900 | 1,900 | 849 |
| | 2012 | 26,000 | 2,430 | 2,050 | | |
| | 2013 | 24,000 | 2,398 | 2,024 | | |

| Year | 2011 | | | | **2012** | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| Region | OFL | ABC | TAC | Catch* | OFL | ABC | OFL | ABC |
| **BS** | 3,360 | 2,850 | 2,850 | 617 | 2,640 | 2,230 | 2,605 | 2,201 |
| **AI** | 2,250 | 1,900 | 1,900 | 849 | 2,430 | 2,050 | 2,398 | 2,024 |
| **GOA** | 13,340 | 11,290 | 11,290 | 10,683 | 15,330 | 12,960 | 15,129 | 12,794 |
| W | -- | 1,620 | 1,620 | 1,321 | -- | 1,780 | -- | 1,757 |
| C | -- | 4,740 | 4,740 | 4,610 | -- | 5,760 | -- | 5,686 |
| WYAK | -- | 1,990 | 1,990 | 1,844 | -- | 2,247 | -- | 2,218 |
| SEO | -- | 2,940 | 2,940 | 2,908 | -- | 3,173 | -- | 3,132 |
| Total | 18,950 | 16,040 | 16,040 | 12,149 | 20,400 | 17,240 | 20,132 | 17,019 |

*Current as of October 4, 2011 (http://www.fakr.noaa.gov).

## Responses to SSC comments

*"The SSC appreciates the responsiveness of the author to our recommendations. The SSC notes that two issues remain a concern. First, while the author initiated the development of a statistical model for estimation of sperm whale and killer whale predation, they did not finalize this model. The SSC requests that the author continues to explore methods to model whale depredation. Second, the author acknowledges that work is underway to develop a migration model for use in apportioning the ABC and OFL by region. We encourage the author to continue to work on this type of model."* (December 2010)

We have initiated a substantial reanalysis of the longline survey index, specifically to address the depredation issues with both killer whales and sperm whales. While substantial progress has been made, regrettably, we were not ready to utilize the new index, until several issues are fully explored. Some numerical difficulties have led us currently to believe we may need to divide the sablefish survey into three areas for modeling purposes Western (Western Gulf, Bering Sea, and Aleutian Islands), Central Gulf, and Eastern Gulf. We hope to incorporate the new index into the 2012 assessment.

We presented an update during the 2011 August Joint Plan Team meeting on the status of movement modeling. An updated model through 2009 that includes Southeast Inside tag releases is near submission for publication. We summarize the results in subsection *Movement update,* in section **Introduction.**

*"The SSC recommends that stock assessment authors and plan teams address this issue in the upcoming stock assessment cycle. Stock assessment authors should clearly lay out which sources of removals are currently included in the assessment, how removals from each source are estimated, and how they are being included in (A) and (B) above. To the extent possible, authors should discuss all known sources of mortality (including handling mortality, indirect mortality, subsistence, etc.) and which of these sources are considered in the assessment."* (June 2011)

Estimates of non-commercial catch of sablefish are documented and discussed in Appendix 3B.

## Responses to Plan team comments

" *…asked if the retrospective pattern affected projections, and whether this could explain the continued prediction that we are at a local maximum in biomass but will decrease next year. There was some question on how the recent peak in abundance apparently shifts forward each year and the projection indicates that abundance will decrease. It may be useful to examine whether this pattern of a peak followed by a projected decrease (the "bump") occurs in a formal retrospective analysis*." (November 2010 Joint Plan Team)

In last year's assessment we showed that the retrospective pattern had been alleviated during the iterative reweighting process. However, we added a slightly different retrospective analysis this year where we conducted projections using this year's model with data from 2002-2010 to see if the trajectory is similar, and how different recommended ABCs would have been, given different assumptions about gender dimorphic growth, gender-specific selectivities, data weighting, and changes in data used. In summary, the trajectory of projections in the early 2000's were all positive, then the series of negative abundance estimates turned the projections downward, and are now beginning to flatten again. In terms of ABCs, given all the model changes since 2002, we would have recommended approximately the same values in a given year. See ***Retrospective analysis*** section for details.

*"The Teams recommended that all authors provide the 2001-2010 HFICE and the 2010 CAS total catch estimates as an appendix to each assessment chapter in November 2011. Since these estimates are preliminary and the Teams have not reviewed the complete database or assessed the potential effects on*

*determination of OFL and ABC for each stock, further analysis is needed before the Teams can recommend incorporation of these estimates in their OFL/ABC recommendations.*

*"For November, several components are recommended to be included in a table in an appendix in each assessment chapter:*

*1.) The 2010 total catch removal estimates along with research catch estimates reported in previous assessments. The major sources of removals should be noted along with any large deviations in total catch between previously used research catches and the new estimates.*

*2.) HFICE estimates should be tabulated for the years 2001-2010 (from Cindy Tribuzio). Comparisons should be made to the corresponding CAS estimates from the AKRO. The impacts of including HFICE estimates on the total catch estimates currently used in the assessments should be discussed and the implications of these estimates on the ABC and OFL recommendations should be explored."* (September 2011 Joint Plan Team)

These data are tabled and discussed in Appendex 3B.

*"The Team discussed the different catch assumptions made across assessments. Rockfish assessments employ a consistent assumption in that catch estimates through a specific date (i.e. not estimated through the end of the year) are employed in making the projections (for those stocks where a projection is appropriate). This differs from the rockfish catch assumption in the BSAI where it is assumed the fishery will catch the whole ABC thus this is the estimate used for total catch. The Team discussion centered on whether or not assessments need to be consistent in catch estimation for current and future years as rockfish assessments differ from others in how catch for a projection is estimated. For species where TAC likely to be taken then it seems appropriate to assume that TAC can be used, but for a species where this does not appear to be a valid assumption, than average catch over a time period would be a better assumption. The purpose of this was to ensure an accurate estimate of the entire year is used rather than an estimate through a certain date. How this is done will vary depending upon the author's specific rationale and estimation procedure. The Team noted that authors should be clear in how catch is projected and what assumptions are made to make the catch estimate for the projection. The Team expressed concern that there may be some indication that rockfish populations are declining. The authors noted that despite a slight decline from last year's model projections this was anticipated."* (September 2011 GOA Team)

We have included a new procedure for catch specification and projection in ***Specified catch estimation*** subsection of **Harvest and Projection Alternatives**.

# Introduction

*Distribution:* Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea (Wolotira et al. 1993). Adult sablefish occur along the continental slope, shelf gullies, and in deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). In contrast to the adult distribution, juvenile sablefish (less than 40 cm) spend their first two to three years on the continental shelf of the Gulf of Alaska, and occasionally on the shelf of the southeast Bering Sea. The Bering Sea shelf is utilized significantly in some years and seldom used during other years (Shotwell 2007).

*Stock structure and management units:* Sablefish form two populations based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). A northern population inhabits Alaska and northern British Columbia waters and a southern population inhabits southern British Columbia, Washington, Oregon, and California waters, with mixing of the two populations occurring off southwest Vancouver Island and northwest Washington.

Sablefish are assessed as a single population in Federal waters off Alaska because northern sablefish are highly migratory for at least part of their life (Heifetz and Fujioka 1991, Maloney and Heifetz 1997, Kimura et al. 1998). Sablefish are managed by discrete regions to distribute exploitation throughout their wide geographical range. There are four management areas in the Gulf of Alaska: Western, Central, West Yakutat, and East Yakutat/Southeast Outside (SEO); and two management areas in the Bering Sea/Aleutian Islands (BSAI): the eastern Bering Sea (EBS) and the Aleutian Islands (AI) region.

*Early life history:* Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (Mason et al. 1983, McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 180 miles (Wing 1997). Average spawning date in Alaska based on otolith analysis is March 30 (Sigler et al. 2001). Along the Canadian coast (Mason et al. 1983) and off Southeast Alaska (Jennifer Stahl, ADF&G, personal communication) sablefish spawn from January-April with a peak in February. Farther down the coast off of central California sablefish spawn earlier, from October-February (Hunter et al. 1989). Sablefish in spawning condition were also noted as far west as Kamchatka in November and December (Orlov and Biryukov 2005). The size of sablefish at 50% maturity off California and Canada is 58-60 cm for females, corresponding to an age of approximately 5 years (Mason et al. 1983, Hunter et al. 1989). In Alaska, most young-of-the-year sablefish are caught in the central and eastern Gulf of Alaska (Sigler et al. 2001). Near the end of the first summer, pelagic juveniles less than 20 cm drift inshore and spend the winter and following summer in inshore waters, reaching 30-40 cm by the end of their second summer (Rutecki and Varosi 1997). After their second summer, they begin moving offshore to deeper water, typically reaching their adult habitat, the upper continental slope at 4 to 5 years. This corresponds to the age range when sablefish start becoming reproductively viable (Mason et al. 1983). Younger fish (age 3-4) inhabit shallower waters on the shelf, while older fish migrate down to the slope. Fish also tend to move counterclockwise through the Gulf of Alaska with age (e.g., Maloney and Sigler 2008, Heifetz and Fujioka 1991).

*Movement:* A movement model for Alaskan sablefish was developed for Alaskan sablefish by Heifetz and Fujioka (1991) based on 10 yrs of tagging data. The model has been updated by incorporating data from 1979-2009 in an AD Model Builder program with time-varying reporting rates. In addition, ADF&G tag data for inside waters (Southern Southeast Inside and Northern Southeast Inside) were added. The model updated the fishing mortality rate with relative population weights and stock assessment catchabilities. There are a total of 305,000 tag releases and 27,000 recoveries in 31 years. For time varying reporting rates, the tag recovery rate for the survey is compared to the fishery. Reporting rates generally have increased over the 31 year period, but there has been an unexplained decrease in reporting rate in the past few years. The likelihood was changed from a Poisson to a negative binomial likelihood, which better fitted the distribution of recoveries.

Including all 31 years of tag data affected the movement model more than any other changes. Changes in absolute movement rate occurred where most fish now have a higher probability of movement than before; for example, large fish now have a 40% higher probability of moving than in previous models. The previous paradigm was that small fish moved west, and large fish moved east. The probability of small fish moving east has now doubled. We examined the uncertainty of the probability of fish moving out of an area through MCMC simulation. In Chatham Strait, sablefish have a precise low probability of moving. In contrast, Western Gulf fish have a precise and high probability of moving. There is also the potential in the future for determining age- and sex-specific movement rates for sablefish.

Directionality of overall movement patterns is more ambiguous than previously thought, with the Western GOA seeming to be a transitional area for sablefish (i.e. high annual movement). The sablefish population center seems to be in central GOA, and the one unit stock (Aleutian Islands, Bering Sea and GOA) hypothesis is strongly supported by these movement data. These results are being prepared for publication.

# 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 3.1, 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 (MSFCMA).

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

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

Other foreign nations besides Japan also caught sablefish. Substantial Soviet Union catches were reported from 1967-73 in the Bering Sea (McDevitt 1986). Substantial Korean 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 Soviet gear was factory-type stern trawl and the Korean 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.

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 incidentally 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 2010) was:

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

| Year | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Vessels | 395 | 388 | 389 | 379 |

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 occurs in the Bering Sea, Aleutian Islands, and Western Gulf of Alaska. Sperm whale depredation occurs in the Central and Eastern Gulf of Alaska.

Pot fishing for sablefish has increased in the Bering Sea and Aleutian Islands as a response to depredation of longline catches by killer whales. In 2000 the pot fishery accounted for less than ten percent of the fixed gear sablefish catch in the Bering Sea and Aleutian Islands. Since 2004, pot gear has accounted for over half of the Bering Sea fixed gear IFQ catch and up to 34% of the catch in the Aleutians. In 2009, pot fishing remained a high portion of the fixed gear catch in the BS (70%), whereas in the Aleutian Islands pot fishing decreased from 22% to 7.6% of the fixed gear catch. This decrease is largely due to several large catcher processor vessels not participating in the pot fishery. 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 1958 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 13,000 t in the late 1990's, and have been near 12,000 t recently. TACs in the Gulf of Alaska are nearly fully utilized, while TACs in the Bering Sea and Aleutian Islands are often not because of depredation and relatively low catch rates. The proportion of catch due to pot fisheries in the Bering Sea and the Aleutian Islands increased starting in 2000 in response to killer whale depredation (Table 3.2) and is discussed further below.

### *Bycatch and discards*

Sablefish discards have decreased in recent years. From 1994 to 2003 discards averaged 1,357 t for the GOA and BSAI combined (Hanselman et al. 2008). The highest amount, 800 t was in 2004, of which 667 t occurred in the GOA and 133 t occurred in the BSAI. Discards decreased after 2004, down to an average in 2005-10 of 640 mt, 89% of which occurred in the GOA. The discards from non-longline fisheries decreased from a 1994-2003 average of 825 t to an average of 164 mt for 2005-2010, while hook and line fisheries decreased slightly from 525 t down to 476 t (Table 3.3).

Table 3.4 shows the bycatch of FMP species in the sablefish targeted fishery. The largest bycatch is arrowtooth flounder (573 t/year, 488 t discarded). Arrowtooth is the only species that has substantial catch from non-longline gear. Thornyhead and shortraker rockfish are the 2nd and 3rd most caught species at 367 t/year and 209 t/year. The next three groups are "Other Species", Gulf of Alaska "Other Skate", and Gulf of Alaska longnose skate which total 473 t/year. Other species in this case is primarily spiny dogfish.

Giant grenadiers make up the bulk of the nontarget species bycatch, peaking at 9,181 t in 2007, but decreasing since with a 2010 catch of 4,385 t. Other nontarget catches that have totals over a ton per year are corals, snails, sponges, and miscellaneous fishes and crabs (Table 3.5).

Prohibited species catches (PSC) in the targeted sablefish fisheries are dominated by halibut (1,700 t/year) and golden king crab (157,000/year). However, catches of both species declined greatly in 2010 (1000 t and 27,000 individuals respectively, Table 3.6). The decrease in golden king crab catch may be attributed to the lower proportion of catch due to pot fisheries in 2010 in the Aleutian Islands.

## Previous management actions

A summary of management measures is shown in Table 3.7.

*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, northern rockfish, dusky rockfish, and 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.

# Data

The following table summarizes the data used for this assessment:

| Source | Data | Years |
|---|---|---|
| Fisheries | Catch | 1960-2011 |
| Trawl fisheries | Catch | 1960-2011 |
| Japanese longline fishery | Catch-per-unit-effort (CPUE) | 1964-1981 |
| U.S. longline fishery | CPUE, length | 1990-2010 |
| | Age | 1999-2010 |
| U.S. trawl fisheries | Length | 1990,1991,1999, 2005-2010 |
| Japan-U.S. cooperative longline survey | CPUE, length | 1979-1994 |
| | Age | 1981, 1983, 1985, 1987, 1989, 1991, 1993 |
| Domestic longline survey | CPUE, length | 1990-2011 |
| | Age | 1996-2010 |
| NMFS GOA trawl survey | Abundance index | 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011 |
| | Lengths | 1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011 |

## *Fishery*

Length, catch, and effort data were historically collected from the Japanese and U.S. longline and trawl fisheries, and are now collected from U.S. longline, trawl, and pot fisheries (Table 3.8). The Japanese data were collected by fishermen trained by Japanese scientists (L. L. Low, Alaska Fisheries Science Center, pers. commun., 25 August 1999). The U.S. fishery length and age data were collected by at-sea and plant observers. No age data were systematically collected from the fisheries until 1999 because of the difficulty of obtaining representative samples from the fishery and because only a small number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A of the 2002 SAFE (Sigler et al. 2002).

The catches used in this assessment (Table 3.1) include catches from minor State-managed fisheries in the northern Gulf of Alaska and in the Aleutian Islands region because fish caught in these State waters are reported using the area code of the adjacent Federal waters in Alaska Regional Office catch reporting system (G. Tromble, Alaska Regional Office, pers. comm., 12 July 1999), the source of the catch data used in this assessment. Minor State fisheries catches averaged 180 t from 1995-1998 (ADFG), about 1% of the average total catch. Most of the catch (80%) is from the Aleutian Islands region. The effect of including these State waters catches in the assessment is to overestimate biomass by about 1%, a negligible error considering statistical variation in other data used in this assessment.

Some catches probably were not reported during the late 1980's (Kinoshita et al. 1995). Unreported catches could account for the Japan-U.S. cooperative longline survey index’s sharp drop from 1989-90 (Table 3.9, 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).

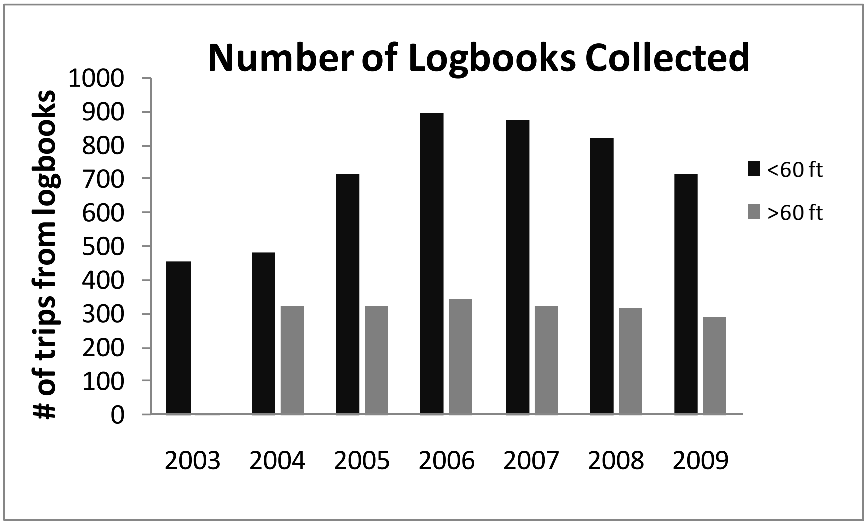
In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Research catches of sablefish have been reported in previous stock assessments (Hanselman et al. 2009). For this year, estimates of all removals not associated with a directed fishery including research catches are available and are presented in

Appendix 3.B. The sablefish research removals are small relative to the fishery catch, but substantial compared to the research removals for many other species. These research removals support a dedicated longline survey. Additional sources of significant removals are bottom trawl surveys and the International Pacific Halibut Commissions longline survey. Other removals such as recreational catch are relatively minor for sablefish. Total removals from activities other than directed fishery were near 359 tons in 2010. This is 2.2% of the 2011 recommended ABC of 16,040 and represents a relatively low risk to the sablefish stock.

One problem with the fishery data has been low length sample sizes for the trawl fishery (Table 3.8). 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. However since 2005, at least several hundred lengths have been collected each year and the data has been incorporated into the assessment.

### *Longline fishery catch rate analysis*

Fishery information is available from longline and pot vessels which target sablefish in the IFQ fishery. Records of catch and effort for these vessels 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 >125 feet carry an observer 100% of the time. Since 1999, logbooks have been required for vessels >60 feet. Vessels <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 <60 feet has increased greatly in recent years. Since 2003 vessels <60 feet have accounted for approximately 69% of all logbooks submitted (see figure below). 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). For logbook data, the target is declared by the captain. The weights reported in logbooks are usually approximate because the captain typically estimates the catch for each set while at sea without an accurate scale measurement. An accurate weight for the entire trip is measured at landing and recorded as the IFQ landing report. We estimate the actual set weight by multiplying the IFQ landing report weight by the proportion of the trip weight that was caught in the set, from logbook reported weights. Hook spacing for both data sets was standardized to a 39 inch (1m) spacing following the method used for standardizing halibut catch rates (Skud and Hamley 1978, Sigler and Lunsford 2001). Each set's catch rate was calculated by dividing the catch in weight by the standardized number of hooks. These catch rates are used to compute average catch rates by vessel and NPFMC region.

Extensive filtering of the logbook and observer data occurs before the catch information for a set is included in analyses. All sets that experienced killer whale depredation are excluded from the observer fishery catch rate analysis since any depredation would bias CPUE downward. From 1990-2010 an average of 23% of observed sets in the Bering Sea were affected by killer whale depredation. In other areas killer whales depredate only 0-2% of observed sets.

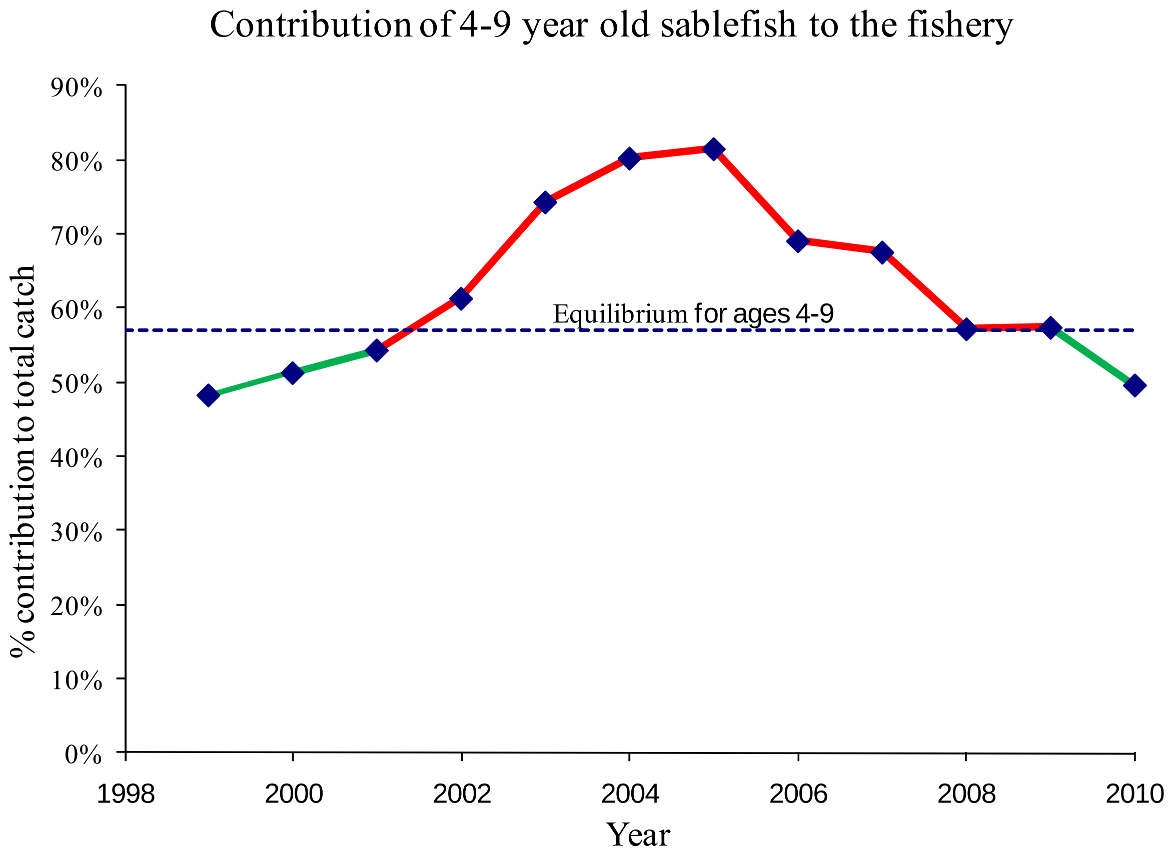
Additionally, some logs are excluded because of other issues. Sets were excluded whenever data were missing for a set and a catch rate could not be calculated or assigned to a season, area, or a year. Some sets use multiple gear configurations with more than one hook spacing. A standardized catch rate cannot be calculated because the number of sablefish caught on each configuration is unknown; logbook sets with multiple configurations were excluded. In logbooks, if catch is reported in number instead of weight, the trip is excluded. A small number of sets were eliminated from the logbook data because skipper estimated trip weight was very different than the IFQ reported trip weight.

*Longline sample sizes:* Observer data used in this analysis represent on average 14% of the annual IFQ hook and line catch. The percent of the IFQ catch observed was lowest in the East Yakutat/SE (5%), highest in West Yakutat and Aleutian Islands (~22%), and moderate in the Bering Sea, Central Gulf, and Western Gulf (10-14%). Although the percent of catch observed is not highest in the Central Gulf, the number of sets and vessels observed is greatest in this area and lowest in the Bering Sea (Table 3.10). In the Bering Sea fewer than 10 sets were observed from 2002-2005; however, since 2006 more sets have been observed. Observer coverage in the Aleutian Islands was consistent in all years except 2005 when only 23 sets from six vessels were observed. Since then, the number of observed sets and vessels has increased. Low longline fishery sample sizes in the Bering Sea are likely a result of poor observer coverage for sablefish directed trips and due to the increase in pot fishing. Additionally, killer whales impact sablefish catch rates in the Bering Sea and Aleutians and these sets are excluded from catch rate analyses.

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 collect, 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 <60 feet are now participating in the program voluntarily. In 2010, the number of vessels turning in logbooks increased in all areas except for the Bering Sea.

*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 3.10, Figures 3.4, 3.5). Catch rate trends are generally similar for both the observer and logbook data, except in the Aleutian Islands and the Bering Sea where sample sizes are relatively small, but they have been more similar in recent years. The general trends are very similar between the two data sources, but over the past two years they have been slightly divergent in the Central Gulf. Since 2004, logbook sample sizes are more substantial than the observer data and have lower CV's and SE's due to the large number of vessels (Table 3.10).

The age structure of the population may help explain why catch rates have remained stable while survey abundance has generally decreased. Year classes typically start to show up in the fishery beginning at age 4. The influence of the 1997 and 2000 year classes to the fishery is evident as catch rates generally increased during the years 2001-2004 for both the observer and logbook data in all areas of the GOA (Figures 3.4 and 3.5). These years correspond to when the 1997 and 2000 year classes were major contributors to the fishery. The percent of catch attributed to 4-9 year old fish increased from 48% in 1999 to nearly 82% of the catch in 2005. As these year classes were fished, the survey estimates declined. By 2009, the catch of this age group had decreased to about what we would expect at equilibrium levels with the current fishing mortality. These large pulses of recruits targeted by the fishery might explain some of the mismatch between the survey and fishery catch rates because the fishery can sustain catch rates by targeting year classes.



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

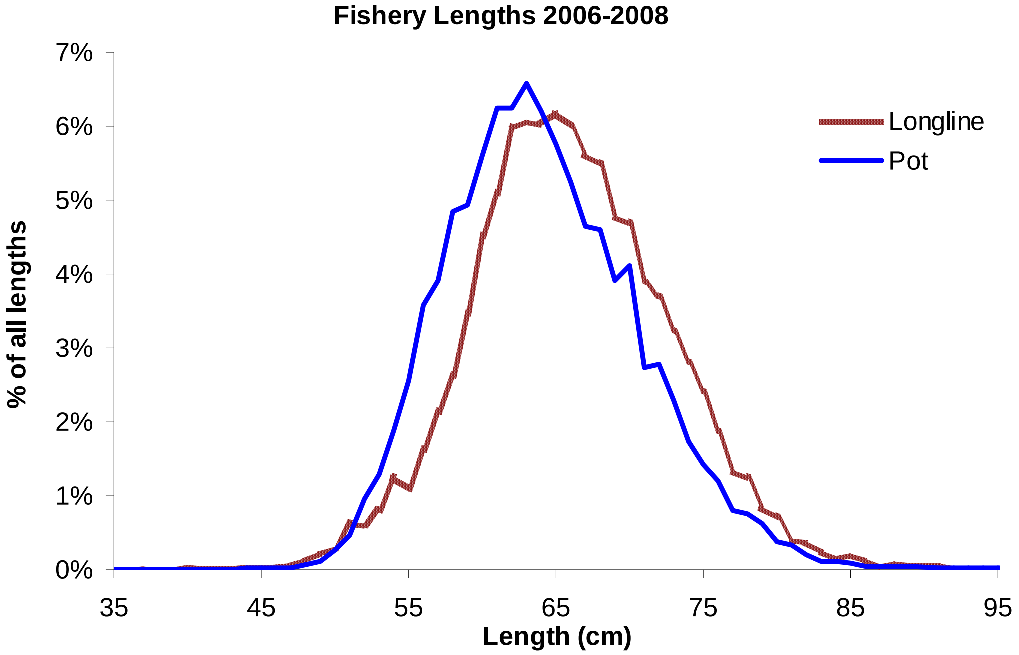
The highest catch rates are also in the spring, moderate in the summer, and lowest in the fall. The majority of the longline effort is located along the continental slope and in deep cross-gullies. Likewise, areas of high catch rates occur throughout the fishing area and do not appear to change over time. Overall, no substantial changes in the fishery were detected over time or on a seasonal basis.

### *Pot fishery catch rate analysis*

*Pot catch rates:* There is more uncertainty in pot catch rates from 1999-2004 because there were few observed vessels during this period. From 2005-2009 the average catch rate was 13 lbs/pot in the Aleutian Islands (there was no observed effort in 2010). In the Bering Sea the average was 24 lbs/pot. In logbooks, the average catch rate in the Aleutian Islands from 2005-2010 was 29 lbs/pot and in the Bering Sea it was 24lbs/pot. In logbooks, more sets are recorded than in observer data. This may help explain the discrepancy between catch rates from the two data sources. The number of documented vessels and sets has increased in the Bering Sea since 2005. Because of the high variability and low sample sizes it is difficult to discern any trends in catch rates in logbooks or observer data.

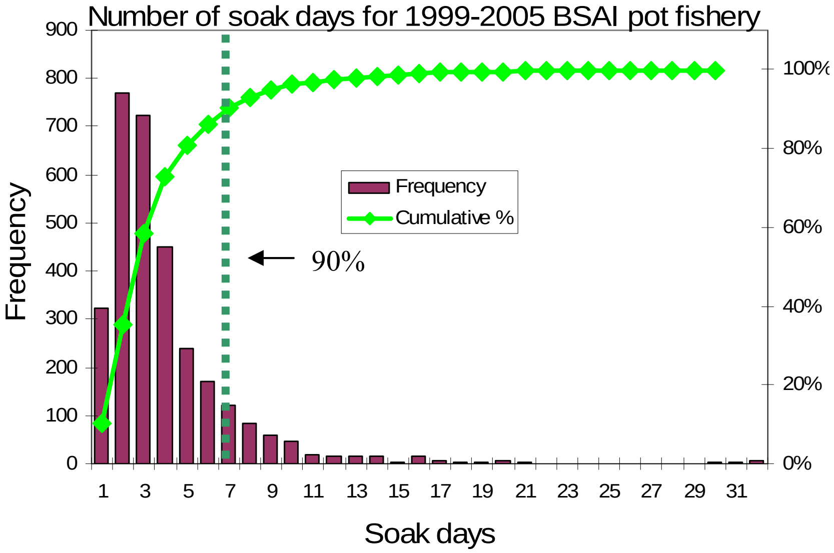
The composition of bycatch species caught in observed pots that retained sablefish in the Bering Sea and Aleutian Islands is comprised mostly of arrowtooth/Kamchatka flounder, golden king crab, Greenland turbot, Pacific halibut, and giant grenadier. Almost all of the golden king crab are caught in the AI. Bycatch of halibut and golden king crab have both declined significantly in 2010, likely due to a decrease in the amount of pot fishing effort (Table 3.6).

*Pot length frequencies:* We compared the length frequencies recorded by observers from the 2006-2008 longline and pot fisheries. The average length of sablefish in the Aleutian Islands and in the Bering Sea was smaller for sablefish caught by pot gear (63.8 cm) than longline gear (66.0 cm), but the distributions indicate that both fisheries focus primarily on adults. Pot and longline gear is set at similar depths in the Aleutians and Bering Sea and catch males and females at the same rates (average % females in BS/AI was 58% for both gear types). We do not believe that the difference in lengths is significant enough to affect population recruitment and did not see any indication that undersized fish were being selected by pots.



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

*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.

## Surveys

A number of fishery independent surveys catch sablefish. While we do not include all possible indices in the model, we describe trends in them below, along with adjacent geographic areas not assessed by NMFS.Research catch removals are documented in Appendix 3B.

### *AFSC Longline Surveys*

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

Aleutians and/or Bering Sea, Western Gulf, Central Gulf, Eastern Gulf. Starting in 1998, the Eastern Gulf area was surveyed before the Central Gulf area.

*Specimen collections:* Sablefish length data were randomly collected for all survey years. Otoliths were collected for age determination for most survey years. From 1979-1994 otolith collections were length-stratified; since 1994 otoliths have been collected randomly. Prior to 1996, otolith collections were aged but not consistently from year to year. Since 1996, a sample of otoliths collected during each survey have been aged in the year they were collected. Approximately one-half of the otoliths collected (~1,000) are aged annually.

*Standardization:* Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to 1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 3.9). Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

*Survey Trends*: Relative population abundance indices are computed annually using survey catch rates from stations sampled on the continental slope. Highest sablefish abundance indices occurred during the Japan-U.S. coopearative survey in the mid-1980's, in response to exceptional recruitment in the late 1970's (Figure 3.6b). Relative population numbers declined through the 1990's in most areas during the domestic longline survey. Abundance decreased fastest in western areas and has been the most stable in the Eastern Gulf. Survey catches and abundance estimates trended down through 2009.Three of the lowest overall abundance estimates in the domestic survey occurred from 2006-2009. Survey estimates in the Eastern Gulf improved in 2010 and in 2011 the Central Gulf estimates helped bring the overall survey index up.

*Whale Depredation:* Killer whale depredation of the survey's sablefish catches has been a problem in the Bering Sea since the beginning of the survey (Sasaki 1987). Killer whale depredation primarily occurs in the eastern Bering Sea, Aleutian Islands, and Western GOA and to a lesser extent in recent years in the Central GOA. Killer whale depredation is easily identified by the reduced sablefish catch and the presence of lips or jaws and bent, straightened, or broken hooks. Since 1990, portions of the gear at stations affected by killer whale depredation during the domestic longline survey have been excluded from the analysis of catch rates, RPNs, and RPWs. Killer whale depredation has been fairly consistent since 1996, which corresponds to when the Aleutians and the Bering Sea were added to the survey (Table 3.11). Killer whales depredated a high of ten Bering Sea stations in 2009, which significantly impacted catch and biased the abundance index leading to using the 2007 Bering Sea RPN estimate to estimate the 2009 Bering Sea RPN. In 2011, depredation levels were similar to previous years with catches at seven stations affected.

Sperm whale depredation affects longline catches in the Gulf of Alaska, but evidence of depredation is not accompanied by obvious decreases in sablefish catch. Data on sperm whale depredation have been collected since the 1998 longline survey (Table 3.11). Sperm whales are often observed from the survey vessel during haulback but do not appear to be depredating on the catch. Sperm whale depredation during the longline survey is recorded at the station level and is defined as sperm whales being present during haulback with the occurrence of damaged sablefish in the catch. Sperm whales are most commonly observed in the Central and Eastern Gulf of Alaska, with the majority of depredation occurring in the West Yakutat and East Yakutat/Southeast areas. Depredation has been variable since 1998.

Multiple studies have attempted to quantify sperm whale depredation rates. An early study using data collected by fisheries observers in Alaskan waters found no significant effect on the commercial fishery catch (Hill et al. 1999). Another study using data collected from commercial vessels in southeast Alaska, found a small, significant effect comparing longline fishery catches between sets with sperm whales present and sets with sperm whales absent (3% reduction, 95% CI of (0.4 – 5.5%), t-test, $p = 0.02$, Straley et al. 2005).

A general linear model fit to longline survey data from 1998-2004 found neither sperm whale presence ($p = 0.71$) nor depredation rate ($p = 0.78$) increased significantly from 1998 to 2004. Catch rates were about 2% less at locations where depredation occurred, but the effect was not significant ($p = 0.34$). This analysis has been updated through 2009 and now shows a significant effect of approximately four kilograms per hundred hooks in the Central and Eastern Gulf regions, which translates into approximately a 2% decrease in overall catch in those areas (J. Liddle pers. comm.). A retrospective analysis of this data indicates the effect is not significant until the 2009 data is added, indicating the increasing depredation effect has combined with accumulating survey data to give increased power to detect the moderate reduction in CPUE.

Longline survey catch rates are not adjusted for sperm whale depredation because we do not know when measureable depredation began during the survey time series, because past studies of depredation on the longline survey showed no significant effect, and because sperm whale depredation is difficult to detect (Sigler et al. 2007). Because of recent increases in presence and depredation at survey stations as indicated by whale observations and significant results of recent studies, we are currently evaluating a statistical adjustment to survey catch rates using a general linear modeling approach (Appendix 3C, Hanselman et al. 2010). This approach has the power to model both sperm whale and killer whale impacts on the survey catch rates and correct depredation-related decreases in catch rates.

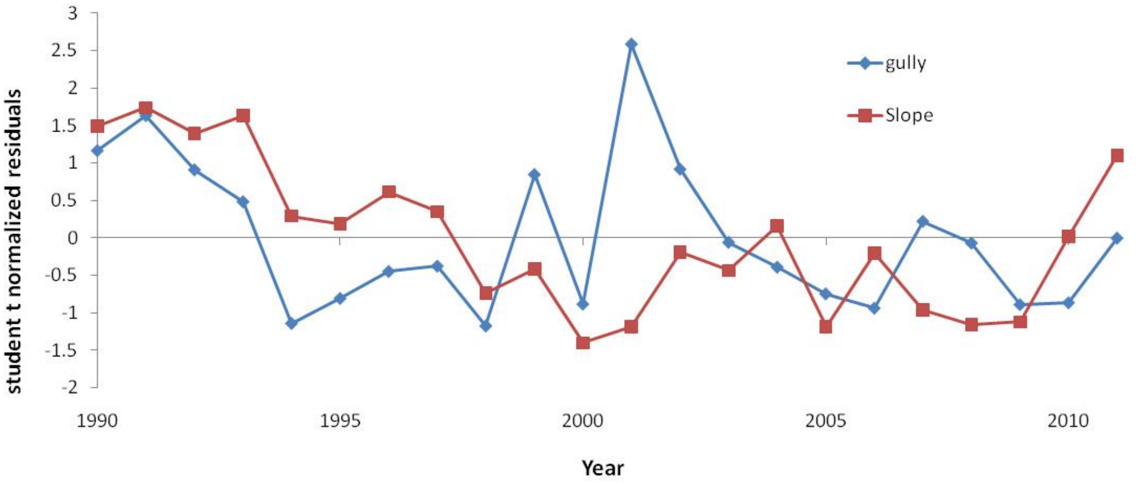
Continued analysis examining both killer whale and sperm whale depredation and their effects on abundance indices is warranted and we hope to explore these modeling approaches that will take advantage of the full data set to interpolate abundance indices for depredated stations.

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

Previous analyses have shown that on average gully stations catch fewer larger fish than adjacent slope stations and length distributions are generally different (Rutecki et al. 1997, Zenger et al. 1994). Compared with the adjacent regions of the slope, sablefish catch rates for gully stations have been mixed with no significant trend (Zenger et al. 1994). Important characteristics of gully catches are that they may indicate recruitment signals before slope areas because of their shallow depth which younger sablefish typically inhabit. Catch rates from these stations have not been included in the historical abundance index calculations because of their locations relative to the more preferred slope habitat of adult sablefish and in particular because of their shallow depths.

These areas do support significant numbers of sablefish, however, and are important areas sampled by the survey. We compared the RPNs of gully stations to the RPNs of slope stations in the GOA to see if catches were comparable, or more importantly, if they portrayed different trends than the RPNs used in this assessment.

Previous analyses have shown gully RPNs were highly correlated with slope RPNs in the East Yakutat/Southeast Outside area but poorly correlated in the West Yakutat and Central Gulf regions (Hanselman et al. 2009). To compare trends, we computed Student's-*t* normalized residuals for all GOA gullies and slope stations and plotted them for the time series. If the indices were correlated, then the residuals would track one another over time.



Overall, gully catches in the GOA from 1990-2011 are poorly correlated with slope catches ($r$ = 0.293). There also is no evidence of major differences in trends. In regards to gully catches being a recruitment indicator, the increase in the gully RPNs in 1999 and 2001-2002 may be in response to the above average 1997 and 2000 year classes. Both the 2001 and 2002 RPNs for the gully stations are higher than the peak in 1999, which supports the current model estimate that the 2000 year class was larger than 1997. Both gully and slope trends are up in 2011, which may support indications of a strong 2008 year class. Therefore, gully stations may show large year classes earlier and be a better gauge of their strength than slope survey stations. In the future, we will continue to explore sablefish catch rates in gullies and explore their usefulness for indicating recruitment; they may also be useful for quantifying depredation, since sperm whales have rarely depredated on catches from gully stations.

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

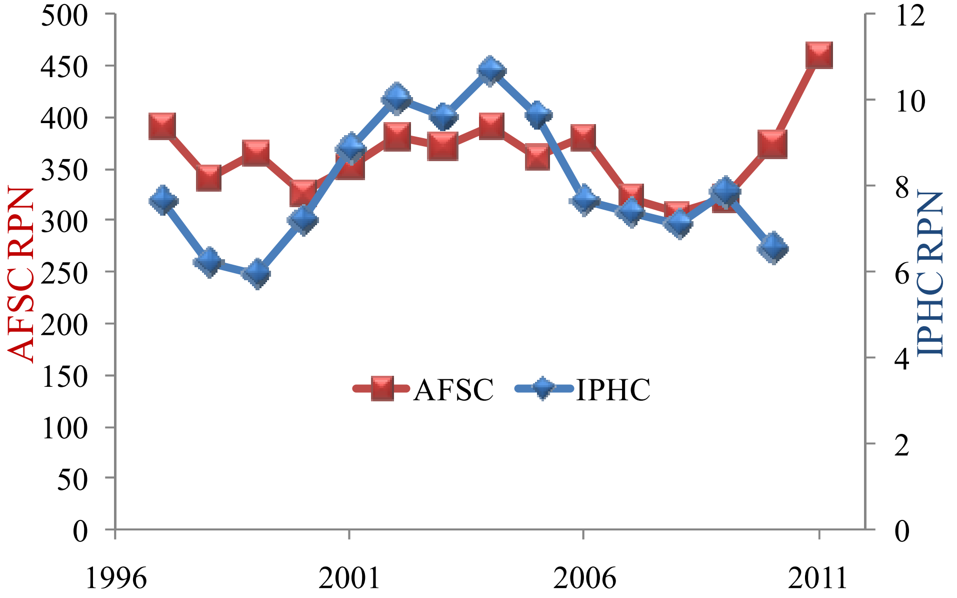
### *IPHC Longline Surveys*

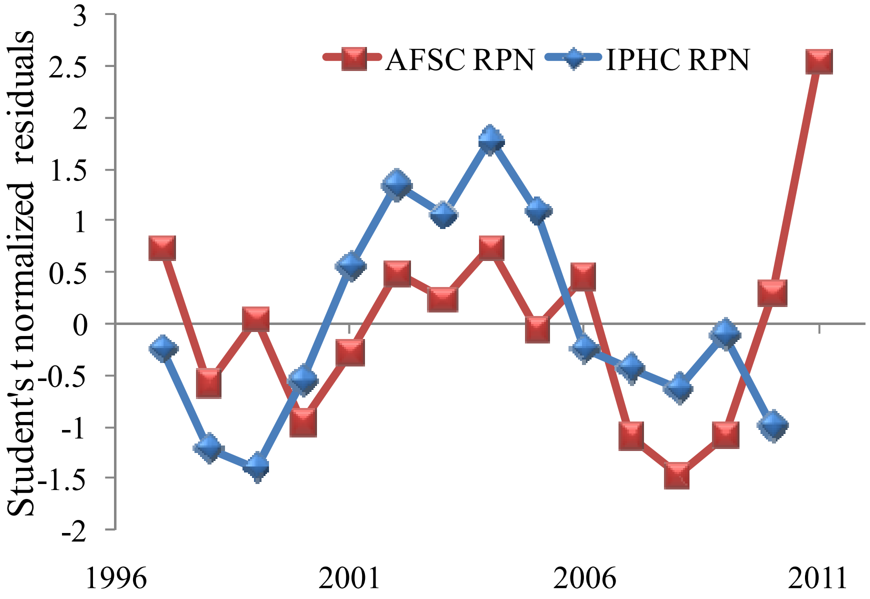
The International Pacific Halibut Commission (IPHC) conducts a longline survey each year to assess Pacific halibut. This survey differs from the AFSC longline survey in gear configuration and sampling design, but catches substantial numbers of sablefish. More information on this survey can be found in Soderlund et al. (2009). A major difference between the two surveys is that the IPHC survey samples the shelf consistently from ~ 10-500 meters, whereas the AFSC survey samples the slope and select gullies from 200-1000 meters. Because the majority of effort occurs on the shelf in shallower depths, the IPHC survey may catch smaller and younger sablefish than the AFSC survey; however, lengths of sablefish are not taken on the IPHC survey.

For comparison to the AFSC survey, IPHC relative population number's (RPN) were calculated using the same methods as the AFSC survey values, the only difference being the depth stratum increments. First an average CPUE was calculated by depth stratum for each region. The CPUE was then multiplied by the area size of that stratum. A region RPN was calculated by summing the RPNs for all strata in the region. Area sizes used to calculate biomass in the RACE trawl surveys were utilized for IPHC RPN calculations. Area sizes differ between the IPHC and AFSC longline surveys because the IPHC surveys the shelf while the AFSC survey samples the slope.

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

Because of their differences in variability we computed Student's t normalized residuals and plotted them for the time series (2$^{nd}$ figure below). The trends have begun to diverge and do not track as closely as they did in the 2010 assessment (2011, Pearson's *r* = 0.42, p-value>0.05, 2010 *r*=0.63, p=0.028). Trends by region were similar but more variable for most areas. We will continue to examine trends in each region and at each depth interval for evidence of recruiting year classes and for comparison to the AFSC longline survey. There is some effort in depths shallower than 200 meters on the AFSC survey, and we will compute RPNs for these depths for future comparisons with the IPHC RPNs.

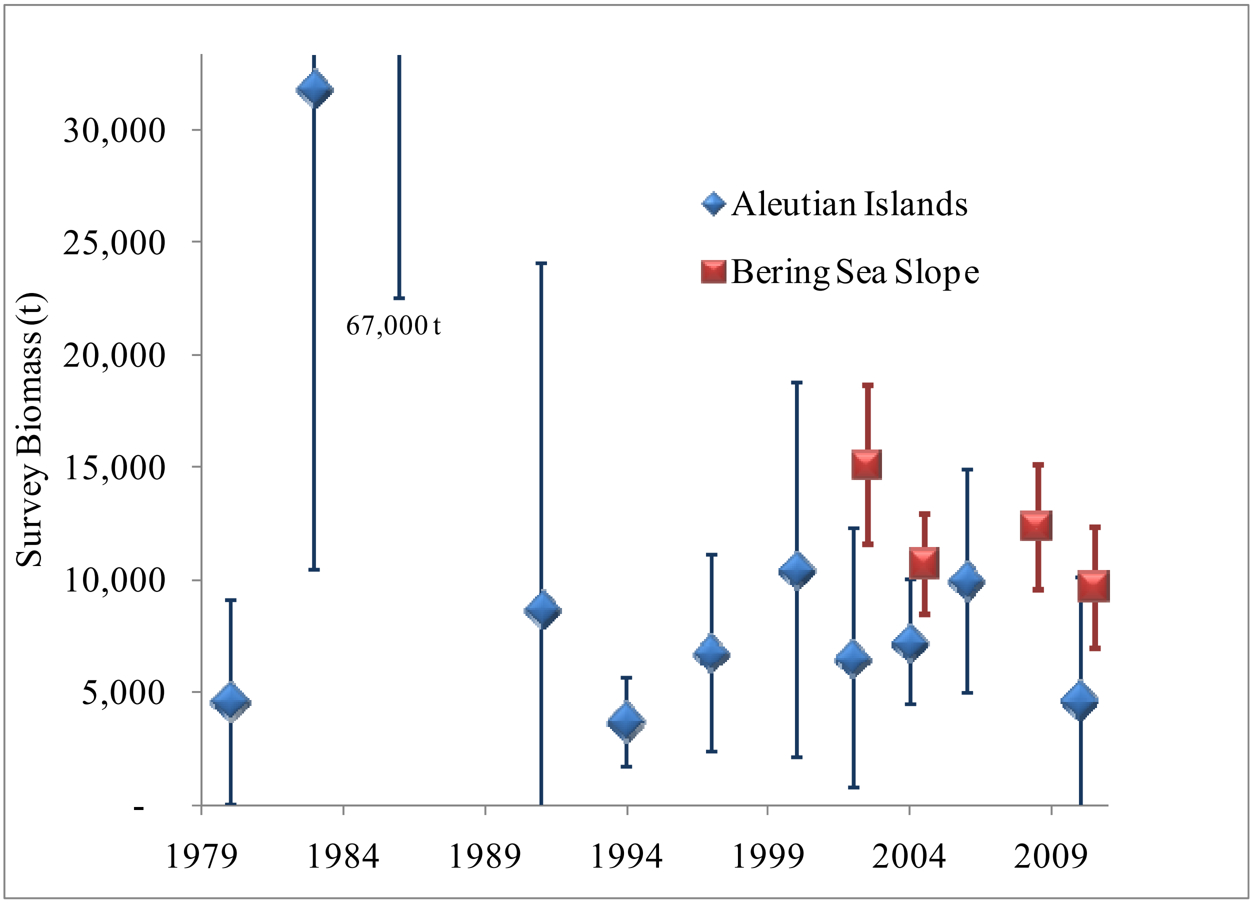




### *Trawl surveys*

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted biennially or triennially since 1980 in the Aleutian Islands, and 1984 in the Gulf of Alaska. Trawl surveys of the Eastern Bering Sea slope were conducted biennially from 1979-1991 and standardized for 2002, 2004, 2008, and 2010. Trawl surveys of the Eastern Bering Sea shelf are conducted annually. Trawl survey abundance indices were not previously used in the sablefish assessment because they were not considered good indicators of the sablefish relative abundance. However, there is a long time series of data available and given the trawl survey's ability to sample smaller fish, it may be a better indicator of recruitment than the longline survey. There is some difficulty with combining estimates from the Bering Sea and Aleutian Islands with the Gulf of Alaska estimates since they occur on alternating years. A method could be developed to combine these indices, but it leaves the problem of how to use the length data to predict recruitment since the data could give mixed signals on year class strength. At this time we are using only the Gulf of Alaska trawl survey biomass estimates (<500 m depth, Figure 3.3) and length data (<500 m depth, Figures 3.12, 3.13) as a recruitment index for the whole population. The largest proportion of sablefish biomass is in the Gulf of Alaska so it should be indicative of the overall population. Biomass estimates used in the assessment for 1984-2011 are shown in Table 3.9. The GOA trawl survey index is at a low level in 2011, similar to 2009 and 1999.

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



### *Other surveys/areas*

The Alaska Department of Fish and Game conducts mark-recapture and a longline survey in Northern Southeast Alaska Inside (NSEI) waters. This population treated as a separate population, but some migration into and out of Inside waters has been confirmed with tagging studies. This population has been low to moderate recently, with their longline survey confirming the lows in 1999/2000 (see figure below), but showing a moderate increase through 2006 and leveling off through 2010. However, their most recent forecast estimates from a mark-recapture program, shows a sizeable decline from 2009 to 2011 with a slow long term decline since 2003 (Dressel per. comm. 2011).

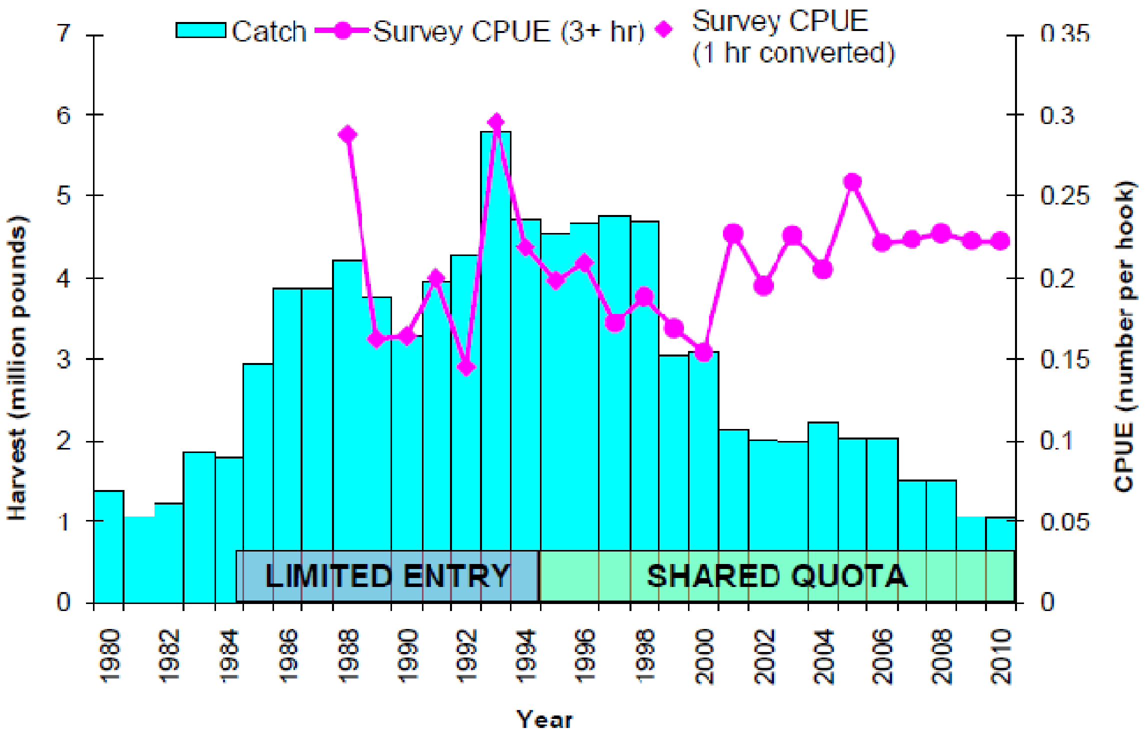


**Figure**. Northern Southeast Inside sablefish long line survey catch per unit effort in round pounds per hook and harvest over time (from Dressel per. comm. 2011).

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

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

In a 2011 Science Advisory Report, DFO reports

*"Stock reconstructions suggest that stock status is currently below* $B_{MSY}$ *for all scenarios, with the stock currently positioned in the mid-Cautious to low-Healthy zones."*

Under these scenarios, recent harvest rates on adult sablefish potentially have been between 0.06 – 0.15[1].

The reported low abundance south of Alaska concerns us, and point to the need to attempt to better understand the contribution to Alaska sablefish productivity from B.C. sablefish. Some ideas we have proposed are to conduct an area-wide study of sablefish tag recoveries, and to attempt to model the population to include B.C. sablefish.

## *Relative abundance trends – long-term*

Relative abundance has cycled through three valleys and two peaks with peaks in about 1970 and 1985 (Table 3.9, 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, recent above average year classes became abundant in the western areas at ages 3-4, in the central area at ages 4-6, and in the eastern area at ages 5-7 (Table 3.12). The 2000 year class became abundant in all areas between ages 4 and 5.

In the East Yakutat/Southeast area, sablefish abundance decreased for many years until 2002, when the fishery index, but not the survey index, increased (Figure 3.4). The survey index continued to generally decrease through 2003, but stabilized in the 2004 and 2005 surveys, and increased in 2006. The recent stabilization and increase in the survey index was likely caused by the 1997 and 2000 year classes entering the fishery. However, surveys in 2008 and 2009 have shown this area to be at its lowest levels during the domestic survey. In 2010, there was a substantial increase in the abundance index in the entire Eastern Gulf of Alaska. While this is positive, there has been an 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). We will continue to monitor this trend closely.

## *Relative abundance trends – short-term*

*Assessment results:* The fishery abundance index was down 9% from 2009 to 2010 (the 2011 data are not available yet). The survey abundance index increased 3% from 2010 to 2011 following a 10% increase from 2009 to 2010.

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[1] Science Advisory Report 2011/25: http://www.dfo-mpo.gc.ca/Csas-sccs/publications/sar-as/2011/2011_025-eng.pdf

# 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), which all stem from the work by Fournier and Archibald (1982). The current model configuration follows a more complex version of the Gulf of Alaska Pacific ocean perch model (Hanselman et al. 2005a) with split sexes to attempt to more realistically represent the underlying population dynamics of sablefish. The current configuration was accepted by the Groundfish Plan Team and NPFMC in 2010 (Hanselman et al. 2010). 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 (ADMB Project 2009).

## 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 | $\overline{L}_a = 75.6(1-e^{-0.208(a+3.63)})$ | $\overline{L}_a = 80.2(1-e^{-0.222(a+1.95)})$ | Hanselman et al. (2007) |
| Length-at-age - males | $\overline{L}_a = 65.3(1-e^{-0.227(a+4.09)})$ | $\overline{L}_a = 67.8(1-e^{-0.290(a+2.27)})$ | Hanselman et al. (2007) |
| Weight-at-age - females | $\ln \hat{W}_a = \ln(5.47) + 3.02 \ln(1-e^{-0.238(a+1.39)})$ | | Hanselman et al. (2007) |
| Weight-at-age - males | $\ln \hat{W}_a = \ln(3.16) + 2.96 \ln(1-e^{-0.356(a+1.13)})$ | | Hanselman et al. (2007) |
| Age-age conversion | Known | Known | Heifetz et al. (1999) |
| Recruitment variability ($\sigma_r$) | 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 fork length of about 45 cm. A higher proportion of young fish are susceptible to trawl gear compared to longline gear because trawl fisheries usually occur on the continental shelf and shelf break inhabited by younger fish, and catching small sablefish may be 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 (first daily otolith mark for larvae) formation, they average 120 mm. Sablefish are currently estimated to reach average maximum lengths and weights of 68 cm and 3.2 kg for males and 80 cm and 5.5 kg for females.

New growth relationships recently were estimated because many more age data were available (Hanselman et al. 2007); this analysis was accepted by the Plan Team in November 2007. We divided the data into two time periods based on the change in sampling design that occurred in 1995. It appears that sablefish maximum length and weight has increased slightly over time. New age-length conversion matrices were constructed using these curves with normal error fit to the standard deviations of the collected lengths at age (Figure 3.8). These new matrices provided for a superior fit to the data. Therefore, we use a bias-corrected and updated growth curve for the older data (1981-1993) and a new growth curve describing recent randomly collected data (1996-2004).

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 3.13). 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 $m_a = 1/(1+e^{-0.84(a-6.60)})$.

*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 113 years[1]. 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 Markov Chain Monte Carlo (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.

*Variance and effective sample sizes:* Several quantities were computed in order to compare the variance of the residuals to the assumed input variances. The standardized deviation of normalized residuals (SDNR) is closely related to the root mean squared error (RMSE) or effective sample size; values of SDNR of approximately 1 indicate that the model is fitting a data component as well as would be expected for a given specified input variance. The normalized residuals for a given year $i$ of the abundance index was computed as

$$\delta_i = \frac{\ln(I_i) - \ln(\hat{I}_i)}{\sigma_i}$$

where $\sigma_i$ is the input sampling standard deviation of the estimated abundance index. For age or length composition data assumed to follow a multinomial distribution, the normalized residuals for age/length group $a$ in year $i$ were computed as

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[1] Fisheries and Oceans Canada; http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/ground-fond/sable-charbon/bio-eng.htm

$$\delta_{i,a} = \frac{(y_{i,a} - \hat{y}_{i,a})}{\sqrt{\hat{y}_{i,a}(1-\hat{y}_{i,a})/n_i}}$$

where $y$ and $\hat{y}$ are the observed and estimated proportion, respectively, and n is the input assumed sample size for the multinomial distribution. The effective sample size was also computed for the age and length compositions modeled with a multinomial distribution, and for a given year *i* was computed as

$$E_i = \frac{\sum_a \hat{y}_a * (1 - \hat{y}_a)}{\sum_a (\hat{y}_a - y_a)^2}.$$

An effective sample size that is nearly equal to the input sample size can be interpreted as having a model fit that is consistent with the input sample size.

For the 2010 recommended assessment model, we used average SDNR as a criterion to help reweight the age and length compositions. SDNR is a common metric used for goodness of fit in other fisheries, particularly in New Zealand (e.g. Langley and Maunder 2009) and has been recommended for use in fisheries models in Alaska during multiple CIE reviews such as Atka mackerel (R.I.C.C. Francis) and rockfish (P. Cordue). We iteratively reweighted the model by setting an objective function penalty to reduce the deviations of average SDNR of a data component from one. Initially, we tried to fit all multinomial components this way, but due to tradeoffs in fit, it was found that the input sample sizes became too large and masked the influence of important data such as abundance indices. Given that we have age and length samples from nearly all years of the longline surveys, we chose to eliminate the attempt to fit the length data well enough to achieve an average SDNR of one, and reweighted all age components and only length components where no age data exists (e.g. domestic trawl fishery). The abundance index SDNRs were calculated, but no attempt was made to adjust their input variance because we have *a priori* knowledge about their sampling variances. This process was completed before the 2010 data were added into the assessment and endorsed by the Plan Teams and SSC in 2010. We continue to use these weightings. The table below shows the input CVs/sample sizes for the data sources and their associated output SDNR for the recommended model. This reweighting is intended to remain fixed for at least several years.

| Multinomial Compositions | Input N/CV | SDNR | Effective N |
|---|---|---|---|
| Domestic LL Fishery Ages | 200 | 0.99 | 187 |
| Domestic LL Fishery Lengths | 120 | 0.85 | 326 |
| Trawl Fishery Lengths | 50 | 1.07 | 89 |
| LL Survey Ages | 160 | 0.97 | 182 |
| NMFS Trawl Survey Lengths | 140 | 0.98 | 147 |
| Domestic LL Survey Lengths | 20 | 0.30 | 207 |
| Japanese/Coop LL Survey Lengths | 20 | 0.32 | 200 |
| Lognormal abundance indices | | | |
| Domestic RPN | 5% | 3.97 | |
| Japanese/Coop RPN | 5% | 2.99 | |
| Domestic Fishery RPW | 10% | 0.87 | |
| Foreign Fishery RPW | 10% | 1.15 | |
| NMFS Trawl Survey | 8-14% | 2.41 | |

### Parameters Estimated Conditionally

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

| Parameter name | Symbol | Number |
|---|---|---|
| Catchability | $q$ | 6 |
| Log-mean-recruitment | $\mu_r$ | 1 |
| Spawners-per-recruit levels | $F_{35}, F_{40}, F_{50}$ | 3 |
| Recruitment deviations | $\tau_y$ | 79 |
| Average fishing mortality | $\mu_f$ | 2 |
| Fishing mortality deviations | $\phi_y$ | 104 |
| Fishery selectivity | $fs_a$ | 8 |
| Survey selectivity | $ss_a$ | 7 |
| Total | | 210 |

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, U.S. longline derby fishery, U.S. longline IFQ fishery, and the NMFS GOA trawl survey. Information is available to link these estimates of catchability. Kimura and Zenger (1997) analyzed the relationship between the cooperative and domestic longline surveys. For assessments through 2006, we used their results to create a prior distribution which linked catchability estimates for the two surveys. For 2007, we estimated new catchability prior distributions based on the ratio of the various abundance indices to a combined Alaskan trawl index. This resulted in similar mean estimates of catchability to those previously used, but allowed us to estimate a prior variance to be used in the model. This also facilitates linking the relative catchabilities between indices. These priors were used in the recommended model for 2008. This analysis was presented at the September 2007 Plan Team and is presented in its entirety in Hanselman et al. (2007). Lognormal prior distributions were used with the parameters shown below and in Figure 3.9:

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

Recruitment is not estimated with a stock-recruit relationship, but is estimated with a level of average recruitment with deviations from average recruitment for the years 1933-2010.

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 1960-2011 for each fishery.

Selectivity is represented using a function and is separately estimated by sex for the longline survey, fixed-gear fishery (pot and longlines combined), and the trawl survey. Selectivity for the trawl fishery is estimated the same for both sexes. Selectivity for the longline surveys and fixed-gear fishery is restricted to be asymptotic by using the logistic function. Selectivity for the trawl fishery and trawl survey are dome-shaped (right descending limb) and estimated with a two-parameter gamma-function and a power function respectively (see Box 1 for equations). This right-descending limb is allowed because we do not expect that the trawl survey and fishery will catch older aged fish as frequently because they fish shallower than the fixed-gear fishery. Selectivity for the fixed-gear fishery is estimated separately for the "derby" fishery prior to 1995 and the IFQ fishery from 1995 thereafter. Fishers may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the 1985-1994 "derby" fishery, when fishers reportedly often fished in less productive depths due to crowding (Sigler and Lunsford 2001). 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. The multidimensional posterior distribution is mapped by Bayesian integration methods. The posterior distribution was computed based on 20 million MCMC simulations drawn from the posterior distribution. A burn-in of 2 million draws was removed from the beginning of the chain and then thinned to 4,500 parameter draws to remove serial correlation between successive draws. 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.

In previous assessments, we estimated the posterior probability that projected abundance will fall below the decision analysis thresholds based on Mace and Sissenwine (1993). However, in the North Pacific Fishery Management Council setting we have thresholds that are defined in the Council harvest rules. These are when the spawning biomass falls below $B_{40\%}$, $B_{35\%}$, 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. To examine the posterior probability, we project spawning biomass into the future with recruitments varied as random draws from a lognormal distribution with the mean and standard deviation of 1979-2009 recruitments. In addition, model uncertainty is propagated during the MCMC simulations.

| **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 |
| $\Omega$ | 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 $s$ |
| $\varphi_a$ | Proportion of females mature at age $a$ |
| $\mu_r$ | Average log-recruitment |
| $\mu_f$ | Average log-fishing mortality |
| $\phi_{y,g}$ | Annual fishing mortality deviation |
| $\tau_y$ | Annual recruitment deviation ~ $(0, \sigma_r)$ |
| $\sigma_r$ | Recruitment standard deviation |
| $N_{y,a,s}$ | Numbers of fish at age $a$ in year $y$ of sex $s$ |
| $M$ | Natural mortality |
| $F_{y,a,g}$ | Fishing mortality for year $y$, age class $a$ and gear $g$ $(=s_a^g \mu_f e^{\phi_{y,g}})$ |
| $Z_{y,a}$ | Total mortality for year $y$ and age class $a$ $(=\sum_g F_{y,a,g} + M)$ |
| $R_y$ | Recruitment in year $y$ |
| $B_y$ | Spawning biomass in year $y$ |
| $s_{a,s}^g$ | Selectivity at age $a$ for gear type $g$ and sex $s$ |
| $A_{50\%}, d_{50\%}$ | Age at 50% selection for ascending limb, age at 50% deselection for descending limb |
| $\delta$ | Slope/shape parameters for different logistic curves |
| $\mathbf{A}$ | Ageing-error matrix dimensioned $a_+ \times a_+$ |
| $\mathbf{A}^l$ | Age to length conversion matrix dimensioned $a_+ \times \Omega$ |
| $q_g$ | Abundance index catchability coefficient by gear |
| $\lambda_x$ | Statistical weight (penalty) for component $x$ |
| $I_y, \hat{I}_y$ | Observed and predicted survey index in year $y$ |
| $P_{y,l,s}^g, \hat{P}_{y,l,s}^g$ | Observed and predicted proportion at length $l$ for gear $g$ in year $y$ and sex $s$ |
| $P_{y,a,s}^g, \hat{P}_{y,a,s}^g$ | Observed and predicted proportion at observed age $a$ for gear $g$ in year $y$ and sex $s$ |
| $\psi_y^g$ | 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 $g$ |
| $M_\mu, \sigma_M$ | 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) |
|---|---|
| $N_{1,a}=\begin{cases} R_1, & a=a_0 \\ e^{\left(\mu_r+\tau_{a_o-a+1}\right)}e^{-(a-a_0)M}, & a_0<a<a_+ \\ e^{(\mu_r)}e^{-(a-a_0)M}\left(1-e^{-M}\right)^{-1}, & a=a_+ \end{cases}$ | Initial year recruitment and numbers at ages. |
| $N_{y,a}=\begin{cases} R_y, & a=a_0 \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}}, & a_0<a<a_+ \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}}+N_{y-1,a}e^{-Z_{y-1,a}}, & a=a_+ \end{cases}$ | Subsequent years recruitment and numbers at ages |
| $R_y=e^{\left(\mu_r+\tau_y\right)}$ | Recruitment |
| **Selectivity equations** | |
| $s_{a,s}^g=\left(1+e^{(-\delta_{g,s}(a-a_{50\%,g,s}))}\right)^{-1}$ | Logistic selectivity |
| $s_{a,s}^g=\dfrac{a^{\delta_{g,s}}}{\max\left(s_{a,s}^g\right)}$ | Inverse power family |
| $s_{a,s}^g=\left(\dfrac{a}{a_{\max}}\right)^{a_{\max,g,s}/p}e^{(a_{\max,g,s}-a)/p}$<br>$p=0.5\left[\sqrt{a_{\max,g,s}{}^2+4\delta_{g,s}{}^2}-a_{\max,g,s}\right]$ | Reparameterized gamma distribution |
| $s_{a,s}^g=\left(1-\varphi_s^g\right)^{-1}\left(\dfrac{\left(1-\varphi_s^g\right)}{\varphi_s^g}\right)^{\varphi_s^g}\dfrac{\left(e^{(\delta_{g,s}\varphi_s^g(a_{50\%,g,s}-a))}\right)}{\left(1+e^{(\delta_{g,s}(a_{50\%,g,s}-a))}\right)}$ | Exponential-logistic selectivity |
| **Observation equations** | |
| $\hat{C}_{y,g}=\sum_1^g\sum_1^s w_{a,s}N_{y,a,g,s}F_{y,a,g,s}\left(1-e^{-Z_{y,a,g,s}}\right)Z_{y,a,g,s}^{-1}$ | Catch biomass in year *y* |
| $\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\dfrac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}w_{a,s}$ | Survey biomass index (RPW) |
| $\hat{I}_{y,g}=q^g\sum_{a_0}^{a_+}N_{y,a,s}\dfrac{s_{a,s}^g}{\max\left(s_{a,s}^g\right)}$ | Survey biomass index (RPN) |
| $\hat{P}_{y,\cdot,s}^g=N_{y,a,s}s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s$ | Vector of fishery or survey predicted proportions at age |
| $\hat{P}_{y,\cdot,s}^g=N_{y,\cdot,s}s_s^g\left(\sum_{a_0}^{a_+}N_{y,a,s}s_{a,s}^g\right)^{-1}\mathbf{A}_s^l$ | Vector of fishery or survey predicted proportions at length |

| **Posterior distribution components** | **Model Description** (continued) |
|---|---|
| $L_C = \lambda_c \sum_1^g \sum_y \left(\ln C_{g,y} - \ln \hat{C}_{g,y}\right)^2 / \left(2\sigma_C^2\right)$ | Catch likelihood |
| $L_I = \lambda_I \sum_1^g \sum_y \left(\ln I_{g,y} - \ln \hat{I}_{g,y}\right)^2 / \left(2\sigma_I^2\right)$ | Survey biomass index likelihood |
| $L_{age} = \lambda_{age} \sum_{i=1}^{n_g} -\psi_y^g \sum_{a_0}^{a_+} \left(P_{i,a}^g + v\right) \ln\left(\hat{P}_{i,a}^g + v\right)$ | Age composition likelihood |
| $L_{length} = \lambda_{length} \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l}^g + v\right) \ln\left(\hat{P}_{i,l}^g + v\right)$ | Length composition likelihood<br>( $\psi_y^g$ =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 $\sigma_r$ |
| $L_\tau = 0.1 \sum_{y=1}^{T} \frac{\tau_y^2}{2\hat{\sigma}_r^2} + n \ln \hat{\sigma}_r$ | 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 2011 with no model changes. A comparison of the model likelihood components and key parameter estimates from 2010 are compared with the 2011 updated model.

**Box 2**: Model comparison of the 2010 and 2011 models by contribution to the objective function (negative log-likelihood values) and key parameters.

| Model<br>Likelihood Components (Data) | **2010** | **2011** |
|---|---:|---:|
| Catch | 8 | 9 |
| Domestic LL survey RPN | 40 | 43 |
| Japanese LL survey RPN | 18 | 18 |
| Domestic LL fishery RPW | 7 | 8 |
| Japanese LL fishery RPW | 11 | 10 |
| NMFS GOA trawl survey | 14 | 17 |
| Domestic LL survey ages | 141 | 154 |
| Domestic LL fishery ages | 148 | 159 |
| Domestic LL survey lengths | 53 | 52 |
| Japanese LL survey ages | 143 | 144 |
| Japanese LL survey lengths | 46 | 46 |
| NMFS trawl survey lengths | 216 | 269 |
| Domestic LL fishery lengths | 195 | 199 |
| Domestic trawl fishery lengths | 126 | 158 |
| Data likelihood | 1165 | 1286 |
| Total objective function value | 1184 | 1307 |
| **Key parameters** | | |
| Number of parameters | 207 | **210** |
| $B_{2012\text{ (Female spawning biomass)}}$ | 102 | 101 |
| $B_{40\%\text{ (Female spawning biomass)}}$ | 110 | 108 |
| $B_{1960\text{ (Female spawning biomass)}}$ | 177 | 180 |
| $B_{0\%\text{ (Female spawning biomass)}}$ | 275 | 271 |
| *SPR% current* | 37% | 37% |
| $F_{40\%}$ | 0.097 | 0.096 |
| $F_{40\%\text{ (adjusted)}}$ | 0.089 | 0.089 |
| *ABC* | 16.0 | **17.2** |
| $q_{\text{Domestic LL survey}}$ | 7.7 | 7.8 |
| $q_{\text{Japanese LL survey}}$ | 6.3 | 6.3 |
| $q_{\text{DomesticLL fishery}}$ | 4.2 | 4.1 |
| $q_{\text{Trawl Survey}}$ | 1.0 | 1.3 |
| $a_{50\%\text{ (domestic LL survey slectivity)}}$ | 3.9 | 3.9 |
| $a_{50\%\text{ (LL fishery selectivity)}}$ | 4.1 | 4.1 |
| $\mu_r$ *(average recruitment)* | 18.5 | 18 |
| $\sigma_r$ *(recruitment variability)* | 1.20 | 1.20 |

The two models are identical in all aspects except for inclusion of new data. Our usual 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, (3) a good visual fit to length and age compositions, and (4) parsimony.

Because the models presented have different amounts of data and different data weightings, it is not reasonable to compare their negative log likelihoods so we cannot compare them by the first criterion above. In general we can only evaluate the 2011 model based on changes in results from 2010. The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. The 2011 update shows some increases in recent recruitment and an increase in total biomass from previous projections. Therefore the 2011 model is utilizing the new information effectively, and we use it to recommend 2012 ABC and OFL.

## Model Results

### *Definitions*

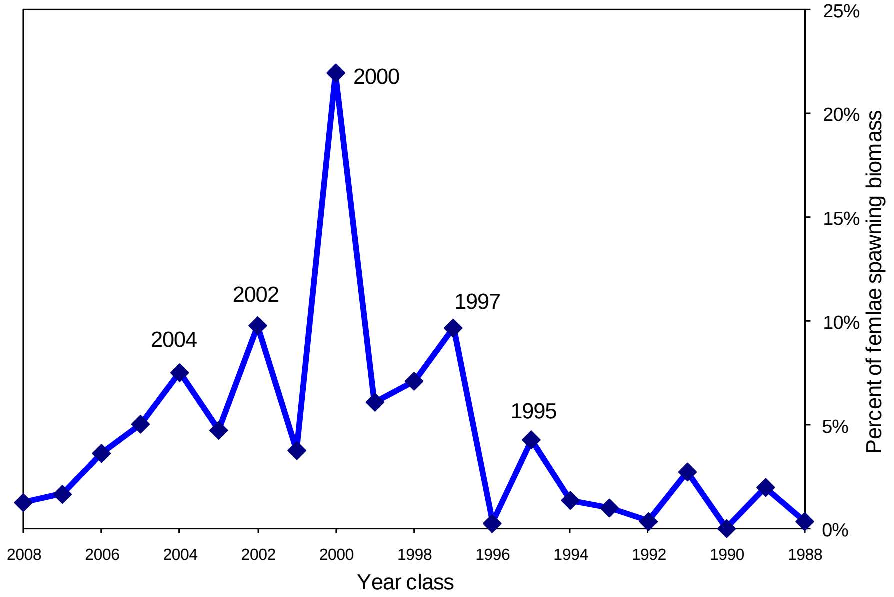
Spawning biomass is the biomass estimate of mature females. Total biomass is the estimate of all sablefish age two and greater. Recruitment is measured as number of age two sablefish. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

### *Abundance trends*

Sablefish abundance increased during the mid-1960's (Table 3.15, Figure 3.10) due to strong year classes in the early 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing and relatively low recruitment; catches peaked at 53,080 t in 1972. The population recovered due to a series of strong year classes from the late 1970's (Figure 3.18, Table 3.14) and also recovered at different rates in different areas (Table 3.15); spawning abundance peaked again in 1987. The population then decreased because these strong year classes expired. The model suggested an increasing trend in spawning biomass since the all-time low in 2002, but has leveled out in 2011 (Figure 3.10).

**Projected 2012 spawning biomass is 37% of unfished spawning biomass.** Spawning biomass has increased from a low of 30% of unfished biomass in 2002 to 37% projected for 2012. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 10% of the 2012 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now mature and should comprise 23% of the spawning biomass in 2012. The 2002 year class is beginning to show signs of strength and will comprise 10% of spawning biomass in 2012 and is 92% mature.

The following figure shows the age composition of spawning biomass projected for 2011 for the last 20 year-classes.



### Recruitment trends

Annual estimated recruitment varies widely (Figure 3.18b). The two recent strong year classes in 1997 and 2000 are evident in all data sources. After 2000, few strong year classes are apparent. Few small fish were caught in the 2005 through 2009 trawl surveys, but a likely 2008 year class is appearing in the 2011 trawl survey length composition (Figures 3.12-13). The 2001 year class appeared to be an above-average year class in the Aleutian Islands and Western Gulf in the 2005-2007 longline survey age compositions. However, the 2001 year class appeared moderate in the Central Gulf in the 2006-2007 survey age composition (Figure 3.7) and is still low in the overall age compositions (Figure 3.17). The 2002 year class appears weak in the 2005 and 2006 longline survey age composition, but showed up somewhat in the Central Gulf in the 2007 age compositions and again in the 2008 Eastern Gulf age compositions. The RPN by age class is quite low in the 2008 age composition (Figure 3.7), but shows an interesting flattening of the middle age distribution. In the Central Gulf, the 1998-2003 year classes all have almost identical RPNs. One possible explanation is that the targeting of year classes discussed earlier is removing the initial peaks caused by large year classes like 2000. The 2009 survey age composition class shows some different year classes looking stronger such as the 2003 year class in the Bering Sea and Western GOA. In the 2010 longline survey age composition, the 2008 year class shows up in all three areas relatively strongly for lightly selected 2 year old fish.

Year classes are 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 estimated recruitment values shows that only one of the last ten year classes (1999-2009) was above average.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Strong** | 1960 | 1963 | 1964 | 1970 | 1971 | 1977 | 1978 | 1980 | 1982 | 1989 | 1991 | 1997 | 2000 |
| **Average** | 1961 | 1962 | 1965 | 1966 | 1967 | 1974 | 1979 | 1981 | 1984 | 1985 | 1987 | 1988 | 1993 |
| | 1994 | 1995 | 1998 | 1999 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | |
| **Weak** | 1958 | 1959 | 1968 | 1969 | 1972 | 1973 | 1975 | 1976 | 1983 | 1986 | 1990 | 1992 | 1996 |

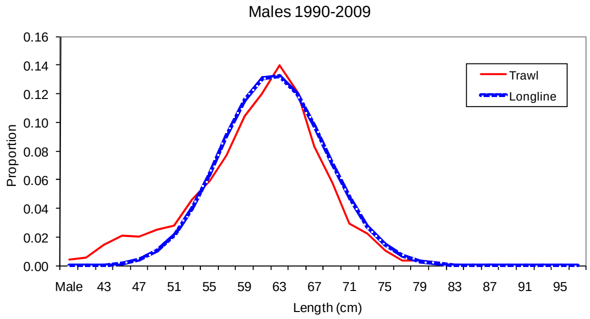
Average recruitment during 1979-2009 is 18.0 million 2-year-old sablefish per year, which is similar to the average recruitment for the 1958-2009 year classes. Estimates of recruitment strength during the 1960's are less certain because they depend on length data but not age data and because the abundance index is based only on the fishery catch rate, which may be a weak measure of abundance. The 2008 year class is being estimated at slightly above average in this year’s model. Assuming the 2008 year class is strong when 2011 longline survey age compositions are included next year, the strength of this year class will likely increase.

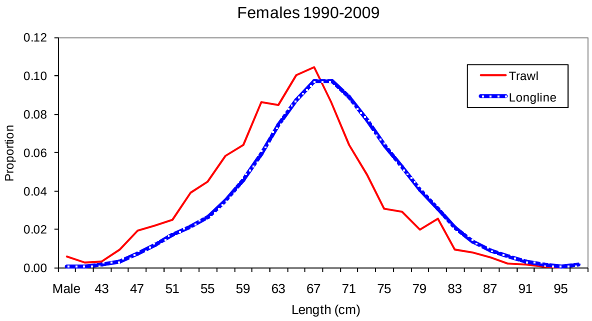
Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles are found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1 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.), the 1998 year class near Kodiak Island (D. Jackson, ADFG, pers. commun.), and the 2008 year class in Uganik Bay on Kodiak Island (P. Rigby, NOAA, pers. commun.).

Sablefish recruitment varies greatly from year to year (Figure 3.18), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success is also coincidental to recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1960-1961 and 1977 year classes also were strong. Some of the largest year classes of sablefish occurred when abundance was near the historic low, the 1977-1978 and 1980-1981 year classes. These strong year classes followed the 1976/1977 North Pacific regime shift. The 1977 year class was associated with the Pacific Decadal Oscillation (PDO) phase change and the 1977 and 1981 year classes were associated with warm water and unusually strong northeast Pacific pressure index (NEPI, Hollowed and Wooster 1992). Larger than average year classes were produced again in 1997-2000, when the population was low. Some species such as walleye pollock and sablefish may exhibit increased production at the beginning of a new environmental regime, when bottom up forcing prevails and high turnover species compete for dominance, which later shifts to top down forcing once dominance is established (Bailey 2000, Hunt et al. 2002). The large year classes of sablefish indicate that the population, though low, still was able to take advantage of favorable environmental conditions and produce large year classes.

### *Selectivities*

Selectivity is asymptotic for the longline survey and fisheries and dome-shaped (or descending right limb) for the trawl survey and trawl fishery (Figure 3.19). The age-of-50% selection is 3.9 years for females in the longline survey and 4.1 years in the IFQ longline fishery. Females are selected at an older age in the IFQ fishery than in the derby fishery (Figure 3.19a). Males were selected at an older age than females in both the derby and IFQ fisheries. Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishers were pushed to fish shallower water that young fish inhabit (Sigler and Lunsford 2001). Relative to the longline survey, small fish are more vulnerable and older fish are less vulnerable to the trawl fishery (see following figure) because trawling often occurs on the continental shelf in shallower waters (< 300 m) where young sablefish reside. The trawl fishery selectivity is the same for males and females (Figure 3.19a). The trawl survey selectivity curves differ between males and females where males stay selected by the trawl survey longer (Figure 3.19). These patterns are consistent with the idea that sablefish move out on the shelf at 2 years of age and then gradually become less available to the trawl fishery and survey as they move offshore into deeper waters. The trawl survey selectivity has a reasonably smooth descending shape that probably describes trawl selectivity to 500 m in the Gulf of Alaska (Figure 3.19b).





### *Fishing mortality and management path*

Fishing mortality was estimated to be high in the 1970s, relatively low in the early 1980s and then increased and held relatively steady in the 1990s and 2000s (Figure 3.20). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. Previously we used the management path as suggested by Goodman et al. (2002), but several reviews have suggested a similar phase-plane plot that shows our harvest control rules. In this “management path” we plot estimated fishing mortality relative to the (current) limit value and the estimated spawning biomass relative to target spawning biomass ($B_{35\%}$). Figure 3.21 shows that recent management has generally constrained fishing mortality below the limit rate, and has recently kept the stock above the $B_{35\%}$ limit.

## *Uncertainty*

We compared a selection of parameter estimates from the Markov-Chain Monte Carlo (MCMC) simulations with the maximum-likelihood estimates, and compared each method's associated level of uncertainty (see following table). Mean and median catchability estimates were identical. The estimate of $F_{40\%}$ was lower by maximum likelihood and shows some skewness as indicated by the difference between the MCMC mean and median values. Under both methods the variances are similar except for estimation of a large year class (2000) where the uncertainty is higher for MCMC methods. Ending female spawning biomass and the last large recruitment (2000) are estimated precisely by both methods. The more recent 2008 year class is not estimated as precisely, and the MCMC estimates are slightly higher.

**Table of key parameter estimates and their uncertainty and Bayesian credible intervals (BCI)**

| Parameter | $\mu$ (MLE) | $\mu$ (MCMC) | Median (MCMC) | $\sigma$ (Hessian) | $\sigma$ (MCMC) | BCI-Lower | BCI-Upper |
|---|---|---|---|---|---|---|---|
| $q_{domesticLL}$ | 7.80 | 7.78 | 7.78 | 0.11 | 0.24 | 7.32 | 8.24 |
| $q_{coopLL}$ | 6.32 | 6.32 | 6.32 | 0.11 | 0.21 | 5.93 | 6.72 |
| $q_{trawl}$ | 1.35 | 1.35 | 1.34 | 0.33 | 0.10 | 1.16 | 1.55 |
| $F_{40\%}$ | 0.10 | 0.11 | 0.10 | 0.02 | 0.03 | 0.06 | 0.18 |
| 2011 SSB (kt) | 103.6 | 104.0 | 103.8 | 4.0 | 4.3 | 95.7 | 112.7 |
| 2000 Year Class | 43.3 | 45.8 | 45.8 | 4.1 | 4.7 | 36.7 | 54.8 |
| 2008 Year Class | 20.1 | 23.0 | 22.7 | 5.4 | 5.5 | 12.8 | 34.7 |

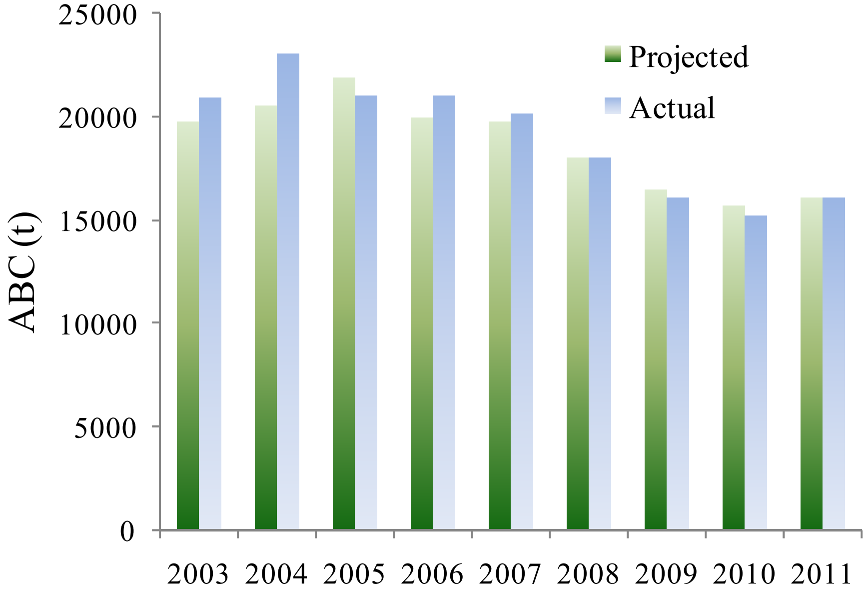
## *Retrospective analysis*

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

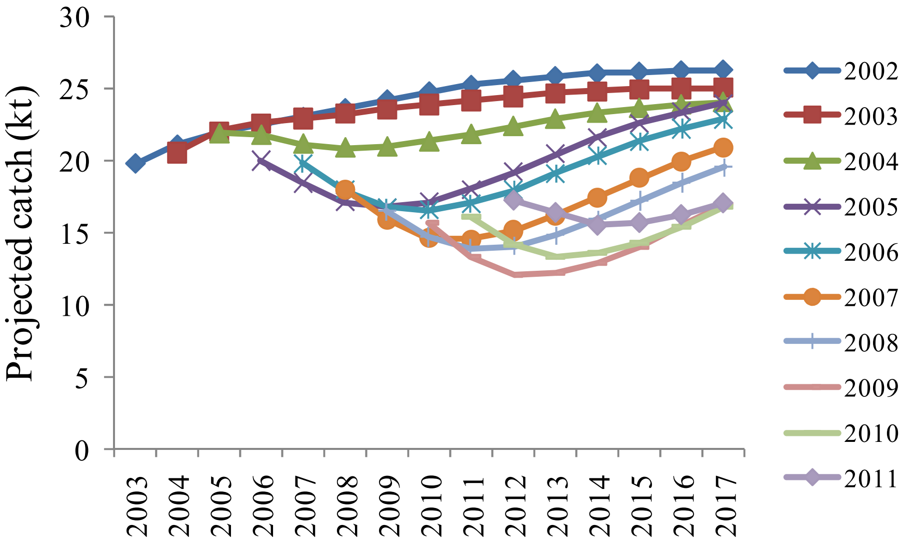
For this assessment, we show the retrospective trend in spawning biomass and total biomass for six years (2006-2011). This analysis is simply removing all new data that have been added for each consecutive year for the preferred model. Each year of the assessment generally adds one year of longline fishery 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.

When the model was reweighted and RPWs were removed in 2010, the previous retrospective pattern all but disappeared. In the recommended model for 2011, this retrospective analysis of spawning biomass shows some small changes in recent estimates but appears to be a reflection of new data (Table 3.16, Figure 3.22a). The 2011 estimates of total biomass are turning toward a neutral trend which is based on two relatively high longline survey abundance indices in succession and not a retrospective pattern (Table 3.16, Figure 3.22b).

The 2010 Joint Plan Team requested that we examine what the current model configuration would have recommended for ABCs going back in time to see how much model and author changes has affected management advice. To examine this, the current model configuration was run backwards with what data we had in each year back to 2002. We then projected an ABC for 2003-2011 in each of those assessment years and compared them to the actual ABC in each of those years. In the following figure, it can be seen that despite many model changes, including growth updates and a split-gender model, the management advice would have been similar.



A second question raised during the same Plan Team discussion was that the projection always seemed to be pointing down then eventually returning as average recruitment was realized. To examine this, we ran multi-year projections from 2002-2010 using the current model configuration. In the following figure, projections in 2002 and 2003 were always increasing into the future, while in 2004-2009 the projections became increasingly negative in the first few years of the projection because of a series of relatively low longline survey abundance estimates. In 2010 and 2011, these projections have started to flatten out again in response to several relatively high longline survey abundance estimates (see following figure).



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

# Projections and Harvest Alternatives

## Reference fishing mortality rate

Sablefish are managed under Tier 3 of NPFMC harvest rules which specify that the fishing rate be adjusted downward when biomass is below the target reference biomass. Compared to a constant fishing rate strategy, the adjustable rate strategy was shown in simulations by Sigler and Fujioka (1993) to significantly reduce the risk of overfishing of sablefish, while attaining nearly the same yield with lower fishing effort. Fujioka et al. (1997) showed analytically the same advantages of an adjustable fishing rate compared to a constant fishing rate strategy. Reference points are calculated using recruitments from 1979-2009. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 108,574 t (combined across the EBS, AI, and GOA), 0.096, and 0.114, respectively. Projected female spawning biomass (combined areas) for 2012 is 101,325 t (93% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of $F_{ABC}$ under Tier 3b is 0.089, which translates into a 2012 ABC (combined areas) of 17,240 t. The OFL fishing mortality rate is 0.106 which translates into a 2012 OFL (combined areas) of 20,400 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.

## Population projections

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

For each scenario, the projections begin with the vector of 2011 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2011 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 2012, 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 2012 and 2013, $F$ is set equal to a constant fraction of *max* $F_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2008-2010 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of F will yield more realistic projections.)

> *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 2006-2011 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 follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2020 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, $F$ 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 2023 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 3.17). 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 more accurate preliminary ABCs and OFLs for 2012 and 2013. The methodology for determining these pre-specified catches is described below in ***Specified catch estimation.***

## Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2012, it does not provide the best estimate of OFL for 2012, because the mean 2012 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2011 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

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

*Is the stock being subjected to overfishing?* The official catch estimate for the most recent complete year (2010) is 11,916 t. This is less than the 2010 OFL of 18,030 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*.

Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

*Is the stock currently overfished?* This depends on the stock's estimated spawning biomass in 2011:

a. If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2011 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 3.17). If the mean spawning biomass for 2021 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

*Is the stock approaching an overfished condition?* This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

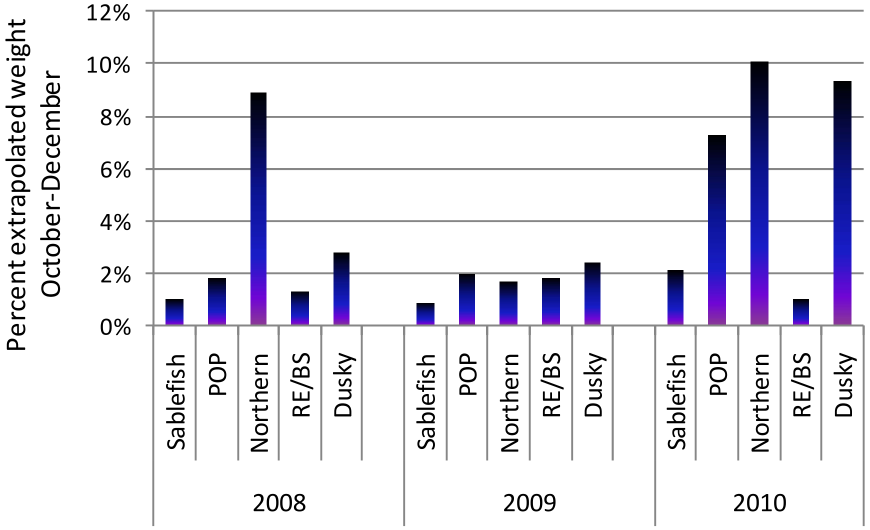
c. If the mean spawning biomass for 2014 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 3.17, the stock is not overfished and is not approaching an overfished condition.

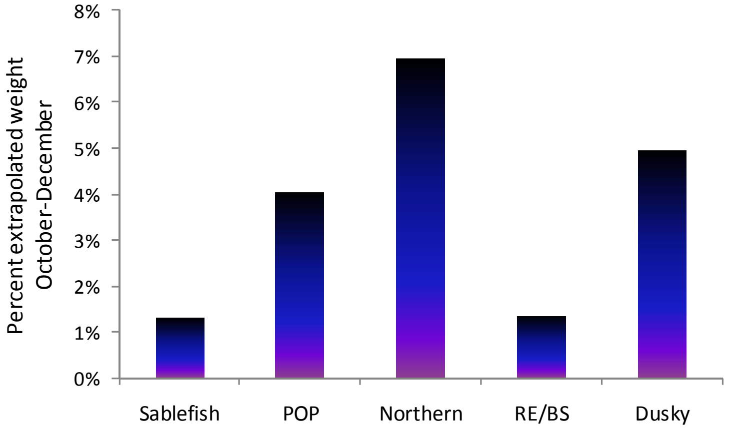
### *Specified catch estimation*

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two different approaches have been used in GOA rockfish models; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October 2011 is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2008-2010 for this year, see example figures below). For sablefish, the expansion factor for 2011 catch is 1.013. Examples are shown in the following figures.

Catches that occur after October 1st from 2008-2010 are shown below:

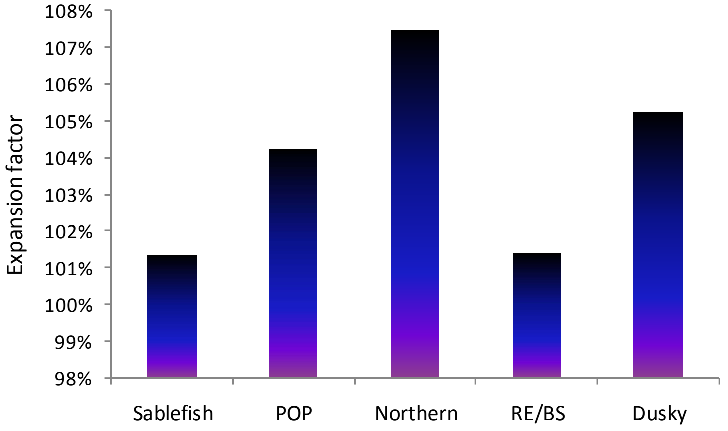


The mean proportion of catch between October-December, 2008-2010, is shown below:



We converted this to an expansion factor:

$x = \sum_1^{12} C_y \,/ \sum_1^{9} C_y$, where $C_y$ is catch in month $y$ shown in the figure below:



For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out.

### Bayesian analysis

The model estimates of spawning biomass fall near the center of the posterior distribution of spawning biomass. Most of the probability lies between 80,000 and 140,000 t (Figure 3.23). The probability changes smoothly and exhibits a relatively normal distribution.

Scatter plots of selected pairs of model parameters were produced to evaluate the shape of the posterior distribution (Figure 3.24). The plots indicate that the parameters are reasonably well defined by the data. As expected, catchabilities and ending spawning biomass are confounded. The catchability of the longline survey is most confounded with ending spawning biomass because it has the most influence in the model in recent abundance predictions.

We estimated the posterior probability that projected abundance will fall, or stay below thresholds of 17.5% (MSST), and 35% (MSY), and 40% ($B_{target}$) of the unfished spawning biomass based on the posterior probability estimates. Abundance was projected for 14 years. For management, it is important to know the risk of falling under these thresholds. The probability that spawning biomass falls below key biological reference points was estimated based on the posterior probability distribution for spawning biomass. The probability that next year's spawning biomass was below $B_{35\%}$ was 0.33. During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of falling below $B_{35\%}$ is 0.6 (down from 0.99 last year), and the probability of staying below $B_{40\%}$ is near 100% (Figure 3.25).

### 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 20,000,000 MCMC (burnt-in and thinned) using the standard Tier 3 harvest rules. The projection shows wide credible intervals on future spawning biomass (Figure 3.26). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1979-2009 recruitments, and this projection predicts that the median spawning biomass will dip below $B_{35\%}$ by 2014, and then return to $B_{40\%}$ if average recruitment is attained. This projection is run with full ABC taken in each year, so its results are more similar to Alternative 1 in Table 3.17.

### Acceptable biological catch

**We recommend a 2012 ABC of 17,240 t.** The maximum permissible ABC for 2012 from an adjusted $F40_{\%}$ strategy is 17,240 t. The maximum permissible ABC for 2012 is a 7% increase from the 2011 ABC of 16,040 t. This increase is supported by a substantial increase in the domestic longline survey index in the past two years that offset the prior year's decrease in the fishery abundance index and a low Gulf of Alaska trawl survey biomass estimate. There was also a slight increase in estimates of incoming recruitment year classes. Spawning biomass is projected to decline through 2016, and then is expected to increase assuming average recruitment is achieved. Because of the indications of recent slightly stronger year classes, the maximum permissible ABC is projected to stabilize at 17,019 t in 2013 and 16,769 in 2014 (using estimated catches, instead of maximum permissible, see Table 3.17).

**Projected 2012 spawning biomass is 37% of unfished spawning biomass.** Spawning biomass has increased from a low of 30% of unfished biomass in 2002 to 37% projected for 2012. The 1997 year class has been an important contributor to the population but has been reduced and should comprise 10% of the 2012 spawning biomass. The 2000 year class appears to be larger than the 1997 year class, and is now mature and should comprise 23% of the spawning biomass in 2012. The 2002 year class is beginning to show signs of strength and will comprise 10% of spawning biomass in 2012 and is 92% mature.

The following table shows the maximum permissible ABC, and ABCs recommended by the stock assessment authors, Plan Teams, SSC, and NPFMC, by fishing year 1997-2010.

| Year | Maximum permissible | Authors | Plan Teams | SSC | NPFMC |
|---|---|---|---|---|---|
| 1997 | 23,200 | 17,200 | 19,600 | 17,200 | 17,200 |
| 1998 | 19,000 | 16,800 | 16,800 | 16,800 | 16,800 |
| 1999 | 15,900 | 15,900 | 15,900 | 15,900 | 15,900 |
| 2000 | 17,300 | 17,000 | 17,300 | 17,300 | 17,300 |
| 2001 | 16,900 | 16,900 | 16,900 | 16,900 | 16,900 |
| 2002 | 21,300 | 17,300 | 17,300 | 17,300 | 17,300 |
| 2003 | 25,400 | 18,400 | 18,400 | 20,900 | 20,900 |
| 2004 | 25,400 | 23,000 or 20,700 | 23,000 | 23,000 | 23,000 |
| 2005 | 21,000 | 21,000 | 21,000 | 21,000 | 21,000 |
| 2006 | 21,000 | 21,000 | 21,000 | 21,000 | 21,000 |
| 2007 | 20,100 | 20,100 | 20,100 | 20,100 | 20,100 |
| 2008 | 18,030 | 18,030 | 18,030 | 18,030 | 18,030 |
| 2009 | 16,080 | 16,080 | 16,080 | 16,080 | 16,080 |
| 2010 | 15,230 | 15,230 | 15,230 | 15,230 | 15,230 |
| 2011 | 16,040 | 16,040 | 16,040 | 16,040 | 16,040 |

### *Area apportionment of harvests*

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of inter-annual changes in the apportionment. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of biomass distribution, while adapting to current information about biomass distribution. The 1993 TAC was apportioned using a 5 year running average with emphasis doubled for the current year survey abundance index in weight (relative population weight or RPW). Since 1995, the ABC was apportioned using an exponential weighting of regional RPWs. Exponential weighting is implied under certain conditions by the Kalman filter. The exponential factor is the measurement error variance divided by the prediction error variance (Meinhold and Singpurwalla 1983). Prediction error variance depends on the variances of the previous year's estimate, the process error, and the measurement error. When the ratio of measurement error variance to process error variance is r, the exponential factor is equal to $1-2/(\sqrt{4r+1}+1)$ (Thompson 2004). For sablefish we do not estimate these values, but instead set the exponential factor at ½, so that, except for the first year, the weight of each year's value is ½ the weight of the following year. The weights are year index 5: 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000. A $(1/2)^x$ weighting scheme reduced annual fluctuations in regional ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model, where $x$ is the year index (J. Heifetz, Auke Bay Lab, pers. comm.). Because mixing rates for sablefish are sufficiently high and fishing rates sufficiently low, moderate variations of biomass-based apportionment would not significantly change overall sablefish yield unless there are strong differences in recruitment, growth, and survival by area (Heifetz et al. 1997).

Previously, the Council approved apportionments of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an apportionment based on survey and fishery data. We continue to use survey and fishery data to apportion the 2012 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** | **2011 ABC Percent** | **2011 Survey RPW** | **2010 Fishery RPW** | **2012 ABC Percent** | **2011 ABC** | **2012 ABC** | **Change** |
|---|---|---|---|---|---|---|---|
| Total | | | | | 16,040 | **17,240** | 7% |
| Bering Sea | 18% | 6% | 13% | 13% | 2,850 | **2,230** | -22% |
| Aleutians | 12% | 11% | 14% | 12% | 1,900 | **2,050** | 8% |
| Gulf of Alaska | 70% | 83% | 73% | 75% | 11,290 | **12,960** | 15% |
| Western | 14% | 14% | 12% | 14% | 1,620 | **1,780** | 9% |
| Central | 42% | 51% | 38% | 44% | 4,740 | **5,760** | 22% |
| W. Yakutat | 16% | 15% | 18% | 16% | 1,830 | **2,080*** | 14% |
| E. Yakutat / Southeast | 28% | 20% | 32% | 26% | 3,100 | **3,350** | 8% |

**After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the 2012 ABC for West Yakutat is 2,247 t and for East Yakutat/Southeast is 3,173 t. This adjustment projected to 2013 is 2,218 t for W. Yakutat and 3,132 t for E. Yakutat.*

| **Adjusted for 95:5 hook-and-line: trawl split in EGOA** | Year | W. Yakutat | E. Yakutat/Southeast |
|---|---|---|---|
| | 2012 | 2,247 t | 3,173 t |
| | 2013 | 2,218 t | 3,132 t |

This year's apportionment reflects a substantial increase in the longline survey index in the Central and Western Gulf areas, while the survey index declined severely in the Bering Sea, and modestly in the Eastern Gulf areas. The Bering Sea and Aleutian Islands fishery RPWs remained low, while all other areas declined (Figure 3.27a). The standard weighted average approach described above, which includes values from 2006-2011 for survey RPWs and 2005-2010 for fishery RPWs, greatly alleviates the effect of an individual year's change in RPW (Figure 3.27b). The Gulf of Alaska, mainly due to the increase in the Central Gulf, is now capturing a larger share of the apportionment. However, the current apportionment is characteristic of most prior years (Figure 3.27c).

### *Overfishing level (OFL)*

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b results in a value of 20,400 t for the combined stock. The OFL is apportioned by region, Bering Sea (2,640 t), Aleutian Islands (2,430 t), and Gulf of Alaska (15,330 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, an ecosystem modeling software package. 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. However, most diet information is from the trawl survey, which does not fully sample the sablefish population. Sampling coverage appeared the broadest geographically in 2005 in the Gulf so we show that data as an example (Figure 3.28). In 2005, more than half of adult 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 their major predators, given the current level of sampling of potential predators. Sufficient sampling of potential predators of adult sablefish, such as sharks and whales, may not be feasible. We will closely monitor developments in these models and their corresponding data for interesting trends and hypotheses.

Ecosystem considerations for the Alaska sablefish fishery are summarized in Table 3.18.

## *Ecosystem effects on the stock*

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

Juvenile and adult sablefish feed opportunistically, so diets differ throughout their range. In general, sablefish < 60 cm FL consume more euphausiids, shrimp, and cephalopods, while sablefish > 60 cm FL consume more fish (Yang and Nelson 2000). In the Gulf of Alaska, fish constituted 3/4 of the stomach content weight of adult sablefish with the remainder being invertebrates (Yang and Nelson 2000). Of the fish found in the diets of adult sablefish, pollock were the most abundant item while eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and flatfish also were found. Squid were the most important invertebrate and euphausiids and jellyfish were also present. In southeast Alaska, juvenile sablefish also consume juvenile salmon at least during the summer months (Sturdevant et al. 2009). Off the coast of Oregon and California, fish made up 76 percent of the diet (Laidig et al. 1997), while euphausiids dominated the diet off the southwest coast of Vancouver Island (Tanasichuk 1997). Off Vancouver Island, herring and other fish were increasingly important as sablefish size increased; however, the most important prey item was euphausiids. It is unlikely that juvenile and adult sablefish are affected by availability and abundance of individual prey species because they are opportunistic feeders. The only likely way prey could affect growth or survival of juvenile and adult sablefish is by overall changes in ecosystem productivity.

*Predators/Competitors:* The main juvenile sablefish predators are adult coho and chinook salmon, which prey on young-of-the-year sablefish during their pelagic stage. Sablefish were the fourth most commonly reported prey species in the salmon troll logbook program from 1977 to 1984 (Wing 1985), however the effect of salmon predation on sablefish survival is unknown. The only other fish species reported to prey on sablefish in the Gulf of Alaska is Pacific halibut; however, sablefish comprised less than 1% of their stomach contents (M-S. Yang, Alaska Fisheries Science Center, 14 October 1999). Although juvenile sablefish may not be a prominent prey item because of their relatively low and sporadic abundance compared to other prey items, they share residence on the continental shelf with arrowtooth flounder, halibut, Pacific cod, bigmouth sculpin, big skate, and Bering skate, which are the main piscivorous groundfishes in the Gulf of Alaska (Yang et al. 2006). It seems possible that predation of sablefish by other fish is significant to the success of sablefish recruitment even though they are not a common prey item.

Sperm whales are likely a major predator of adult sablefish. Fish are an important part of sperm whale diet in some parts of the world, including the northeastern Pacific Ocean (Kawakami 1980). Fish have appeared in the diets of sperm whales in the eastern Aleutians and Gulf of Alaska. Although fish species were not identified in sperm whale diets in Alaska, sablefish were found in 8.3% of sperm whale stomachs off of California (Kawakami 1980).

Sablefish distribution is typically thought to be on the upper continental slope in deeper waters than most groundfish. However, during the first two to three years of their life sablefish inhabit the continental shelf. Length samples from the NMFS bottom trawl survey suggest that the range of juvenile sablefish on the shelf varies dramatically from year to year. In particular, juveniles utilize the Bering Sea shelf extensively in some years, while not at all in others (Hanselman et al. 2008). 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. 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 (Sigler et al. 2001).

*Anthropogenic changes in the physical environment:* The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of sablefish is minimal or temporary in the current fishery management regime primarily based on the criterion that sablefish are currently above Minimum Stock Size Threshold (MSST).

Juvenile sablefish are substantially dependent on benthic prey (18% of diet by weight) and the availability of benthic prey may be adversely affected by fishing. Little is known about effects of fishing on benthic habitat or the habitat requirements for growth to maturity. Although sablefish do not appear to be directly dependent on physical structure, reduction of living structure is predicted in much of the area where juvenile sablefish reside and this may indirectly reduce juvenile survivorship by reducing prey availability or by altering the abilities of competing species to feed and avoid predation.

## Effects of the sablefish fishery 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 (Table 3.4). The sablefish fishery catches the majority of grenadier total catch and the trend is decreasing (Table 3.5). The trend in seabird catch is variable but appears to be decreasing, presumably due to widespread use of measures to reduce seabird catch. Prohibited species catches (PSC) in the targeted sablefish fisheries are dominated by halibut (1,700 t/year) and golden king crab (157,000/year). However, catches of both species declined greatly in 2010 (1000 t and 27,000 individuals respectively, Table 3.6).

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 on average accounts for about

10% of the total catch, often catches slightly smaller fish. The trawl fishery typically occurs on the continental shelf where juvenile sablefish sometimes 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 3.3). 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 almost always 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 2001).

*Fishery-specific effects on EFH non-living substrate*:

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

## *Data gaps and research priorities*

There is little information on early life history of sablefish and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the sablefish population. Improved fishery observer coverage in the Bering Sea and Aleutian Islands would provide additional data to monitor the emerging pot fishery in these areas and would improve the fishery catch rate analyses.

Future sablefish research is going to focus on several directions:

1) Refine survey index model for inclusion in the 2012 assessment model that accounts for whale depredation and potentially includes gully abundance data and other covariates.
2) Improve knowledge of sperm whale and killer whale depredation in the fishery and begin to quantify depredation effects on fishery catch rates.
3) Explore the use of environmental data to aid in determining recruitment
4) An integrated Gulf of Alaska Ecosystem project funded by the North Pacific Research Board is underway and is looking at recruitment processes of major groundfish including sablefish. We hope to work closely with this project to help understand sablefish recruitment dynamics.
5) We hope to develop a spatially explicit research assessment model that includes movement, which will help in examining smaller-scale population dynamics while retaining a single stock hypothesis Alaska-wide sablefish model.

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# Tables

Table 3.1. 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 | Aleutians | Western | Central | Eastern | West Yakutat | East Yakutat/ SEO. | Unknown | 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 | 23,580 | 694 | 1,727 | 539 | 9,377 | 11,243 | 4,493 | 6,750 | 0 | 20,642 | 2,938 |
| 1995 | 20,692 | 930 | 1,119 | 1,747 | 7,673 | 9,223 | 3,872 | 5,352 | 0 | 18,079 | 2,613 |
| 1996 | 17,393 | 648 | 764 | 1,649 | 6,773 | 7,558 | 2,899 | 4,659 | 0 | 15,206 | 2,187 |
| 1997 | 14,607 | 552 | 781 | 1,374 | 6,234 | 5,666 | 1,930 | 3,735 | 0 | 12,976 | 1,632 |
| 1998 | 13,874 | 563 | 535 | 1,432 | 5,922 | 5,422 | 1,956 | 3,467 | 0 | 12,387 | 1,487 |
| 1999 | 13,587 | 675 | 683 | 1,488 | 5,874 | 4,867 | 1,709 | 3,159 | 0 | 11,603 | 1,985 |
| 2000 | 15,570 | 742 | 1,049 | 1,587 | 6,173 | 6,020 | 2,066 | 3,953 | 0 | 13,551 | 2,019 |
| 2001 | 14,065 | 864 | 1,074 | 1,588 | 5,518 | 5,021 | 1,737 | 3,284 | 0 | 12,281 | 1,783 |
| 2002 | 14,748 | 1,144 | 1,119 | 1,865 | 6,180 | 4,441 | 1,550 | 2,891 | 0 | 12,505 | 2,243 |
| 2003 | 16,491 | 999 | 1,120 | 2,118 | 7,084 | 5,170 | 1,822 | 3,347 | 0 | 14,398 | 2,093 |
| 2004 | 17,670 | 1,038 | 955 | 2,170 | 7,457 | 6,050 | 2,250 | 3,800 | 0 | 16,014 | 1,656 |
| 2005 | 16,574 | 1,064 | 1,481 | 1,929 | 6,701 | 5,399 | 1,824 | 3,575 | 0 | 15,018 | 1,556 |
| 2006 | 15,339 | 1,037 | 1,132 | 2,140 | 5,870 | 5,161 | 1,865 | 3,296 | 0 | 14,097 | 1,242 |
| 2007 | 15,014 | 1,173 | 1,149 | 2,064 | 5,613 | 5,015 | 1,772 | 3,243 | 0 | 13,778 | 1,235 |
| 2008 | 14,626 | 1,135 | 900 | 1,670 | 5,547 | 5,373 | 2,055 | 3,318 | 0 | 13,504 | 1,122 |
| 2009 | 13,091 | 891 | 1,096 | 1,391 | 4,971 | 4,743 | 1,794 | 2,948 | 0 | 12,034 | 1,057 |
| 2010 | 11,915 | 754 | 1,076 | 1,351 | 4,477 | 4,258 | 1,576 | 2,682 | 0 | 10,912 | 1,004 |
| 2011 | 12,149 | 617 | 849 | 1,321 | 4,610 | 4,752 | 1,844 | 2,908 | 0 | 11,110 | 1,039 |

Table 3.2. 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.

| Year | Pot | Trawl | Longline | Total |
|---|---|---|---|---|
| Aleutian Islands | | | | |
| 1991-1999 | 6 | 73 | 1,210 | 1,289 |
| 2000 | 103 | 33 | 913 | 1,049 |
| 2001 | 111 | 39 | 925 | 1,074 |
| 2002 | 105 | 39 | 975 | 1,119 |
| 2003 | 316 | 42 | 761 | 1,120 |
| 2004 | 384 | 32 | 539 | 955 |
| 2005 | 688 | 115 | 679 | 1,481 |
| 2006 | 458 | 60 | 614 | 1,132 |
| 2007 | 632 | 40 | 476 | 1,149 |
| 2008 | 177 | 76 | 647 | 900 |
| 2009 | 78 | 75 | 943 | 1,096 |
| 2010 | 59 | 74 | 943 | 1,076 |
| 2011 | 124 | 31 | 694 | 849 |
| Bering Sea | | | | |
| 1991-1999 | 5 | 189 | 539 | 733 |
| 2000 | 40 | 284 | 418 | 742 |
| 2001 | 106 | 353 | 405 | 864 |
| 2002 | 382 | 295 | 467 | 1,144 |
| 2003 | 355 | 231 | 413 | 999 |
| 2004 | 432 | 293 | 312 | 1,038 |
| 2005 | 590 | 273 | 202 | 1,064 |
| 2006 | 584 | 84 | 368 | 1,037 |
| 2007 | 878 | 92 | 203 | 1,173 |
| 2008 | 754 | 183 | 199 | 1,135 |
| 2009 | 557 | 93 | 240 | 891 |
| 2010 | 452 | 30 | 272 | 754 |
| 2011 | 342 | 37 | 238 | 617 |

Table 3.3. Discarded catches of sablefish (amount [t], percent of total catch, total catch [t]) by gear (H&L=hook & line, Other = Pot, trawl, and jig, combined for confidentiality) by FMP area for 2005-2010. Source: NMFS Alaska Regional Office via AKFIN, October 10, 2011.

| | | BSAI | | | GOA | | | Combined | | |
|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | Gear | Discard | % Discard | Catch | Discard | % Discard | Catch | Discard | % Discard | Catch |
| 2005 | H&L | 28 | 3.18% | 880 | 255 | 1.98% | 12,860 | 283 | 2.06% | 13,741 |
| | Other | 65 | 3.90% | 1,665 | 181 | 15.46% | 1,169 | 246 | 8.67% | 2,834 |
| | Total | 93 | 3.65% | 2,545 | 436 | 3.11% | 14,029 | 529 | 3.19% | 16,574 |
| 2006 | H&L | 46 | 4.68% | 982 | 286 | 2.37% | 12,073 | 332 | 2.55% | 13,055 |
| | Other | 16 | 1.38% | 1,186 | 269 | 24.54% | 1,098 | 286 | 12.51% | 2,284 |
| | Total | 62 | 2.87% | 2,168 | 556 | 4.22% | 13,171 | 618 | 4.03% | 15,339 |
| 2007 | H&L | 16 | 2.32% | 679 | 242 | 2.09% | 11,586 | 258 | 2.10% | 12,265 |
| | Other | 54 | 3.29% | 1,643 | 177 | 16.00% | 1,106 | 231 | 8.40% | 2,748 |
| | Total | 70 | 3.01% | 2,322 | 419 | 3.30% | 12,692 | 489 | 3.26% | 15,014 |
| 2008 | H&L | 92 | 10.86% | 845 | 737 | 6.28% | 11,727 | 829 | 6.59% | 12,572 |
| | Other | 7 | 0.55% | 1,190 | 72 | 8.36% | 864 | 79 | 3.83% | 2,053 |
| | Total | 98 | 4.83% | 2,035 | 809 | 6.43% | 12,590 | 907 | 6.20% | 14,626 |
| 2009 | H&L | 18 | 1.49% | 1,183 | 736 | 7.20% | 10,216 | 754 | 6.61% | 11,399 |
| | Other | 8 | 0.98% | 803 | 81 | 9.10% | 889 | 89 | 5.25% | 1,692 |
| | Total | 26 | 1.28% | 1,986 | 817 | 7.36% | 11,105 | 842 | 6.43% | 13,091 |
| 2010 | H&L | 34 | 2.81% | 1,215 | 368 | 4.01% | 9,186 | 402 | 3.87% | 10,400 |
| | Other | 7 | 1.19% | 615 | 47 | 5.26% | 900 | 55 | 3.61% | 1,515 |
| | Total | 41 | 2.26% | 1,830 | 416 | 4.12% | 10,085 | 457 | 3.84% | 11,915 |
| 2005-2010 | H&L | 39 | 4.03% | 964 | 437 | 3.88% | 11,275 | 476 | 3.89% | 12,239 |
| Average | Other | 26 | 2.21% | 1,184 | 138 | 13.74% | 1,004 | 164 | 7.50% | 2,188 |
| | Total | 65 | 3.03% | 2,148 | 575 | 4.69% | 12,279 | 640 | 4.44% | 14,427 |

Table 3.4. Bycatch (t) of FMP Groundfish species in the targeted sablefish fishery averaged from 2006-2010. Other = Pot and trawl combined because of confidentiality. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN, October 10, 2011.

| | Hook and Line | | | Other Gear | | | All Gear | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Discard | Retained | Total | Discard | Retained | Total | Discard | Retained | Total |
| Arrowtooth Flounder | 336 | 71 | 407 | 152 | 15 | 166 | 488 | 85 | 573 |
| Thornyhead rockfish | 49 | 293 | 342 | 3 | 22 | 25 | 52 | 315 | 367 |
| Shortraker Rockfish | 87 | 103 | 190 | 6 | 12 | 19 | 94 | 115 | 209 |
| Other Species | 180 | 2 | 181 | 3 | 1 | 4 | 183 | 3 | 185 |
| GOA Other Skate | 142 | 5 | 147 | 1 | 0 | 1 | 143 | 5 | 148 |
| GOA Longnose Skate | 133 | 4 | 137 | 2 | 1 | 4 | 135 | 5 | 140 |
| Greenland Turbot | 46 | 56 | 102 | 18 | 2 | 21 | 64 | 58 | 122 |
| Other Rockfish | 35 | 77 | 112 | 2 | 1 | 4 | 38 | 78 | 116 |
| Rougheye Rockfish | 38 | 78 | 116 | 3 | 2 | 5 | 42 | 80 | 122 |
| Pacific Cod | 18 | 64 | 82 | 1 | 8 | 9 | 19 | 72 | 91 |
| Pacific Ocean Perch | 9 | 0 | 9 | 2 | 16 | 18 | 11 | 16 | 27 |
| GOA Deep Water Flatfish | 8 | 0 | 8 | 14 | 4 | 18 | 22 | 4 | 27 |
| GOA Demersal Shelf Rockfish | 8 | 7 | 16 | 0 | 0 | 1 | 9 | 7 | 16 |
| GOA Shallow Water Flatfish | 9 | 1 | 10 | 1 | 0 | 1 | 9 | 1 | 10 |
| Pollock | 0 | 0 | 1 | 4 | 4 | 7 | 4 | 4 | 8 |
| BSAI Other Flatfish | 4 | 3 | 7 | 0 | 0 | 1 | 4 | 3 | 7 |
| GOA Pelagic Shelf Rockfish | 5 | 0 | 5 | 0 | 2 | 2 | 5 | 2 | 7 |
| GOA Rex Sole | 0 | 0 | 0 | 5 | 2 | 6 | 5 | 2 | 7 |
| GOA Big Skate | 4 | 1 | 5 | 1 | 0 | 1 | 5 | 1 | 6 |
| Flathead Sole | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 2 | 4 |
| Total | 1,112 | 765 | 1,876 | 222 | 95 | 316 | 1,333 | 859 | 2,193 |

Table 3.5. Bycatch of nontarget species and HAPC biota in the targeted sablefish fishery. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN, October 10, 2011.

| | | Estimated Catch (t) | | | | |
|---|---|---|---|---|---|---|
| Group Name | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| Benthic urochordata | 0.00 | 0.07 | 0.00 | - | 0.01 | 0.12 |
| Birds | 0.61 | 0.89 | 1.57 | 0.55 | 0.40 | 0.35 |
| Bivalves | - | 0.00 | Conf. | - | 0.02 | 0.00 |
| Brittle star unidentified | 0.23 | 0.05 | 0.10 | 0.06 | 0.33 | 0.11 |
| Corals Bryozoans | 0.64 | 1.56 | 0.16 | 1.55 | 1.63 | 2.45 |
| Dark Rockfish | - | - | - | Conf. | 0.15 | Conf. |
| Eelpouts | 1.52 | 1.30 | 2.26 | 7.86 | 1.77 | 1.34 |
| Eulachon | - | - | 0.29 | Conf. | 0.10 | Conf. |
| Giant Grenadier | 3,167 | 3,905 | 9,181 | 8,848 | 5,366 | 4,385 |
| Greenlings | 0.01 | - | 75.83 | 0.02 | 0.02 | - |
| Grenadier | 3,663 | 4,782 | 109 | 127 | 961 | 745 |
| Hermit crab unidentified | 0.02 | 0.05 | 0.05 | 0.07 | 0.09 | 0.19 |
| Invertebrate unidentified | 0.00 | 0.07 | 0.02 | 0.01 | 0.32 | 0.76 |
| Lanternfishes (myctophidae) | 0.00 | - | - | - | - | - |
| Misc crabs | 0.32 | 0.47 | 1.12 | 0.94 | 3.21 | 1.90 |
| Misc crustaceans | - | - | - | - | 1.53 | 0.00 |
| Misc deep fish | - | 0.00 | 0.00 | - | 0 | - |
| Misc fish | 20.63 | 18.06 | 16.93 | 21.06 | 4.64 | 4.00 |
| Misc inverts (worms etc) | - | 0.00 | Conf. | 0.00 | 0.01 | 0.00 |
| Other osmerids | - | - | - | Conf. | - | - |
| Pandalid shrimp | - | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Polychaete unidentified | - | - | - | 0.00 | 0.00 | 0.00 |
| Scypho jellies | 0.16 | 0.10 | 0.00 | Conf. | 0 | 0 |
| Sea anemone unidentified | 0.12 | 0.29 | 3.34 | 0.67 | 1.99 | 1.32 |
| Sea pens whips | 0.03 | 0.19 | 0.07 | 0.32 | 0.49 | 0.03 |
| Sea star | 1.24 | 5.13 | 35.24 | 1.54 | 2.45 | 2.55 |
| Snails | 4.29 | 9.41 | 8.09 | 6.43 | 11.22 | 11.56 |
| Sponge unidentified | 0.63 | 0.70 | 0.16 | 14.64 | 1.92 | 0.76 |
| Urchins, dollars, cucumbers | 0.21 | 0.15 | 0.14 | 0.47 | 1.05 | 0.55 |

Table 3.6. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, thousands of animals for crab and salmon, by year, and fisheries management plan area for the sablefish fishery. Other = Pot and trawl combined because of confidentiality. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN, October 10, 2011.

| | 2007 | | | 2008 | | | 2009 | | | 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BSAI | GOA | Total | BSAI | GOA | Total | BSAI | GOA | Total | BSAI | GOA | Total | Average |
| **Hook and Line** | | | | | | | | | | | | | |
| Bairdi Crab | 0.00 | 0.17 | 0.17 | 0.00 | 0.01 | 0.01 | 0.03 | 0.24 | 0.28 | 0.00 | 0.07 | 0.07 | 0.13 |
| Blue King Crab | 0.04 | 0.03 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Chinook Salmon | 0.00 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Golden K. Crab | 1.30 | 0.04 | 1.34 | 0.17 | 0.08 | 0.25 | 0.32 | 0.03 | 0.35 | 0.97 | 0.00 | 0.97 | 0.73 |
| Halibut | 107 | 3,402 | 3,509 | 149 | 932 | 1,081 | 149 | 1,023 | 1,172 | 176 | 761 | 937 | 1,675 |
| Other Salmon | 0.00 | 0.13 | 0.13 | 0.01 | 0.22 | 0.23 | 0.01 | 0.21 | 0.22 | 0.00 | 0.16 | 0.16 | 0.19 |
| Opilio Crab | 0.00 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.05 | 0.02 |
| Red King Crab | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |
| **Other** | | | | | | | | | | | | | |
| Bairdi Crab | 0.23 | 0.17 | 0.40 | 0.24 | 0.18 | 0.42 | 1.65 | 0.09 | 1.74 | 0.00 | 0.06 | 0.06 | 0.65 |
| Golden K. Crab | 281 | 0 | 281 | 181 | 0 | 181 | 139 | 0 | 139 | 26 | 0 | 26 | 157 |
| Halibut | 22.2 | 6.6 | 28.8 | 23.1 | 6.9 | 30.0 | 14.9 | 3.5 | 18.4 | 24.5 | 4.5 | 29.0 | 26.5 |
| Herring | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Other Salmon | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.00 |
| Opilio Crab | 0.10 | 0.00 | 0.10 | 0.28 | 0.00 | 0.28 | 0.01 | 0.10 | 0.11 | 2.15 | 0.03 | 2.18 | 0.67 |
| Red King Crab | 0.01 | 0.00 | 0.01 | 0.42 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |

Table 3.7. Summary of management measures with time series of catch, ABC, and TAC.

| 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 | Amendment 14 of the GOA FMP allocated sablefish quota by gear type: 80% to fixed gear and 20% to trawl gear in WGOA and CGOA and 95% fixed to 5% trawl in the EGOA. |
| 1986 | 28,892 | | 21,450 | Pot fishing banned in Eastern GOA. |
| 1987 | 35,163 | | 27,700 | Pot fishing banned in Central GOA. |
| 1988 | 38,406 | | 36,400 | |
| 1989 | 34,829 | | 32,200 | Pot fishing banned in Western GOA. |
| 1990 | 32,115 | | 33,200 | Amendment 15 of the BSAI FMP allocated sablefish quota by gear type: 50% to fixed gear in and 50% to trawl in the EBS, and 75% fixed to 25% trawl in the Aleutian Islands. |
| 1991 | 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 | 16,371 | 18,400 | 20,900 | |
| 2004 | 17,720 | 23,000 | 23,000 | |
| 2005 | 16,619 | 21,000 | 21,000 | |
| 2006 | 15,417 | 21,000 | 21,000 | |
| 2007 | 15,011 | 20,100 | 20,100 | |
| 2008 | 14,335 | 18,030 | 18,030 | Pot fishing ban repealed in Bering Sea for June 1-30 (74 FR 28733). |
| 2009 | 13,206 | 16,080 | 16,080 | |
| 2010 | 11,916 | 15,230 | 15,230 | |
| 2011 | 12,149 | 16,040 | 16,040 | |

Table 3.8. 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 | 12,964 | | | | | 100,029 | | | | |
| 1985 | | | | | | 125,129 | | 1,294 | | |
| 1986 | | | | | | 128,718 | | | | |
| 1987 | 9,610 | | | | | 102,639 | | 1,057 | | |
| 1988 | | | | | | 114,239 | | | | |
| 1989 | | | | | | 115,067 | | 655 | | |
| 1990 | 4,969 | | | 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 | 7,282 | | | 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 | 4,408 | | | 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 | 5,039 | | | 503 | 37,386 | | 77,678 | | 1,198 | 1,128 |
| 2004 | | | | 694 | 31,746 | | 82,767 | | 1,185 | 1,029 |
| 2005 | 4,956 | | | 2,306 | 33,914 | | 74,433 | | 1,187 | 1,040 |
| 2006 | | | | 721 | 30,594 | | 78,625 | | 1,178 | 1,154 |
| 2007 | 3,804 | | | 860 | 28,650 | | 73,480 | | 1,174 | 1,115 |
| 2008 | | | | 2,018 | 23,893 | | 71,661 | | 1,182 | 1,146 |
| 2009 | 3,975 | | | 1,837 | 25,945 | | 67,978 | | 1,198 | 1,126 |
| 2010 | | | | 1,634 | 24,410 | | 75,010 | | 1,176 | 1,160 |
| 2011 | 2,118 | | | | | | 87,498 | | | |

Table 3.9. Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. Relative population number equals CPUE in numbers weighted by respective strata areas. Relative population weight equals CPUE measured in weight multiplied by strata areas. Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands 1979, 1995, 1997, 1999, 2001, 2003, 2005, and 2007 and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2009, and 2010. 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 | | 477 | | | 1,662 | 1,130 | |
| 1999 | | 520 | | | 1,740 | 1,316 | 104 |
| 2000 | | 462 | | | 1,597 | 1,139 | |
| 2001 | | 535 | | | 1,798 | 1,111 | 238 |
| 2002 | | 561 | | | 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 | | 580 | | | 1,848 | 1,206 | |
| 2007 | | 500 | | | 1,584 | 1,268 | 111 |
| 2008 | | 472 | | | 1,550 | 1,361 | |
| 2009 | | 491 | | | 1,580 | 1,152 | 107 |
| 2010 | | 542 | | | 1,778 | 1,054 | |
| 2011 | | 556 | | | 1,888 | | 84 |

Table 3.10. 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 | 0.05 | 0.10 | 193 | 8 |
| 1991 | 0.50 | 0.03 | 0.07 | 246 | 8 |
| 1992 | 0.40 | 0.06 | 0.15 | 131 | 8 |
| 1993 | 0.28 | 0.04 | 0.14 | 308 | 12 |
| 1994 | 0.29 | 0.05 | 0.18 | 138 | 13 |
| 1995 | 0.30 | 0.04 | 0.14 | 208 | 14 |
| 1996 | 0.23 | 0.03 | 0.12 | 204 | 17 |
| 1997 | 0.35 | 0.07 | 0.20 | 117 | 9 |
| 1998 | 0.29 | 0.05 | 0.17 | 75 | 12 |
| 1999 | 0.38 | 0.07 | 0.17 | 305 | 14 |
| 2000 | 0.29 | 0.03 | 0.11 | 313 | 15 |
| 2001 | 0.26 | 0.04 | 0.15 | 162 | 9 |
| 2002 | 0.32 | 0.03 | 0.11 | 245 | 10 |
| 2003 | 0.26 | 0.04 | 0.17 | 170 | 10 |
| 2004 | 0.21 | 0.04 | 0.21 | 138 | 7 |
| 2005 | 0.15 | 0.05 | 0.34 | 23 | 6 |
| 2006 | 0.23 | 0.04 | 0.16 | 205 | 11 |
| 2007 | 0.35 | 0.10 | 0.29 | 198 | 7 |
| 2008 | 0.37 | 0.04 | 0.10 | 247 | 6 |
| 2009 | 0.29 | 0.05 | 0.22 | 335 | 10 |
| 2010 | 0.27 | 0.04 | 0.14 | 459 | 12 |

Bering Sea-Observer

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1990 | 0.72 | 0.11 | 0.15 | 42 | 8 |
| 1991 | 0.28 | 0.06 | 0.20 | 30 | 7 |
| 1992 | 0.25 | 0.11 | 0.43 | 7 | 4 |
| 1993 | 0.09 | 0.03 | 0.36 | 4 | 3 |
| 1994 | 0.35 | 0.16 | 0.45 | 2 | 2 |
| 1995 | 0.41 | 0.07 | 0.17 | 38 | 10 |
| 1996 | 0.63 | 0.19 | 0.30 | 35 | 15 |
| 1997 | | | | 0 | 0 |
| 1998 | 0.17 | 0.03 | 0.18 | 28 | 9 |
| 1999 | 0.29 | 0.09 | 0.32 | 27 | 10 |
| 2000 | 0.28 | 0.09 | 0.31 | 21 | 10 |
| 2001 | 0.31 | 0.02 | 0.07 | 18 | 10 |
| 2002 | 0.10 | 0.02 | 0.22 | 8 | 4 |
| 2003 | 0.16 | 0.05 | 0.29 | 8 | 2 |
| 2004 | 0.17 | 0.05 | 0.31 | 9 | 4 |
| 2005 | 0.23 | 0.02 | 0.16 | 9 | 6 |
| 2006 | 0.17 | 0.05 | 0.21 | 68 | 15 |
| 2007 | 0.28 | 0.05 | 0.18 | 34 | 8 |
| 2008 | 0.38 | 0.22 | 0.58 | 12 | 5 |
| 2009 | 0.14 | 0.04 | 0.21 | 24 | 5 |
| 2010 | 0.17 | 0.03 | 0.19 | 26 | 9 |

Western Gulf-Observer

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1990 | 0.64 | 0.14 | 0.22 | 178 | 7 |
| 1991 | 0.44 | 0.06 | 0.13 | 193 | 16 |
| 1992 | 0.38 | 0.05 | 0.14 | 260 | 12 |
| 1993 | 0.35 | 0.03 | 0.09 | 106 | 12 |
| 1994 | 0.32 | 0.03 | 0.10 | 52 | 5 |
| 1995 | 0.51 | 0.04 | 0.09 | 432 | 22 |
| 1996 | 0.57 | 0.05 | 0.10 | 269 | 20 |
| 1997 | 0.50 | 0.05 | 0.10 | 349 | 20 |
| 1998 | 0.50 | 0.03 | 0.07 | 351 | 18 |
| 1999 | 0.53 | 0.07 | 0.12 | 244 | 14 |
| 2000 | 0.49 | 0.06 | 0.13 | 185 | 12 |
| 2001 | 0.50 | 0.05 | 0.10 | 273 | 16 |
| 2002 | 0.51 | 0.05 | 0.09 | 348 | 15 |
| 2003 | 0.45 | 0.04 | 0.10 | 387 | 16 |
| 2004 | 0.47 | 0.08 | 0.17 | 162 | 10 |
| 2005 | 0.58 | 0.07 | 0.13 | 447 | 13 |
| 2006 | 0.42 | 0.04 | 0.13 | 306 | 15 |
| 2007 | 0.37 | 0.04 | 0.11 | 255 | 12 |
| 2008 | 0.46 | 0.07 | 0.16 | 255 | 11 |
| 2009 | 0.44 | 0.09 | 0.21 | 208 | 11 |
| 2010 | 0.42 | 0.06 | 0.14 | 198 | 10 |

Central Gulf-Observer

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1990 | 0.54 | 0.04 | 0.07 | 653 | 32 |
| 1991 | 0.62 | 0.06 | 0.09 | 303 | 24 |
| 1992 | 0.59 | 0.05 | 0.09 | 335 | 19 |
| 1993 | 0.60 | 0.04 | 0.07 | 647 | 32 |
| 1994 | 0.65 | 0.06 | 0.09 | 238 | 15 |
| 1995 | 0.90 | 0.07 | 0.08 | 457 | 41 |
| 1996 | 1.04 | 0.07 | 0.07 | 441 | 45 |
| 1997 | 1.07 | 0.08 | 0.08 | 377 | 41 |
| 1998 | 0.90 | 0.06 | 0.06 | 345 | 32 |
| 1999 | 0.87 | 0.08 | 0.10 | 269 | 28 |
| 2000 | 0.93 | 0.05 | 0.06 | 319 | 30 |
| 2001 | 0.70 | 0.04 | 0.06 | 347 | 31 |
| 2002 | 0.84 | 0.07 | 0.08 | 374 | 29 |
| 2003 | 0.99 | 0.07 | 0.07 | 363 | 34 |
| 2004 | 1.08 | 0.10 | 0.09 | 327 | 29 |
| 2005 | 0.89 | 0.06 | 0.07 | 518 | 32 |
| 2006 | 0.82 | 0.06 | 0.08 | 361 | 33 |
| 2007 | 0.93 | 0.06 | 0.07 | 289 | 30 |
| 2008 | 0.84 | 0.07 | 0.08 | 207 | 27 |
| 2009 | 0.77 | 0.06 | 0.07 | 320 | 33 |
| 2010 | 0.80 | 0.05 | 0.07 | 286 | 31 |

Table 3.10 (cont.)

| Observer Fishery Data | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| West Yakutat-Observer | | | | | | East Yakutat/SE-Observer | | | | | |
| Year | CPUE | SE | CV | Sets | Vessels | Year | CPUE | SE | CV | Sets | Vessels |
| 1990 | 0.95 | 0.24 | 0.25 | 75 | 9 | 1990 | | | | 0 | 0 |
| 1991 | 0.65 | 0.07 | 0.10 | 164 | 12 | 1991 | 0.52 | 0.37 | 0.71 | 17 | 2 |
| 1992 | 0.64 | 0.18 | 0.27 | 98 | 6 | 1992 | 0.87 | | | 20 | 1 |
| 1993 | 0.71 | 0.07 | 0.10 | 241 | 12 | 1993 | 1.02 | 0.19 | 0.19 | 26 | 2 |
| 1994 | 0.65 | 0.17 | 0.27 | 81 | 8 | 1994 | 0.36 | | | 5 | 1 |
| 1995 | 1.02 | 0.10 | 0.10 | 158 | 21 | 1995 | 1.45 | 0.20 | 0.14 | 101 | 19 |
| 1996 | 0.97 | 0.07 | 0.07 | 223 | 28 | 1996 | 1.20 | 0.11 | 0.09 | 137 | 24 |
| 1997 | 1.16 | 0.11 | 0.09 | 126 | 20 | 1997 | 1.10 | 0.14 | 0.13 | 84 | 17 |
| 1998 | 1.21 | 0.10 | 0.08 | 145 | 23 | 1998 | 1.27 | 0.12 | 0.10 | 140 | 25 |
| 1999 | 1.20 | 0.15 | 0.13 | 110 | 19 | 1999 | 0.94 | 0.12 | 0.13 | 85 | 11 |
| 2000 | 1.28 | 0.10 | 0.08 | 193 | 32 | 2000 | 0.84 | 0.13 | 0.16 | 81 | 14 |
| 2001 | 1.03 | 0.07 | 0.07 | 184 | 26 | 2001 | 0.84 | 0.08 | 0.09 | 110 | 14 |
| 2002 | 1.32 | 0.13 | 0.10 | 155 | 23 | 2002 | 1.20 | 0.23 | 0.19 | 121 | 14 |
| 2003 | 1.36 | 0.10 | 0.07 | 216 | 27 | 2003 | 1.29 | 0.13 | 0.10 | 113 | 19 |
| 2004 | 1.23 | 0.09 | 0.08 | 210 | 24 | 2004 | 1.08 | 0.10 | 0.09 | 135 | 17 |
| 2005 | 1.32 | 0.09 | 0.07 | 352 | 24 | 2005 | 1.18 | 0.13 | 0.11 | 181 | 16 |
| 2006 | 0.96 | 0.10 | 0.10 | 257 | 30 | 2006 | 0.93 | 0.11 | 0.11 | 104 | 18 |
| 2007 | 1.02 | 0.11 | 0.11 | 208 | 24 | 2007 | 0.92 | 0.15 | 0.17 | 85 | 16 |
| 2008 | 1.40 | 0.12 | 0.08 | 173 | 23 | 2008 | 1.06 | 0.13 | 0.12 | 103 | 17 |
| 2009 | 1.34 | 0.12 | 0.09 | 148 | 23 | 2009 | 0.98 | 0.12 | 0.12 | 94 | 13 |
| 2010 | 1.11 | 0.09 | 0.08 | 136 | 22 | 2010 | 0.97 | 0.17 | 0.17 | 76 | 12 |

Table 3.10 (cont.)

Logbook Fishery Data

Aleutian Islands-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 0.29 | 0.04 | 0.15 | 167 | 15 |
| 2000 | 0.24 | 0.05 | 0.21 | 265 | 16 |
| 2001 | 0.38 | 0.16 | 0.41 | 36 | 5 |
| 2002 | 0.48 | 0.19 | 0.39 | 33 | 5 |
| 2003 | 0.36 | 0.11 | 0.30 | 139 | 10 |
| 2004 | 0.45 | 0.11 | 0.25 | 102 | 7 |
| 2005 | 0.46 | 0.15 | 0.33 | 109 | 8 |
| 2006 | 0.51 | 0.16 | 0.31 | 61 | 5 |
| 2007 | 0.38 | 0.22 | 0.58 | 61 | 3 |
| 2008 | 0.30 | 0.03 | 0.12 | 119 | 4 |
| 2009 | 0.23 | 0.07 | 0.06 | 204 | 7 |
| 2010 | 0.25 | 0.05 | 0.20 | 497 | 9 |

Bering Sea-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 0.56 | 0.08 | 0.14 | 291 | 43 |
| 2000 | 0.21 | 0.05 | 0.22 | 169 | 23 |
| 2001 | 0.35 | 0.11 | 0.33 | 61 | 8 |
| 2002 | 0.24 | 0.15 | 0.63 | 5 | 2 |
| 2003 | 0.24 | 0.13 | 0.53 | 25 | 6 |
| 2004 | 0.38 | 0.09 | 0.24 | 202 | 8 |
| 2005 | 0.36 | 0.07 | 0.19 | 86 | 10 |
| 2006 | 0.38 | 0.07 | 0.18 | 106 | 9 |
| 2007 | 0.37 | 0.08 | 0.21 | 147 | 8 |
| 2008 | 0.52 | 0.20 | 0.39 | 94 | 7 |
| 2009 | 0.25 | 0.04 | 0.14 | 325 | 18 |
| 2010 | 0.30 | 0.07 | 0.23 | 766 | 12 |

Western Gulf-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 0.64 | 0.06 | 0.09 | 245 | 27 |
| 2000 | 0.60 | 0.05 | 0.09 | 301 | 32 |
| 2001 | 0.47 | 0.05 | 0.10 | 109 | 24 |
| 2002 | 0.60 | 0.08 | 0.13 | 78 | 14 |
| 2003 | 0.39 | 0.04 | 0.11 | 202 | 24 |
| 2004 | 0.65 | 0.06 | 0.09 | 766 | 26 |
| 2005 | 0.78 | 0.08 | 0.11 | 571 | 33 |
| 2006 | 0.69 | 0.08 | 0.11 | 1067 | 38 |
| 2007 | 0.59 | 0.06 | 0.10 | 891 | 31 |
| 2008 | 0.71 | 0.06 | 0.08 | 516 | 29 |
| 2009 | 0.53 | 0.06 | 0.11 | 824 | 33 |
| 2010 | 0.48 | 0.04 | 0.08 | 1297 | 46 |

Central Gulf-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 0.80 | 0.05 | 0.06 | 817 | 60 |
| 2000 | 0.79 | 0.04 | 0.05 | 746 | 64 |
| 2001 | 0.74 | 0.06 | 0.08 | 395 | 52 |
| 2002 | 0.83 | 0.06 | 0.07 | 276 | 41 |
| 2003 | 0.87 | 0.07 | 0.08 | 399 | 45 |
| 2004 | 1.08 | 0.05 | 0.05 | 1676 | 80 |
| 2005 | 0.98 | 0.07 | 0.07 | 1154 | 63 |
| 2006 | 0.87 | 0.04 | 0.05 | 1358 | 80 |
| 2007 | 0.83 | 0.04 | 0.05 | 1190 | 69 |
| 2008 | 0.88 | 0.05 | 0.06 | 1039 | 68 |
| 2009 | 0.95 | 0.08 | 0.08 | 1081 | 73 |
| 2010 | 0.66 | 0.03 | 0.05 | 1171 | 80 |

West Yakutat-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 1.08 | 0.08 | 0.08 | 233 | 36 |
| 2000 | 1.04 | 0.06 | 0.06 | 270 | 42 |
| 2001 | 0.89 | 0.09 | 0.11 | 203 | 29 |
| 2002 | 0.99 | 0.07 | 0.07 | 148 | 28 |
| 2003 | 1.26 | 0.10 | 0.08 | 104 | 23 |
| 2004 | 1.27 | 0.06 | 0.05 | 527 | 54 |
| 2005 | 1.13 | 0.05 | 0.04 | 1158 | 70 |
| 2006 | 0.97 | 0.05 | 0.06 | 1306 | 84 |
| 2007 | 0.97 | 0.05 | 0.05 | 1322 | 89 |
| 2008 | 0.97 | 0.05 | 0.05 | 1118 | 74 |
| 2009 | 1.23 | 0.07 | 0.06 | 1077 | 81 |
| 2010 | 0.98 | 0.05 | 0.05 | 1077 | 85 |

East Yakutat/SE-Logbook

| Year | CPUE | SE | CV | Sets | Vessels |
|---|---|---|---|---|---|
| 1999 | 0.91 | 0.08 | 0.08 | 183 | 22 |
| 2000 | 0.98 | 0.08 | 0.08 | 190 | 26 |
| 2001 | 0.98 | 0.09 | 0.09 | 109 | 21 |
| 2002 | 0.83 | 0.06 | 0.07 | 108 | 22 |
| 2003 | 1.13 | 0.10 | 0.09 | 117 | 22 |
| 2004 | 1.19 | 0.05 | 0.04 | 427 | 55 |
| 2005 | 1.15 | 0.05 | 0.05 | 446 | 77 |
| 2006 | 1.06 | 0.04 | 0.04 | 860 | 107 |
| 2007 | 1.13 | 0.04 | 0.04 | 972 | 122 |
| 2008 | 1.08 | 0.05 | 0.05 | 686 | 97 |
| 2009 | 1.12 | 0.05 | 0.05 | 620 | 87 |
| 2010 | 1.04 | 0.05 | 0.05 | 744 | 99 |

Table 3.11. Count of stations where sperm (S) or killer whale (K) depredation occurred in the six sablefish management areas. The number of stations sampled that are used for RPN calculations are in parentheses. Areas not surveyed in a given year are left blank. If there were no whale depredation data taken, it is denoted with an "n/a".

| | **BS (16)** | | **AI (14)** | | **WG (10)** | | **CG (16)** | | **WY (8)** | | **EY/SE (17)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | **S** | **K** | **S** | **K** | **S** | **K** | **S** | **K** | **S** | **K** | **S** | **K** |
| 1996 | | | n/a | 1 | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 |
| 1997 | n/a | 2 | | | n/a | 0 | n/a | 0 | n/a | 0 | n/a | 0 |
| 1998 | | | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | | 0 |
| 1999 | 0 | 7 | | | 0 | 0 | 3 | 0 | 6 | 0 | 4 | 0 |
| 2000 | | | 0 | 1 | 0 | 1 | 0 | 0 | 4 | 0 | 2 | 0 |
| 2001 | 0 | 5 | | | 0 | 0 | 3 | 0 | 2 | 0 | 2 | 0 |
| 2002 | | | 0 | 1 | 0 | 4 | 3 | 0 | 4 | 0 | 2 | 0 |
| 2003 | 0 | 7 | | | 0 | 3 | 2 | 0 | 1 | 0 | 2 | 0 |
| 2004 | | | 0 | 0 | 0 | 4 | 3 | 0 | 4 | 0 | 6 | 0 |
| 2005 | 0 | 2 | | | 0 | 4 | 0 | 0 | 2 | 0 | 8 | 0 |
| 2006 | | | 0 | 1 | 0 | 3 | 2 | 1 | 4 | 0 | 2 | 0 |
| 2007 | 0 | 7 | | | 0 | 5 | 1 | 1 | 5 | 0 | 6 | 0 |
| 2008 | | | 0 | 3 | 0 | 2 | 2 | 0 | 8 | 0 | 9 | 0 |
| 2009 | 0 | 10 | | | 0 | 2 | 5 | 1 | 3 | 0 | 2 | 0 |
| 2010 | | | 0 | 3 | 0 | 1 | 2 | 1 | 2 | 0 | 6 | 0 |
| 2011 | 0 | 7 | | | 0 | 5 | 1 | 1 | 4 | 0 | 9 | 0 |

Table 3.12. 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.

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

Table 3.13. Sablefish fork length (cm), weight (kg), and proportion mature by age and sex (weights from 1996-2004 age-length data).

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

Table 3.14. Sablefish recruits, total biomass (2+), and spawning biomass plus upper and lower 95% credible intervals (2.5%, 97.5%). Recruits are in millions, and biomass is in kt.

| | **Recruits (Age 2)** | | | **Total Biomass** | | | **Spawning Biomass** | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Mean | 2.5% | 97.5% | Mean | 2.5% | 97.5% | Mean | 2.5% | 97.5% |
| 1960 | 3 | 0 | 53 | 533 | 468 | 628 | 180 | 136 | 242 |
| 1961 | 4 | 0 | 65 | 543 | 480 | 645 | 185 | 154 | 235 |
| 1962 | 95 | 12 | 145 | 613 | 543 | 704 | 195 | 170 | 239 |
| 1963 | 5 | 0 | 79 | 614 | 546 | 713 | 204 | 178 | 246 |
| 1964 | 5 | 0 | 61 | 609 | 543 | 716 | 217 | 189 | 259 |
| 1965 | 41 | 0 | 108 | 636 | 560 | 731 | 233 | 204 | 275 |
| 1966 | 60 | 2 | 133 | 683 | 615 | 765 | 249 | 220 | 291 |
| 1967 | 6 | 0 | 76 | 682 | 627 | 767 | 260 | 231 | 303 |
| 1968 | 23 | 0 | 57 | 680 | 626 | 753 | 266 | 237 | 309 |
| 1969 | 5 | 0 | 39 | 646 | 600 | 712 | 266 | 238 | 306 |
| 1970 | 2 | 0 | 24 | 593 | 553 | 656 | 262 | 236 | 299 |
| 1971 | 2 | 0 | 25 | 533 | 498 | 594 | 253 | 229 | 287 |
| 1972 | 24 | 0 | 50 | 486 | 440 | 536 | 235 | 213 | 267 |
| 1973 | 28 | 4 | 60 | 442 | 410 | 483 | 207 | 188 | 235 |
| 1974 | 2 | 0 | 14 | 398 | 370 | 436 | 183 | 165 | 209 |
| 1975 | 3 | 0 | 21 | 355 | 330 | 389 | 161 | 144 | 184 |
| 1976 | 18 | 0 | 27 | 329 | 307 | 357 | 144 | 129 | 164 |
| 1977 | 1 | 0 | 13 | 290 | 271 | 315 | 128 | 115 | 145 |
| 1978 | 2 | 0 | 9 | 260 | 243 | 283 | 117 | 106 | 132 |
| 1979 | 82 | 66 | 106 | 316 | 299 | 346 | 112 | 102 | 126 |
| 1980 | 28 | 0 | 46 | 349 | 330 | 374 | 107 | 98 | 119 |
| 1981 | 7 | 0 | 32 | 366 | 346 | 391 | 105 | 97 | 116 |
| 1982 | 49 | 28 | 72 | 410 | 391 | 440 | 108 | 101 | 119 |
| 1983 | 21 | 1 | 41 | 437 | 417 | 461 | 120 | 113 | 131 |
| 1984 | 43 | 32 | 57 | 479 | 460 | 505 | 136 | 128 | 147 |
| 1985 | 0 | 0 | 3 | 482 | 463 | 508 | 151 | 143 | 163 |
| 1986 | 22 | 10 | 33 | 492 | 473 | 516 | 164 | 156 | 177 |
| 1987 | 21 | 13 | 31 | 483 | 465 | 506 | 171 | 162 | 183 |
| 1988 | 3 | 0 | 13 | 449 | 433 | 471 | 169 | 161 | 181 |
| 1989 | 6 | 0 | 12 | 408 | 393 | 427 | 162 | 153 | 174 |
| 1990 | 6 | 3 | 11 | 367 | 354 | 384 | 153 | 144 | 163 |
| 1991 | 28 | 22 | 33 | 348 | 336 | 364 | 142 | 134 | 152 |
| 1992 | 0 | 0 | 2 | 318 | 306 | 333 | 131 | 123 | 140 |
| 1993 | 25 | 21 | 30 | 310 | 299 | 326 | 120 | 113 | 129 |
| 1994 | 3 | 0 | 8 | 288 | 276 | 302 | 110 | 103 | 118 |
| 1995 | 6 | 2 | 11 | 267 | 256 | 281 | 101 | 95 | 109 |
| 1996 | 7 | 5 | 10 | 249 | 238 | 263 | 97 | 90 | 104 |
| 1997 | 20 | 16 | 23 | 245 | 234 | 259 | 94 | 88 | 101 |
| 1998 | 1 | 0 | 4 | 231 | 219 | 245 | 91 | 85 | 98 |
| 1999 | 31 | 27 | 36 | 242 | 230 | 257 | 87 | 81 | 94 |
| 2000 | 19 | 13 | 29 | 252 | 239 | 269 | 84 | 78 | 90 |
| 2001 | 14 | 2 | 21 | 255 | 241 | 271 | 81 | 76 | 87 |
| 2002 | 43 | 37 | 55 | 287 | 273 | 306 | 80 | 75 | 87 |
| 2003 | 7 | 0 | 12 | 292 | 277 | 311 | 83 | 77 | 90 |
| 2004 | 15 | 10 | 21 | 297 | 281 | 317 | 87 | 81 | 94 |
| 2005 | 7 | 4 | 11 | 290 | 273 | 310 | 92 | 85 | 99 |
| 2006 | 12 | 7 | 16 | 284 | 268 | 304 | 99 | 92 | 107 |
| 2007 | 9 | 6 | 14 | 277 | 260 | 297 | 104 | 97 | 113 |
| 2008 | 10 | 4 | 14 | 269 | 252 | 288 | 107 | 99 | 116 |
| 2009 | 9 | 6 | 13 | 260 | 242 | 280 | 107 | 99 | 116 |
| 2010 | 20 | 13 | 35 | 263 | 245 | 288 | 105 | 98 | 114 |
| 2011 | 18 | 11 | 33 | 258 | 237 | 283 | 104 | 96 | 113 |
| 2012 | - | - | - | - | - | - | 101 | 64 | 143 |

Table 3.15. Regional estimates of sablefish total biomass (Age 2+). Partitioning was done using RPWs from Japanese LL survey from 1979-1989 and domestic LL survey from 1990-2011. For 1960-1978, a retrospective 4:6:9 pseudo-exponential 3 - year average of proportions was used.

| Year | Bering Sea | Aleutian Islands | Western GOA | Central GOA | West Yakutat | EYakutat/ Southeast | Alaska |
|---|---|---|---|---|---|---|---|
| 1960 | 98 | 118 | 51 | 148 | 46 | 71 | 533 |
| 1961 | 100 | 120 | 52 | 151 | 47 | 72 | 543 |
| 1962 | 113 | 135 | 59 | 171 | 53 | 82 | 613 |
| 1963 | 113 | 136 | 59 | 171 | 53 | 82 | 614 |
| 1964 | 113 | 135 | 58 | 170 | 53 | 81 | 609 |
| 1965 | 118 | 141 | 61 | 177 | 55 | 85 | 636 |
| 1966 | 126 | 151 | 66 | 190 | 59 | 91 | 683 |
| 1967 | 126 | 151 | 65 | 190 | 59 | 91 | 682 |
| 1968 | 126 | 150 | 65 | 189 | 59 | 91 | 680 |
| 1969 | 119 | 143 | 62 | 180 | 56 | 86 | 646 |
| 1970 | 110 | 131 | 57 | 165 | 52 | 79 | 593 |
| 1971 | 99 | 118 | 51 | 148 | 46 | 71 | 533 |
| 1972 | 90 | 107 | 47 | 135 | 42 | 65 | 486 |
| 1973 | 82 | 98 | 42 | 123 | 38 | 59 | 442 |
| 1974 | 74 | 88 | 38 | 111 | 35 | 53 | 398 |
| 1975 | 66 | 79 | 34 | 98 | 31 | 47 | 355 |
| 1976 | 61 | 72 | 31 | 92 | 29 | 44 | 329 |
| 1977 | 53 | 64 | 28 | 81 | 25 | 38 | 290 |
| 1978 | 48 | 59 | 25 | 71 | 23 | 35 | 260 |
| 1979 | 60 | 65 | 30 | 94 | 27 | 41 | 316 |
| 1980 | 63 | 83 | 34 | 93 | 30 | 46 | 349 |
| 1981 | 65 | 91 | 39 | 81 | 34 | 56 | 366 |
| 1982 | 74 | 85 | 53 | 100 | 40 | 59 | 410 |
| 1983 | 78 | 91 | 68 | 110 | 36 | 53 | 437 |
| 1984 | 90 | 111 | 76 | 115 | 34 | 53 | 479 |
| 1985 | 99 | 110 | 69 | 120 | 35 | 48 | 482 |
| 1986 | 105 | 103 | 67 | 123 | 42 | 52 | 492 |
| 1987 | 79 | 105 | 64 | 129 | 48 | 58 | 483 |
| 1988 | 47 | 92 | 60 | 145 | 46 | 59 | 449 |
| 1989 | 55 | 80 | 47 | 131 | 43 | 53 | 408 |
| 1990 | 56 | 60 | 39 | 113 | 43 | 56 | 367 |
| 1991 | 38 | 41 | 37 | 110 | 46 | 77 | 348 |
| 1992 | 23 | 36 | 25 | 100 | 50 | 84 | 318 |
| 1993 | 15 | 34 | 28 | 103 | 53 | 78 | 310 |
| 1994 | 17 | 33 | 31 | 95 | 44 | 67 | 288 |
| 1995 | 25 | 30 | 27 | 87 | 38 | 60 | 267 |
| 1996 | 24 | 26 | 27 | 90 | 32 | 51 | 249 |
| 1997 | 23 | 23 | 26 | 95 | 30 | 49 | 245 |
| 1998 | 20 | 29 | 26 | 81 | 27 | 48 | 231 |
| 1999 | 20 | 40 | 28 | 80 | 26 | 49 | 242 |
| 2000 | 20 | 41 | 33 | 84 | 26 | 48 | 252 |
| 2001 | 28 | 40 | 40 | 80 | 22 | 45 | 255 |
| 2002 | 40 | 44 | 43 | 93 | 23 | 45 | 287 |
| 2003 | 40 | 45 | 41 | 99 | 25 | 42 | 292 |
| 2004 | 39 | 46 | 37 | 105 | 27 | 42 | 297 |
| 2005 | 42 | 44 | 38 | 94 | 26 | 47 | 290 |
| 2006 | 45 | 40 | 40 | 86 | 26 | 48 | 284 |
| 2007 | 48 | 35 | 30 | 86 | 29 | 49 | 277 |
| 2008 | 52 | 34 | 26 | 84 | 26 | 46 | 269 |
| 2009 | 50 | 34 | 30 | 81 | 23 | 42 | 260 |
| 2010 | 52 | 29 | 28 | 77 | 29 | 49 | 263 |
| 2011 | 33 | 28 | 28 | 92 | 31 | 46 | 258 |

Table 3.16. Comparison of 2010 results versus 2011 results. Biomass is in kilotons.

| Year | 2010 SAFE Spawning Biomass | 2011 SAFE Spawning Biomass | 2010 SAFE Total Biomass | 2011 SAFE Total Biomass |
|---|---|---|---|---|
| 1960 | 177 | 180 | 528 | 533 |
| 1961 | 183 | 185 | 540 | 543 |
| 1962 | 193 | 195 | 605 | 613 |
| 1963 | 202 | 204 | 605 | 614 |
| 1964 | 215 | 217 | 603 | 609 |
| 1965 | 231 | 233 | 628 | 636 |
| 1966 | 246 | 249 | 674 | 683 |
| 1967 | 257 | 260 | 677 | 682 |
| 1968 | 264 | 266 | 674 | 680 |
| 1969 | 264 | 266 | 641 | 646 |
| 1970 | 261 | 262 | 589 | 593 |
| 1971 | 252 | 253 | 530 | 533 |
| 1972 | 235 | 235 | 484 | 486 |
| 1973 | 207 | 207 | 440 | 442 |
| 1974 | 184 | 183 | 397 | 398 |
| 1975 | 162 | 161 | 354 | 355 |
| 1976 | 145 | 144 | 329 | 329 |
| 1977 | 130 | 128 | 290 | 290 |
| 1978 | 118 | 117 | 261 | 260 |
| 1979 | 113 | 112 | 317 | 316 |
| 1980 | 108 | 107 | 350 | 349 |
| 1981 | 106 | 105 | 368 | 366 |
| 1982 | 110 | 108 | 412 | 410 |
| 1983 | 121 | 120 | 440 | 437 |
| 1984 | 137 | 136 | 480 | 479 |
| 1985 | 152 | 151 | 483 | 482 |
| 1986 | 166 | 164 | 490 | 492 |
| 1987 | 172 | 171 | 482 | 483 |
| 1988 | 171 | 169 | 448 | 449 |
| 1989 | 163 | 162 | 406 | 408 |
| 1990 | 153 | 153 | 368 | 367 |
| 1991 | 142 | 142 | 347 | 348 |
| 1992 | 131 | 131 | 317 | 318 |
| 1993 | 120 | 120 | 312 | 310 |
| 1994 | 110 | 110 | 289 | 288 |
| 1995 | 102 | 101 | 268 | 267 |
| 1996 | 97 | 97 | 252 | 249 |
| 1997 | 94 | 94 | 247 | 245 |
| 1998 | 92 | 91 | 234 | 231 |
| 1999 | 88 | 87 | 244 | 242 |
| 2000 | 85 | 84 | 255 | 252 |
| 2001 | 82 | 81 | 259 | 255 |
| 2002 | 82 | 80 | 290 | 287 |
| 2003 | 84 | 83 | 297 | 292 |
| 2004 | 88 | 87 | 300 | 297 |
| 2005 | 94 | 92 | 294 | 290 |
| 2006 | 101 | 99 | 286 | 284 |
| 2007 | 107 | 104 | 276 | 277 |
| 2008 | 109 | 107 | 262 | 269 |
| 2009 | 108 | 107 | 248 | 260 |
| 2010 | 106 | 105 | 240 | 263 |
| 2011 |  | 104 |  | 258 |

Table 3.17. Sablefish spawning biomass (kilotons), fishing mortality, and yield (kilotons) for seven harvest scenarios. Abundance projected using 1979-2009 recruitments. Sablefish are not classified as overfished because abundance currently exceeds $B_{35\%}$.

| Year | Maximum permissible F | Author's F* (specified catch) | Half max. F | 5-year average F | No fishing | Overfished? | Approaching overfished? |
|---|---|---|---|---|---|---|---|
| Spawning biomass (kt) | | | | | | | |
| 2011 | 103.6 | 103.6 | 103.6 | 103.6 | 103.6 | 103.6 | 103.6 |
| 2012 | 101.3 | 101.3 | 101.3 | 101.3 | 101.3 | 101.3 | 101.3 |
| 2013 | 97.2 | 99.0 | 101.1 | 99.6 | 105.6 | 95.6 | 97.2 |
| 2014 | 94.6 | 98.1 | 101.3 | 98.8 | 111.0 | 91.9 | 94.6 |
| 2015 | 93.5 | 96.5 | 101.3 | 99.2 | 117.5 | 89.9 | 92.1 |
| 2016 | 93.9 | 96.3 | 100.7 | 100.9 | 125.2 | 89.5 | 91.3 |
| 2017 | 95.6 | 97.6 | 100.1 | 103.9 | 134.2 | 90.6 | 92.1 |
| 2018 | 98.2 | 99.8 | 101.2 | 107.6 | 144.2 | 92.6 | 93.7 |
| 2019 | 100.9 | 102.2 | 103.4 | 111.6 | 154.3 | 94.7 | 95.6 |
| 2020 | 103.6 | 104.6 | 106.4 | 115.4 | 164.2 | 96.8 | 97.4 |
| 2021 | 106.0 | 106.8 | 110.8 | 118.9 | 173.6 | 98.6 | 99.1 |
| 2022 | 108.2 | 108.8 | 114.4 | 122.2 | 182.5 | 100.3 | 100.7 |
| 2023 | 110.2 | 110.7 | 117.2 | 125.3 | 191.1 | 101.9 | 102.2 |
| 2024 | 112.1 | 112.5 | 121.2 | 128.2 | 199.1 | 103.4 | 103.6 |
| Fishing mortality | | | | | | | |
| 2011 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| 2012 | 0.089 | 0.069 | 0.045 | 0.063 | - | 0.106 | 0.106 |
| 2013 | 0.085 | 0.065 | 0.044 | 0.063 | - | 0.100 | 0.100 |
| 2014 | 0.083 | 0.086 | 0.045 | 0.063 | - | 0.096 | 0.096 |
| 2015 | 0.081 | 0.084 | 0.045 | 0.063 | - | 0.093 | 0.093 |
| 2016 | 0.080 | 0.082 | 0.044 | 0.063 | - | 0.091 | 0.091 |
| 2017 | 0.079 | 0.080 | 0.044 | 0.063 | - | 0.090 | 0.090 |
| 2018 | 0.078 | 0.079 | 0.045 | 0.063 | - | 0.088 | 0.088 |
| 2019 | 0.077 | 0.078 | 0.046 | 0.063 | - | 0.088 | 0.088 |
| 2020 | 0.077 | 0.078 | 0.047 | 0.063 | - | 0.088 | 0.088 |
| 2021 | 0.078 | 0.078 | 0.048 | 0.063 | - | 0.088 | 0.088 |
| 2022 | 0.078 | 0.078 | 0.048 | 0.063 | - | 0.089 | 0.089 |
| 2023 | 0.079 | 0.079 | 0.048 | 0.063 | - | 0.090 | 0.090 |
| 2024 | 0.079 | 0.080 | 0.048 | 0.063 | - | 0.091 | 0.091 |
| Yield (kt) | | | | | | | |
| 2011 | 12.2 | 12.2 | 12.2 | 12.2 | 12.2 | 12.2 | 12.2 |
| 2012 | 17.2 | 17.2 | 8.8 | 12.4 | - | 20.4 | 17.2 |
| 2013 | 16.4 | 17.0 | 9.1 | 12.6 | - | 18.8 | 16.4 |
| 2014 | 15.7 | 16.8 | 9.2 | 12.5 | - | 17.5 | 18.5 |
| 2015 | 16.1 | 17.0 | 9.9 | 13.1 | - | 17.8 | 18.6 |
| 2016 | 16.7 | 17.4 | 10.5 | 13.7 | - | 18.4 | 18.9 |
| 2017 | 17.2 | 17.7 | 10.9 | 14.2 | - | 18.9 | 19.3 |
| 2018 | 17.7 | 18.1 | 11.3 | 14.7 | - | 19.4 | 19.7 |
| 2019 | 18.2 | 18.5 | 11.7 | 15.2 | - | 19.8 | 20.0 |
| 2020 | 18.7 | 18.9 | 12.1 | 15.5 | - | 20.3 | 20.4 |
| 2021 | 19.1 | 19.3 | 12.5 | 15.9 | - | 20.8 | 20.9 |
| 2022 | 19.6 | 19.7 | 12.9 | 16.3 | - | 21.2 | 21.3 |
| 2023 | 20.1 | 20.1 | 13.3 | 16.6 | - | 21.7 | 21.7 |
| 2024 | 20.5 | 20.6 | 13.6 | 17.0 | - | 22.2 | 22.3 |

* Projections in Author's F (Alternative 2) are based on estimated catches of 13,539 t and 12,896 t used in place of maximum permissible ABC for 2012 and 2013. This was done in response to management requests for a more accurate two-year projection.

Table 3.18. Analysis of ecosystem considerations for the 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 | Possible concern |
| Marine mammals and birds | Bird catch about 10% total | Appears to be decreasing | Possible concern |
| Sensitive non-target species | Grenadier, spiny dogfish, and unidentified shark catch notable | Grenadier catch high but stable, recent shark catch is small | Possible concern for grenadiers |
| *Fishery concentration in space and time* | IFQ less concentrated | IFQ improves | No concern |
| *Fishery effects on amount of large size target fish* | IFQ reduces catch of immature | IFQ improves | No concern |
| *Fishery contribution to discards and offal production* | sablefish <5% in longline fishery, but 30% in trawl fishery | IFQ improves, but notable discards in trawl fishery | Trawl fishery discards definite concern |
| *Fishery effects on age-at-maturity and fecundity* | trawl fishery catches smaller fish, but only small part of total catch | slightly decreases | No concern |

# Figures

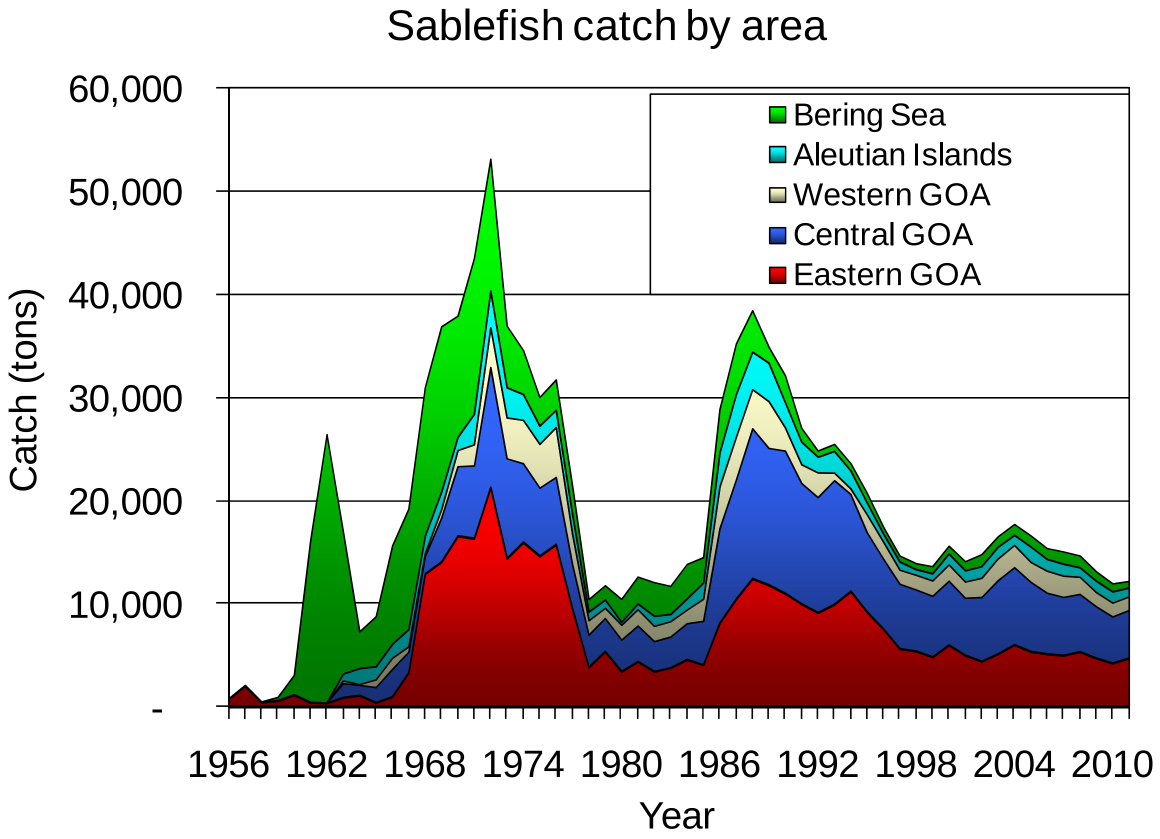


Figure 3.1. Sablefish fishery total reported catch (t) by North Pacific Fishery Management Council area and year.

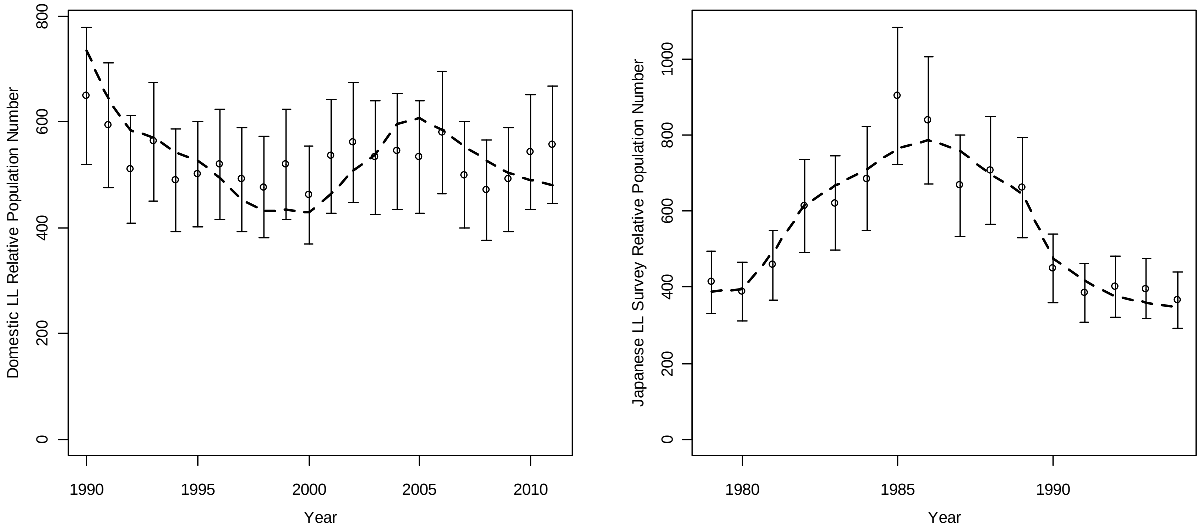


Figure 3.2. Observed and predicted sablefish relative population weight and numbers versus year. Points are observed estimates with approximate 95% confidence intervals, dashed line is model predicted.

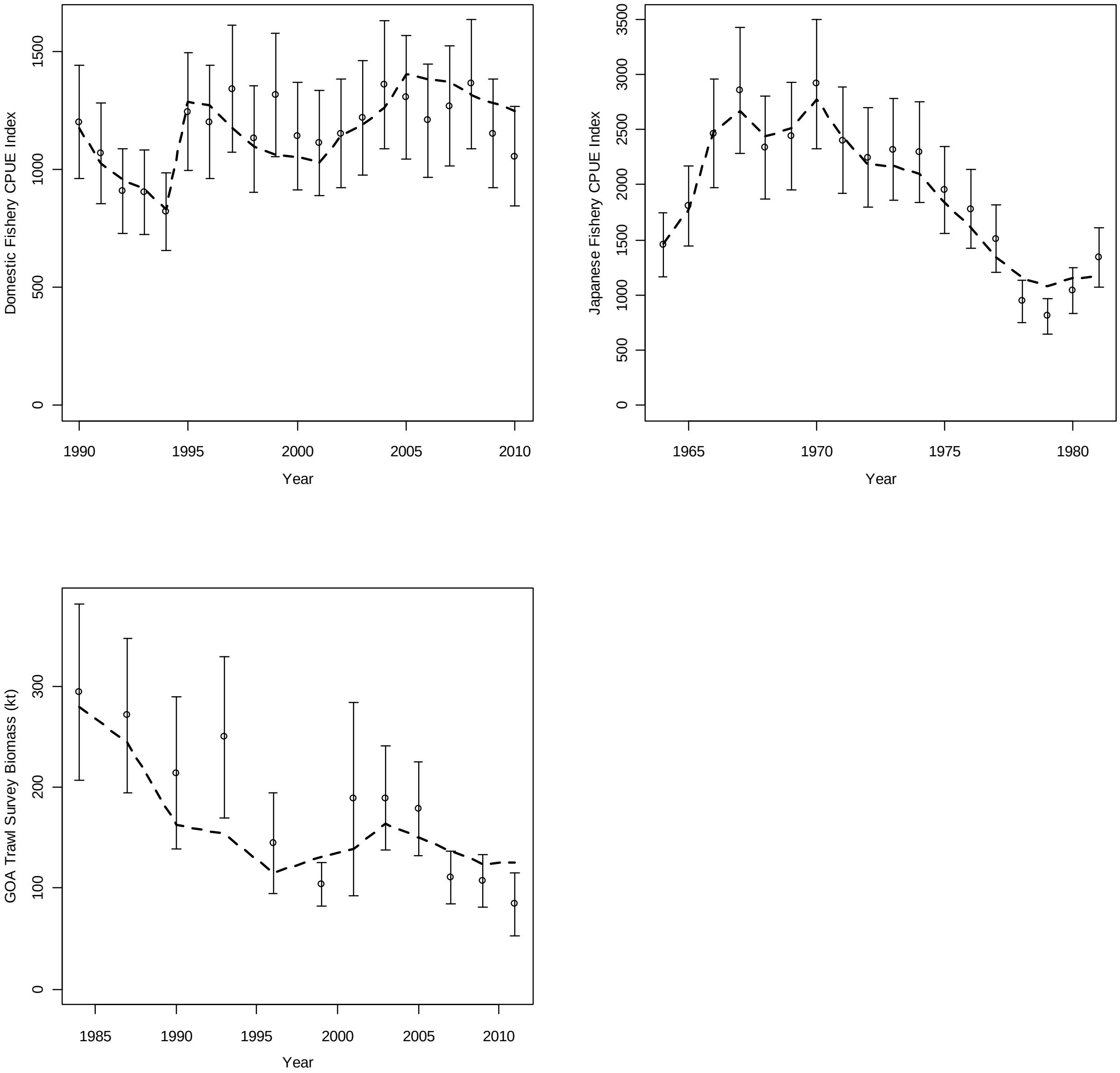


Figure 3.3. Observed and predicted sablefish abundance indices. Fishery indices are on top two panels, GOA trawl survey is on the bottom left panel. Points are observed estimates with approximate 95% confidence intervals while dashed lines are model predictions.

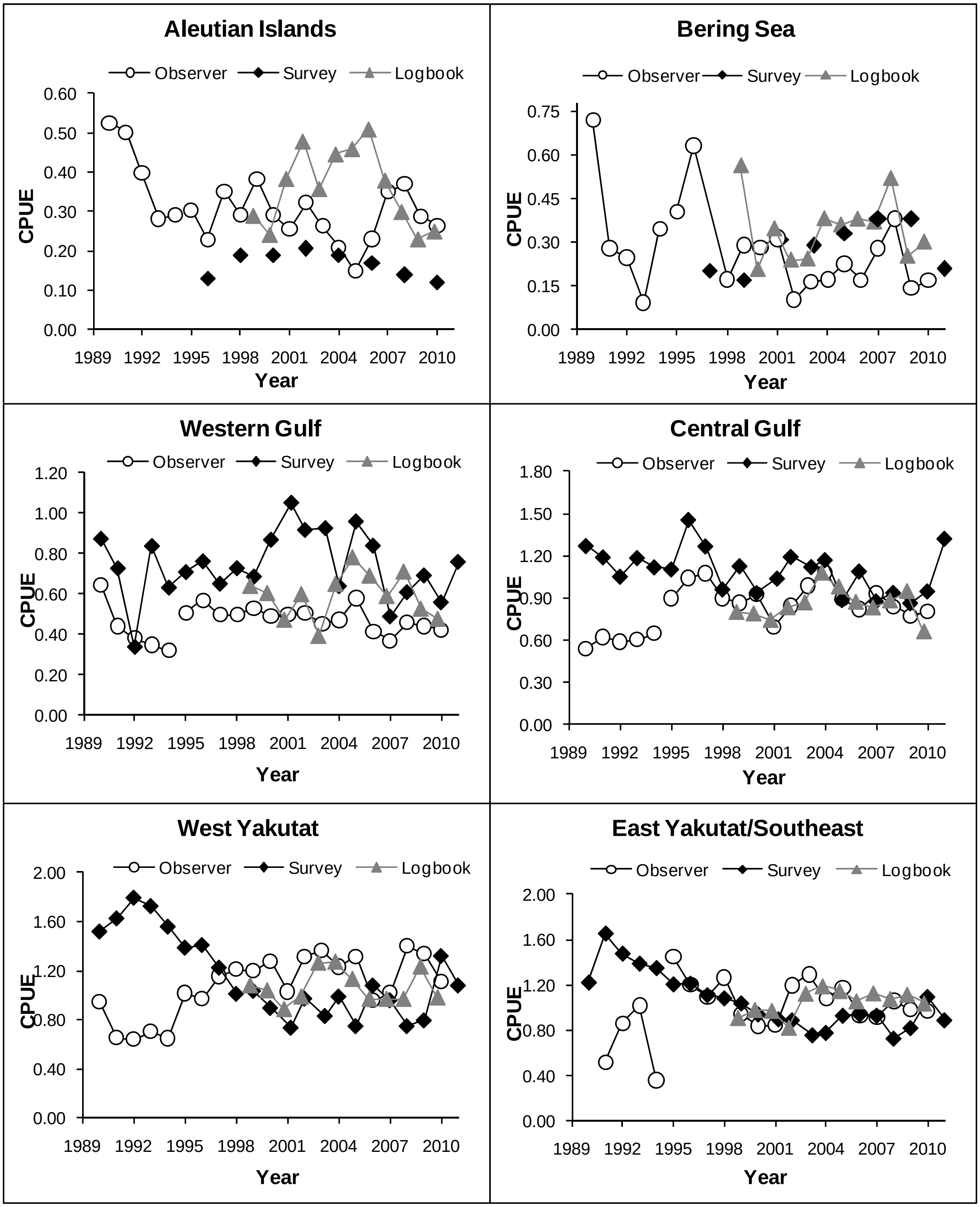


Figure 3.4. Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

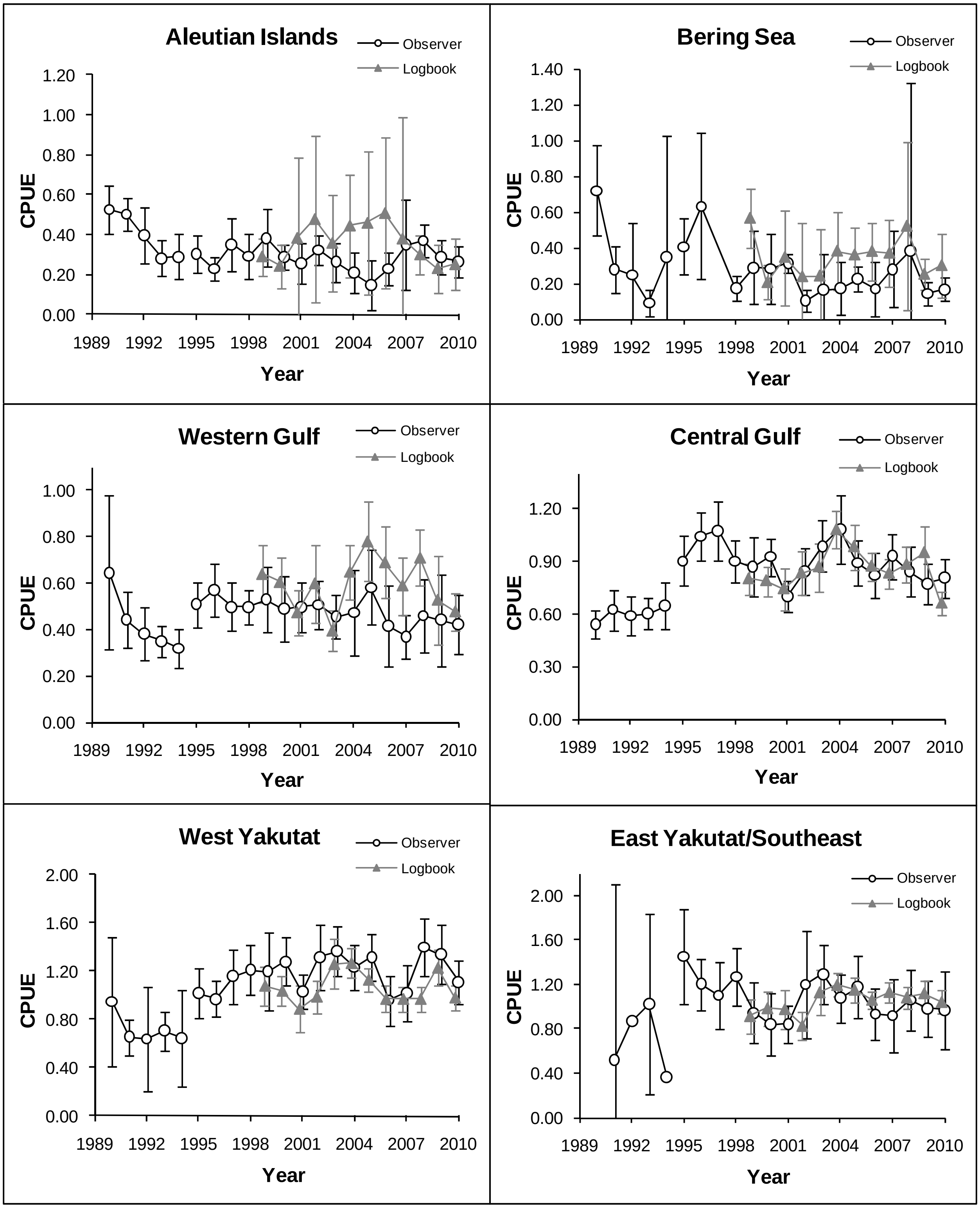


Figure 3.5. Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

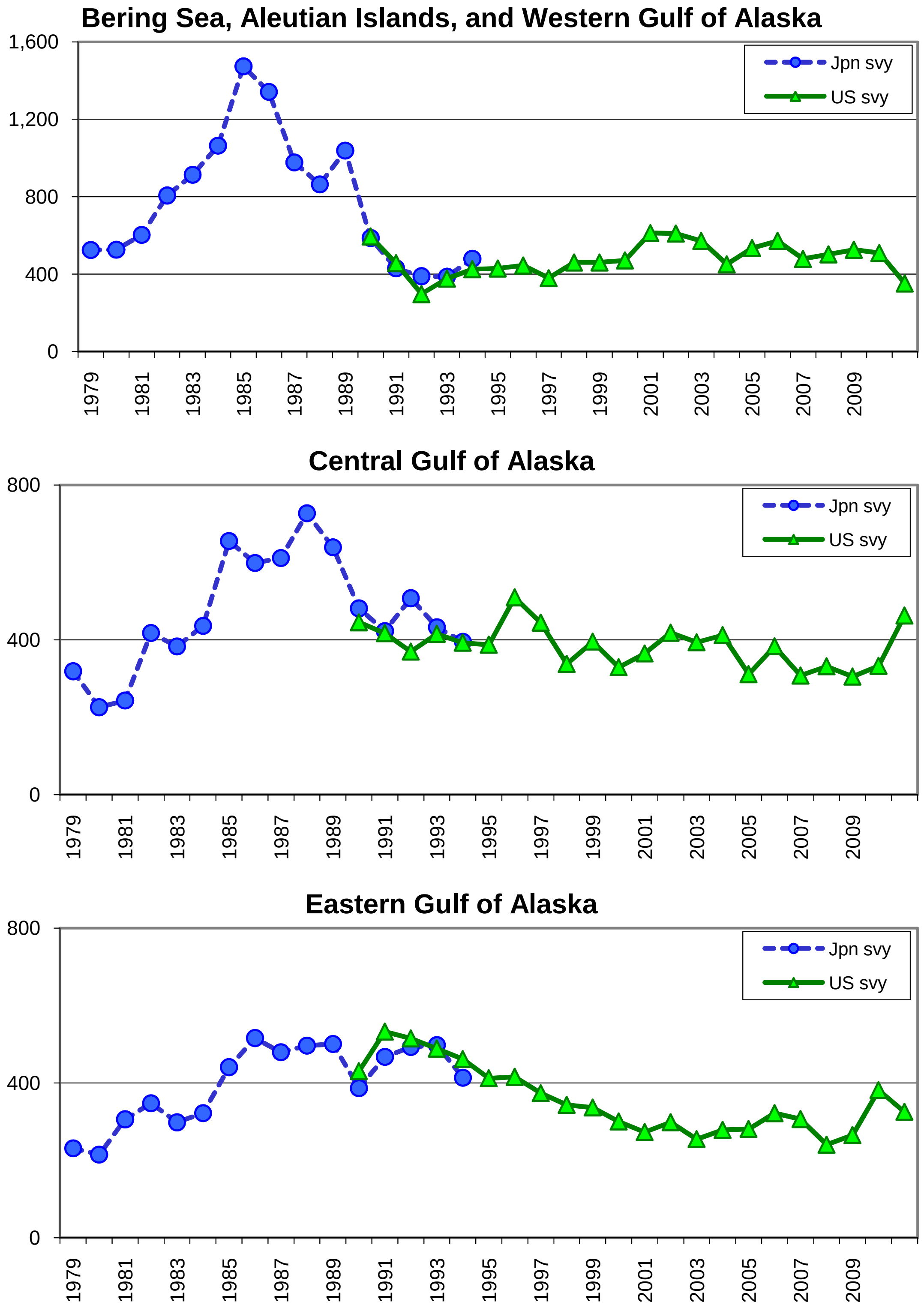


Figure 3.6a. Relative abundance (weight) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the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

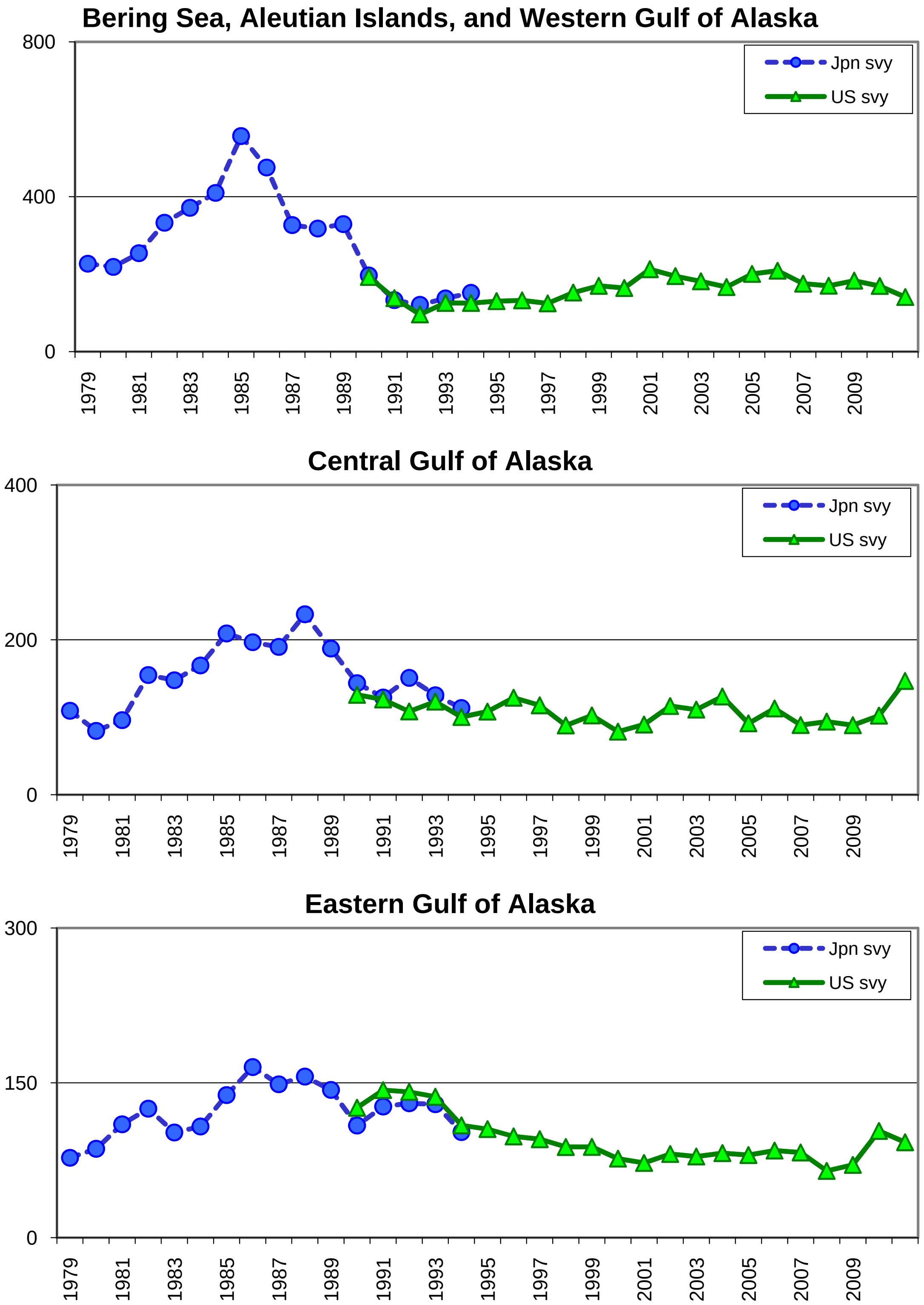


Figure 3.6b. Relative abundance (numbers) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the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

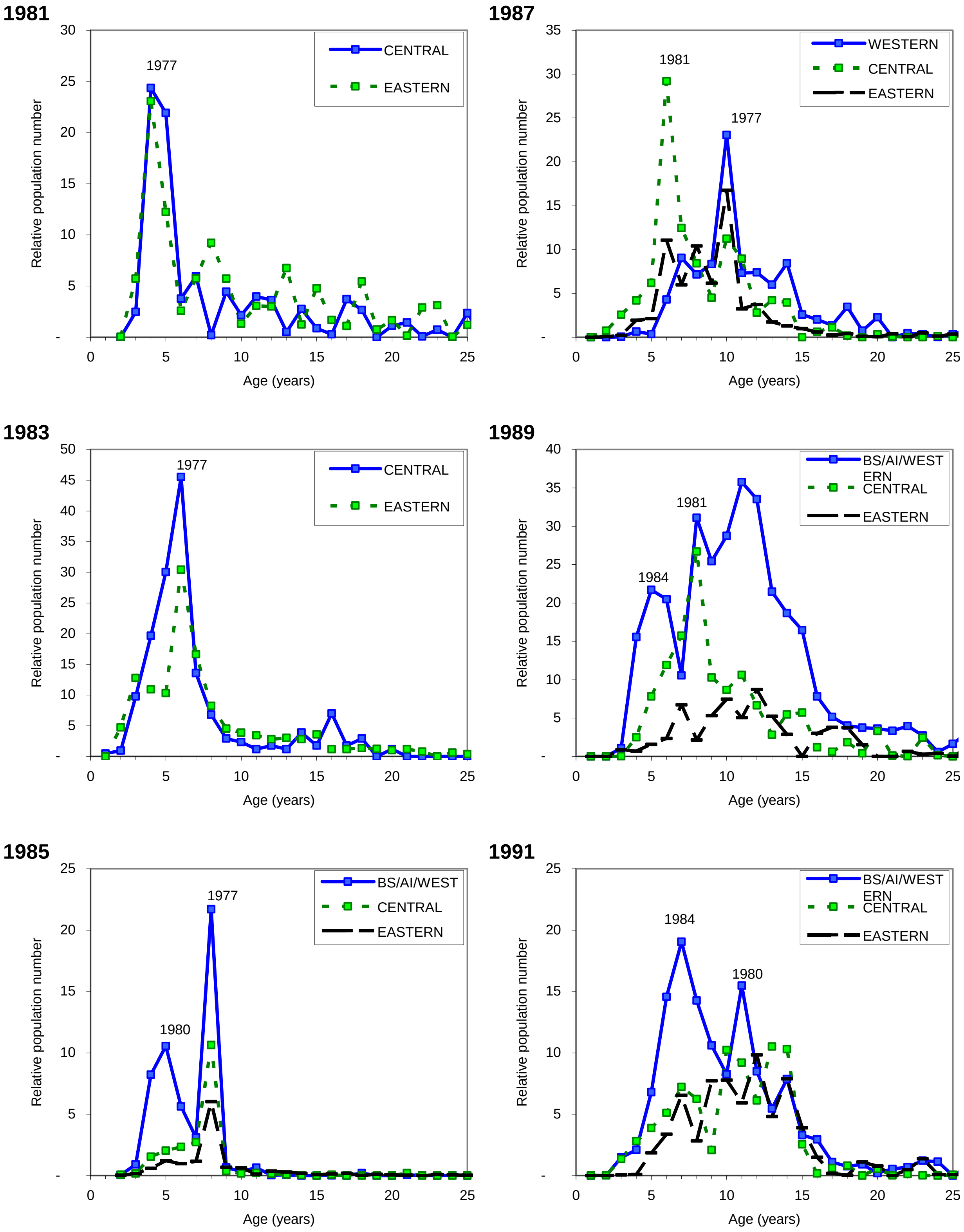


Figure 3.7. Relative abundance (number in thousands) by age and region from two surveys, the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

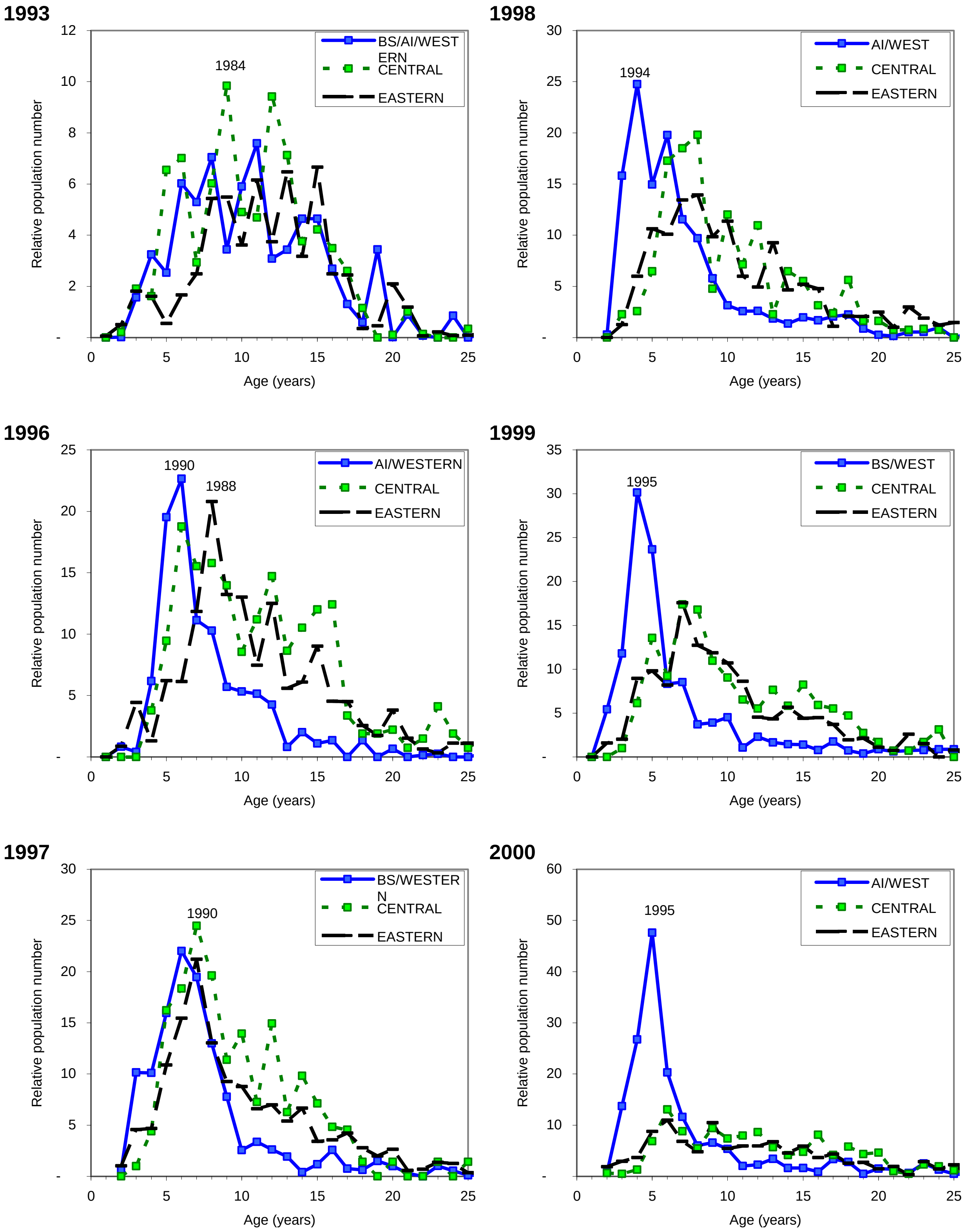


Figure 3.7 cont.

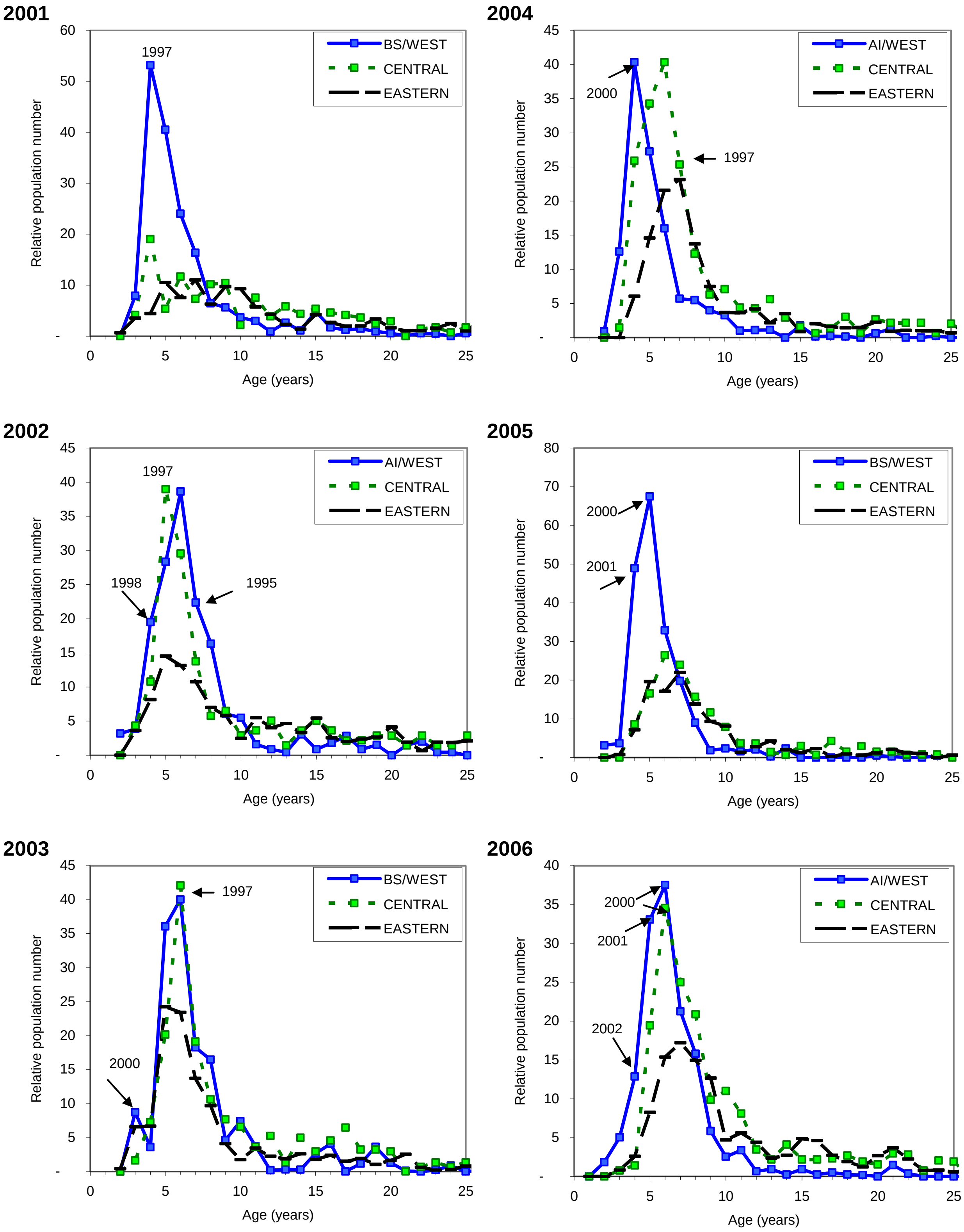


Figure 3.7 cont.

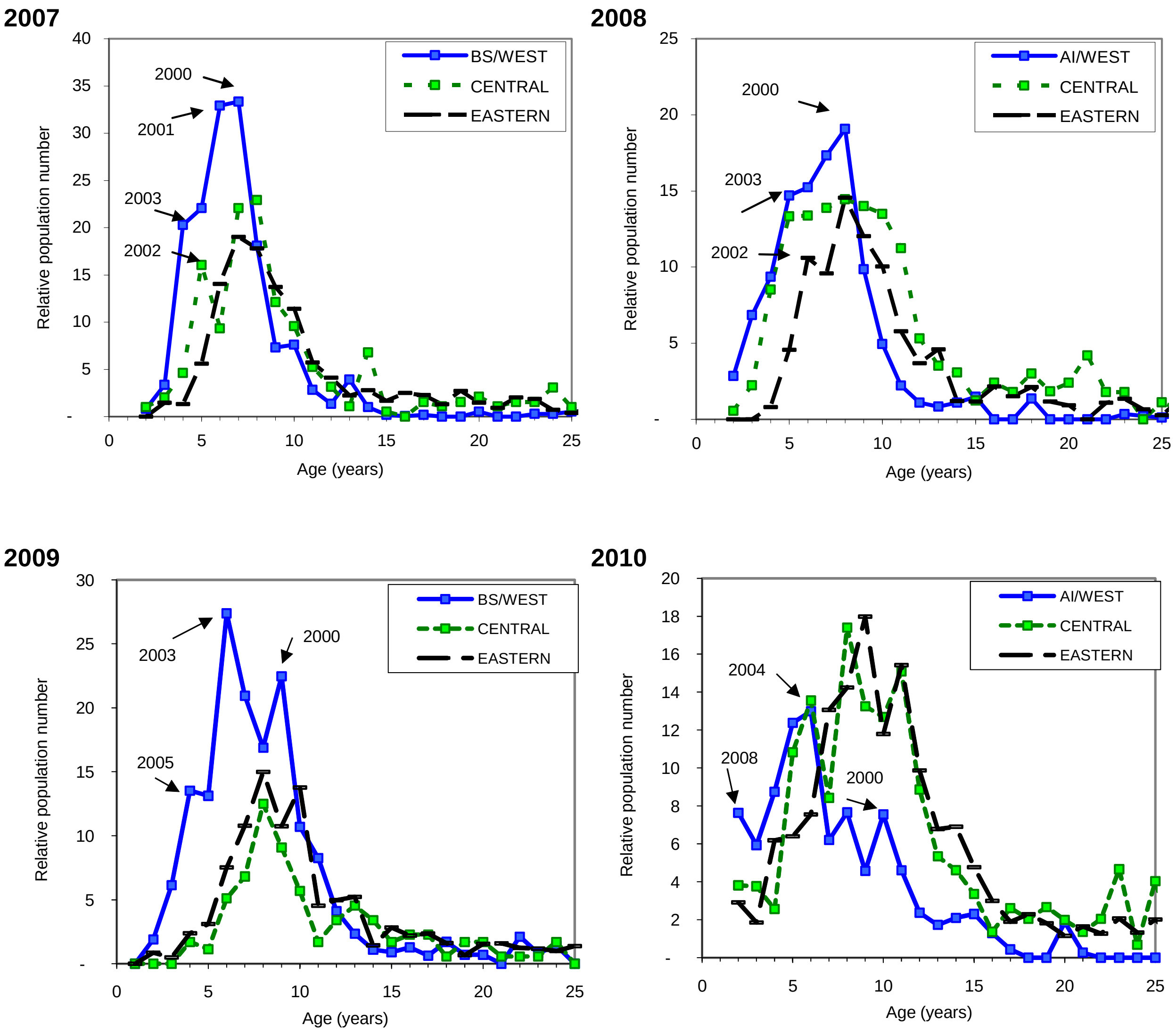


Figure 3.7. cont.

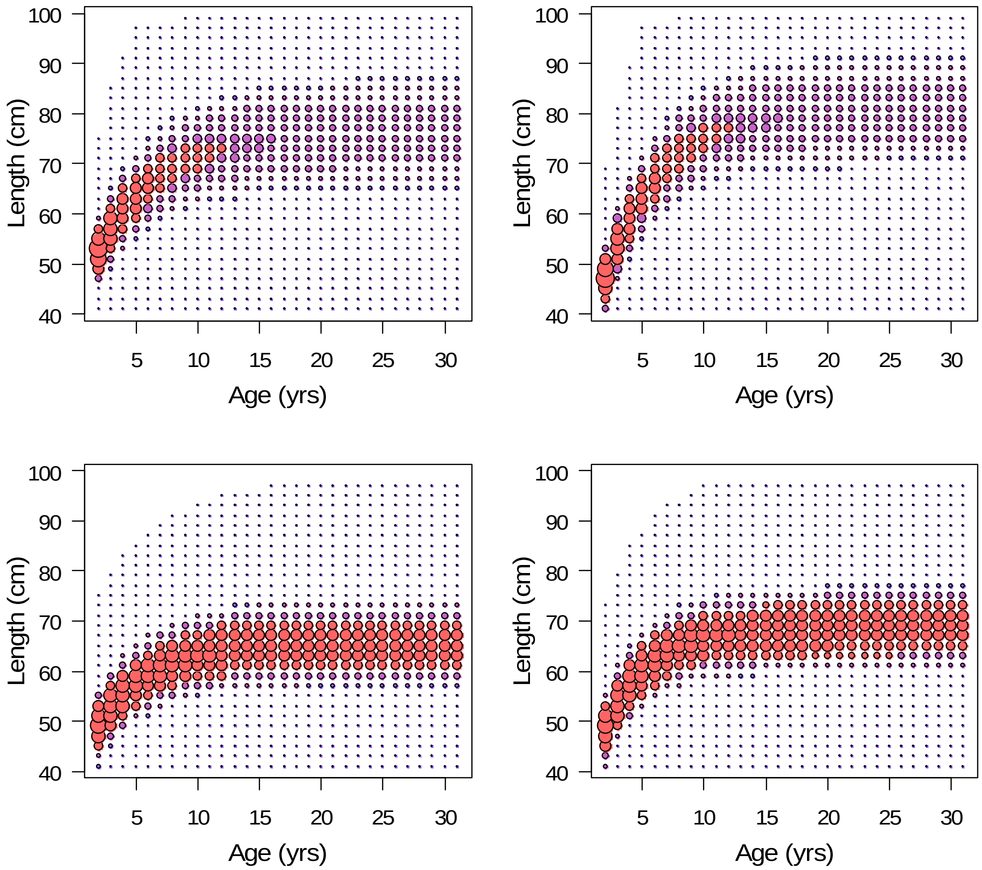


Figure 3.8. Age-length conversion matrices for sablefish. Top panels are female, bottom panel are males, left is 1981-1993, right is 1996-2011.

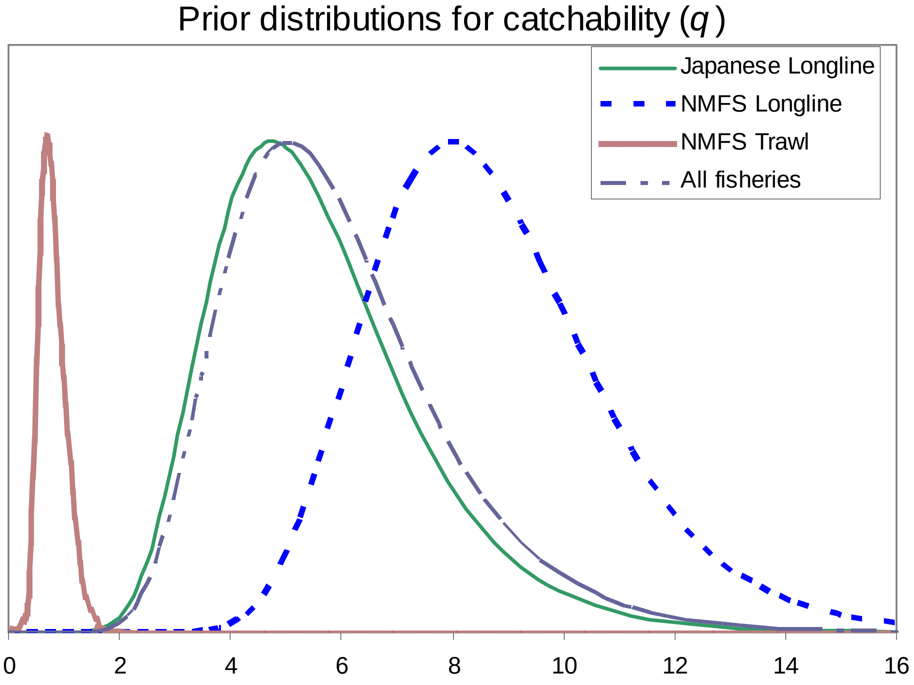


Figure 3.9. Prior distributions for catchability for four sablefish abundance indices.

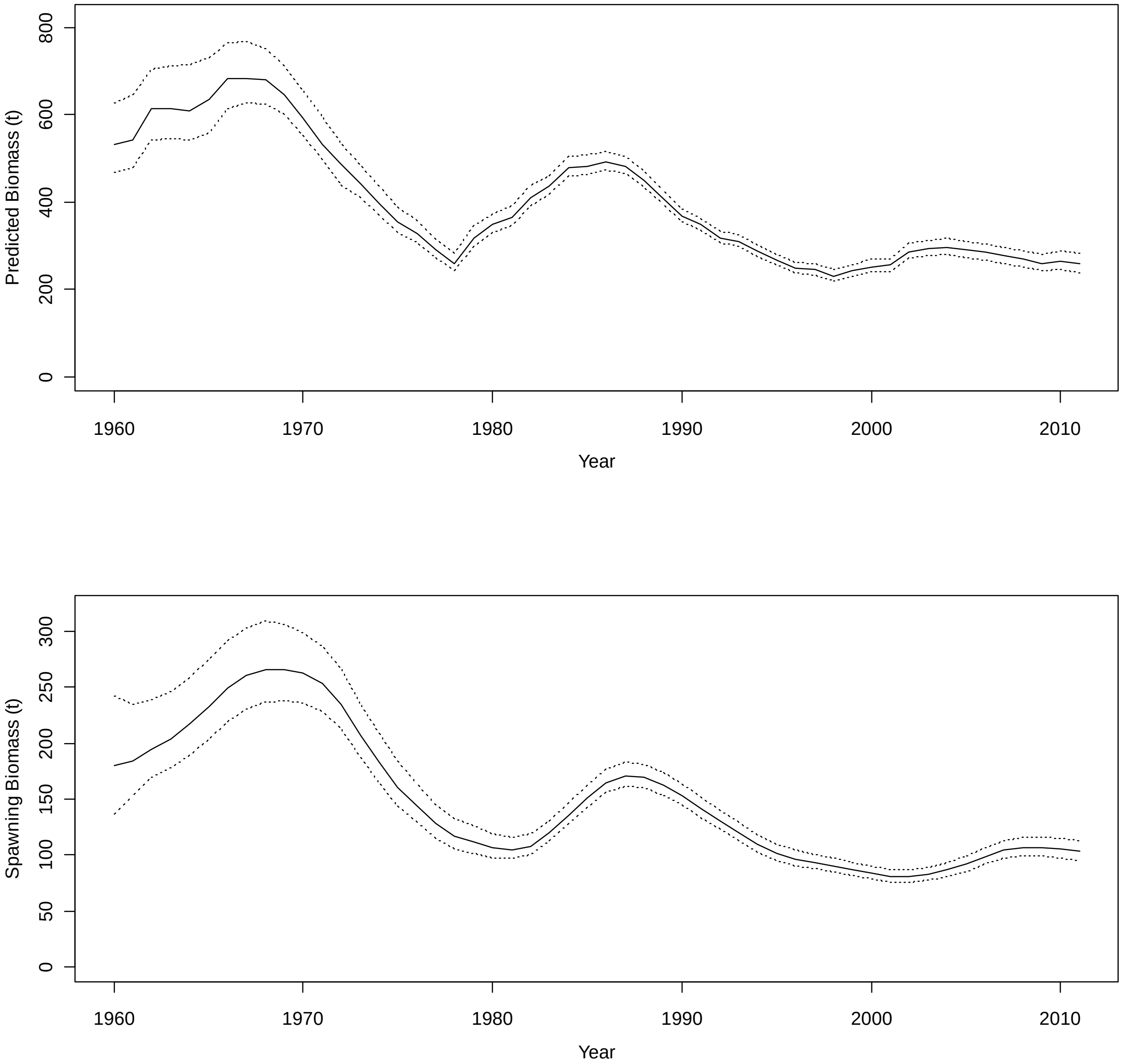


Figure 3.10.--Estimated sablefish total biomass (thousands t) and spawning biomass (bottom) with 95% MCMC credible intervals.

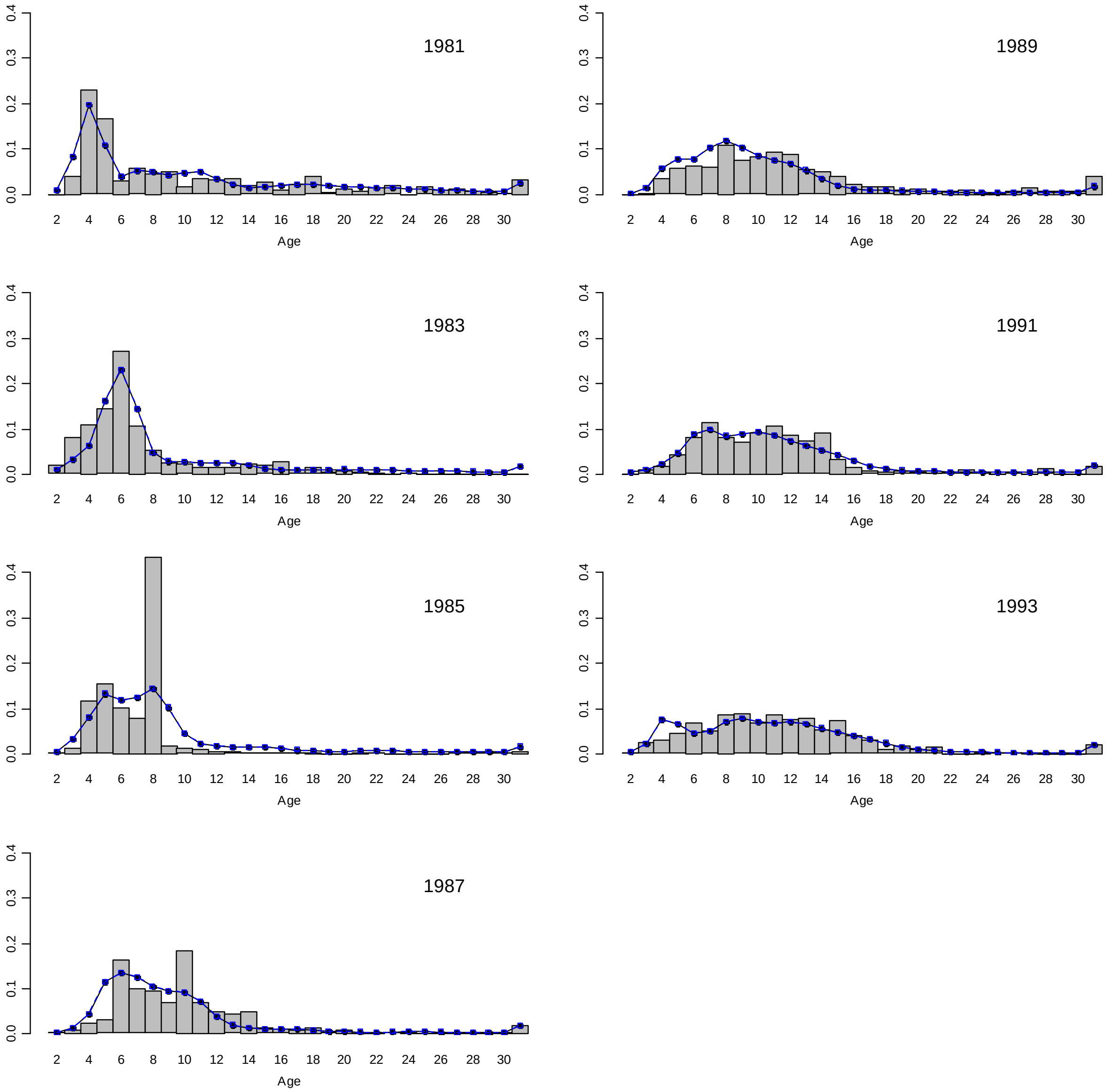


Figure 3.11. Japanese longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

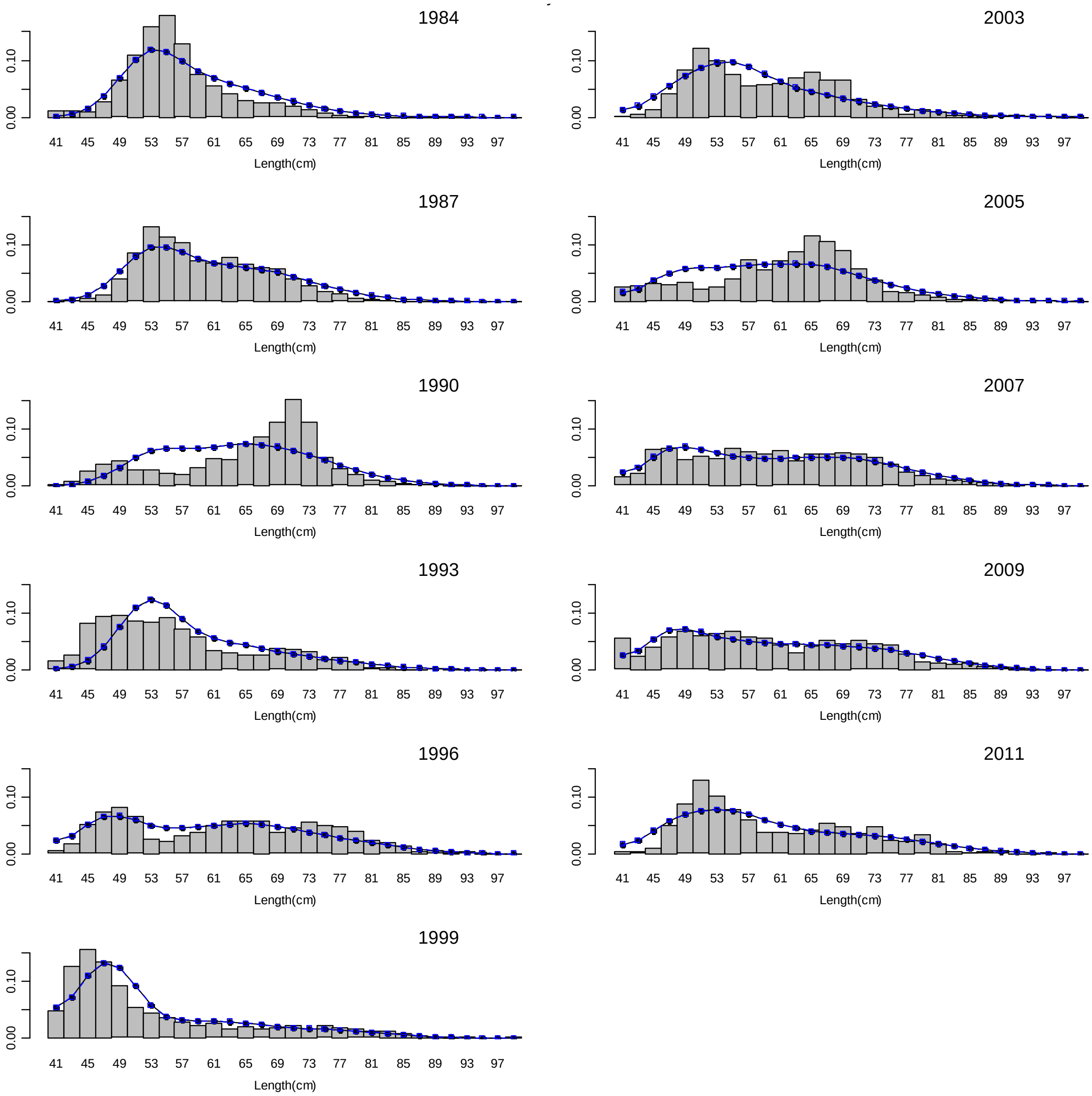


Figure 3.12. Gulf of Alaska bottom trawl survey lengths for female sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

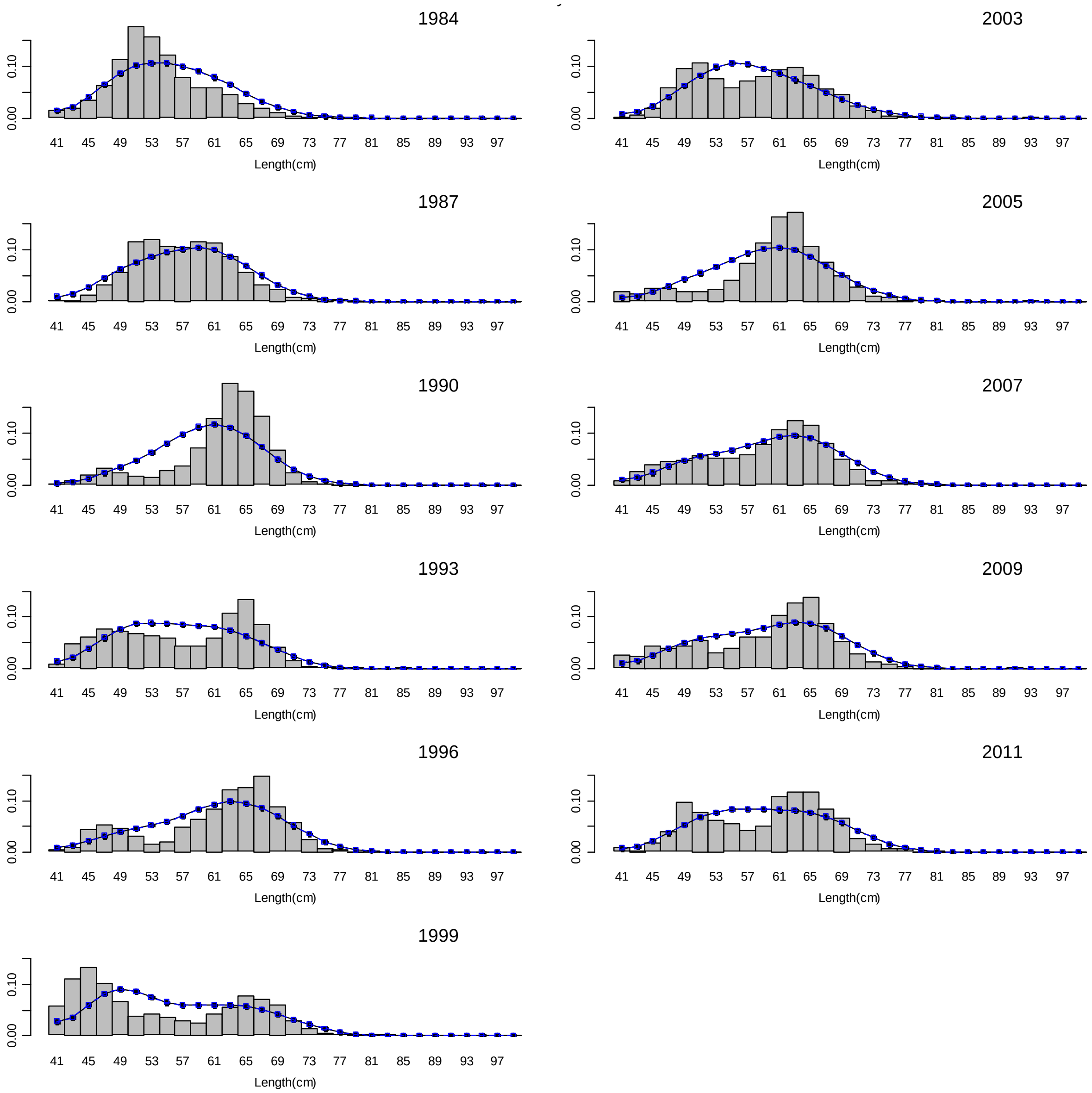


Figure 3.13. Gulf of Alaska bottom trawl survey lengths for male sablefish at depths <500 m. Bars are observed frequencies and line is predicted frequencies.

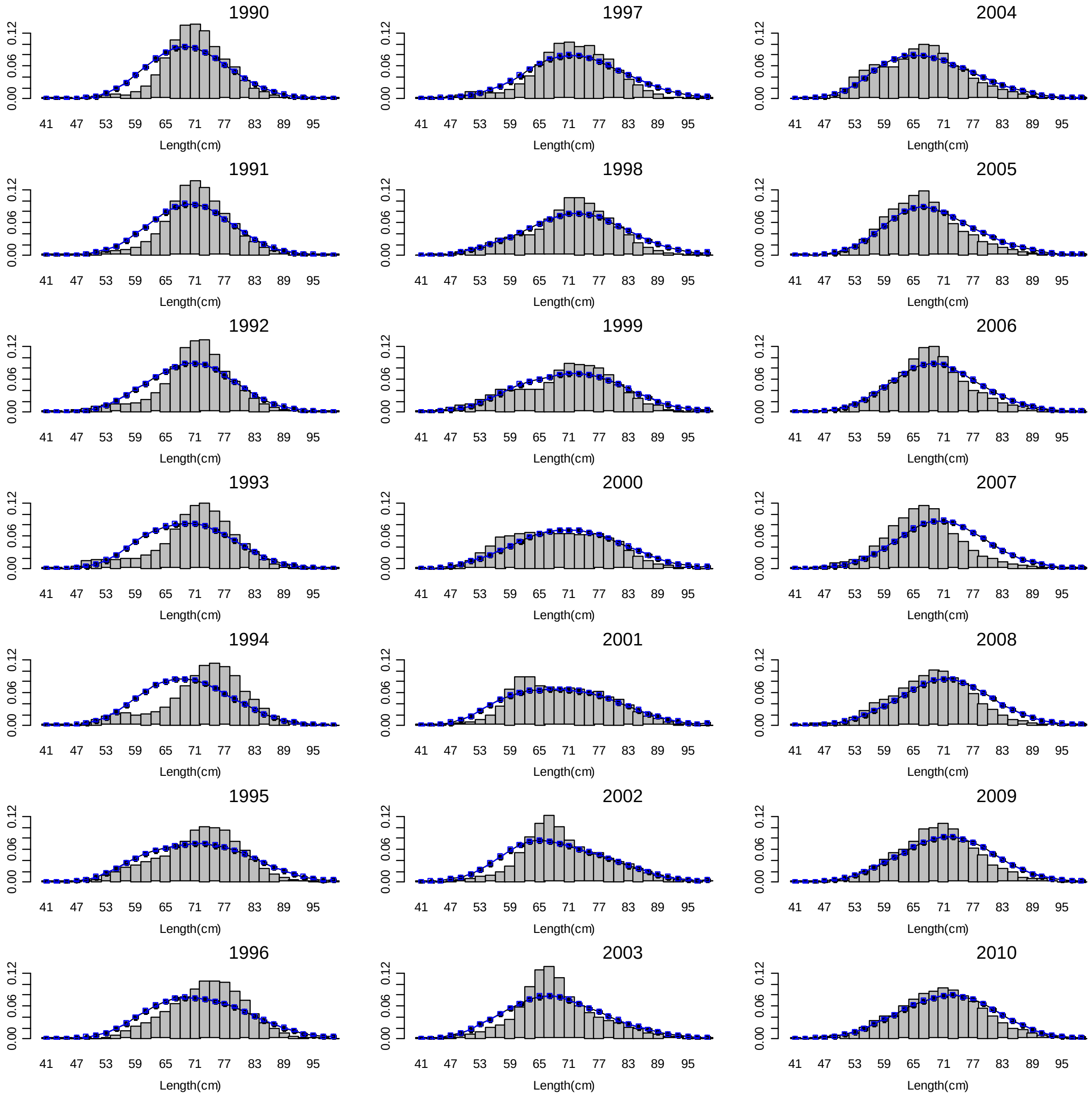


Figure 3.14. Domestic fixed gear fishery lengths compositions for females. Bars are observed frequencies and line is predicted frequencies.

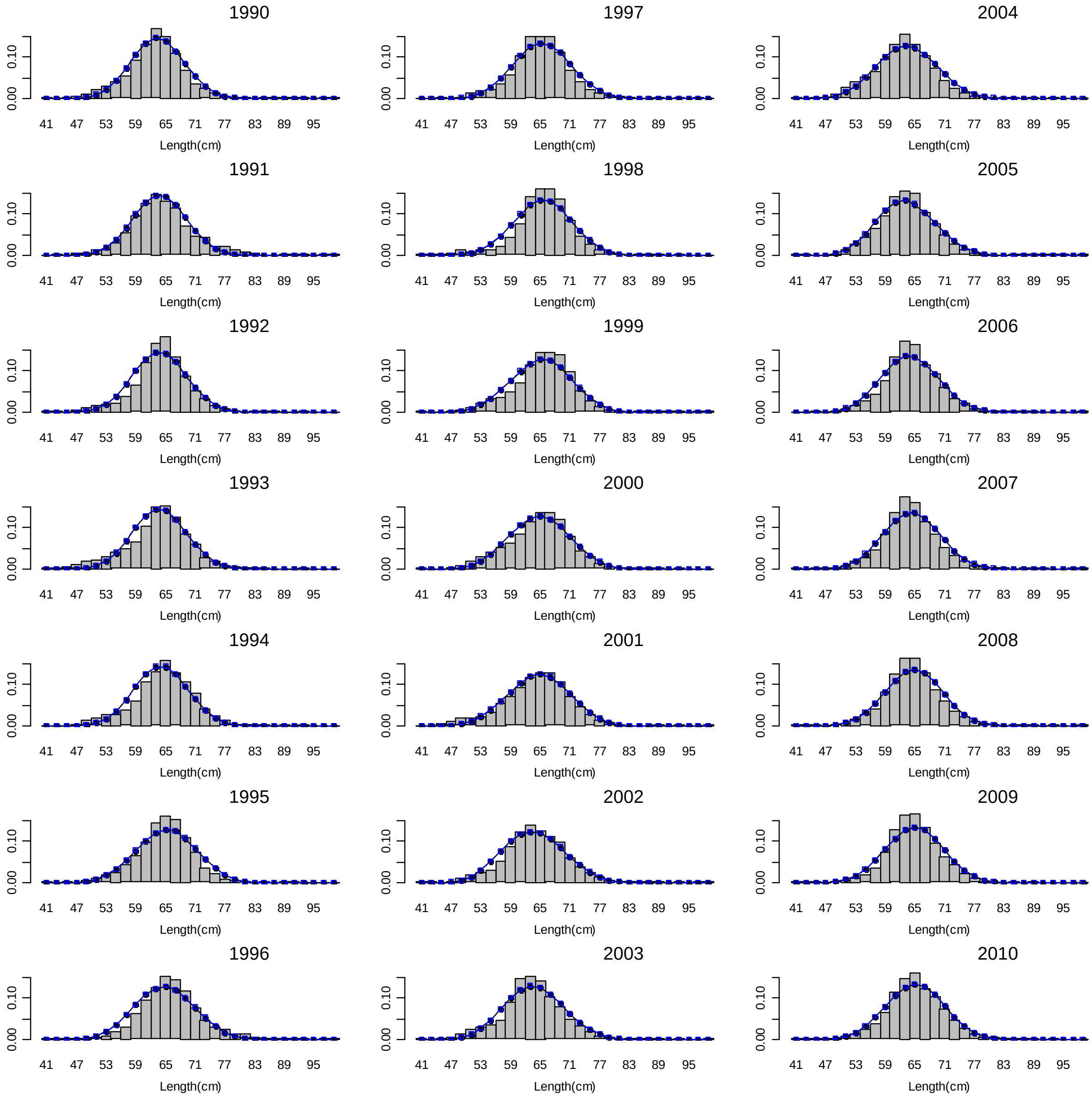


Figure 3.15. Domestic fixed gear fishery lengths compositions for males. Bars are observed frequencies and line is predicted frequencies.

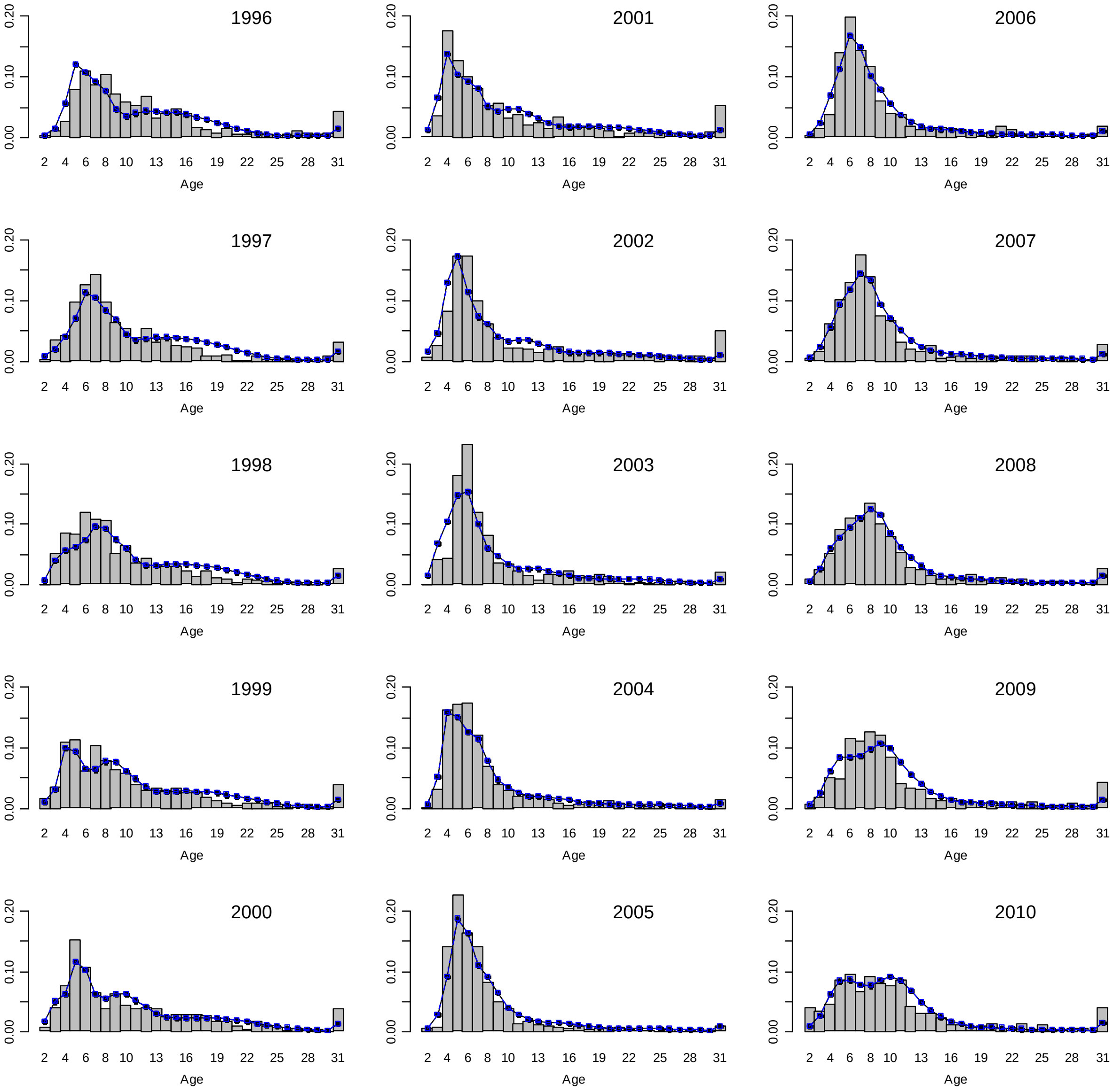


Figure 3.16. Domestic longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

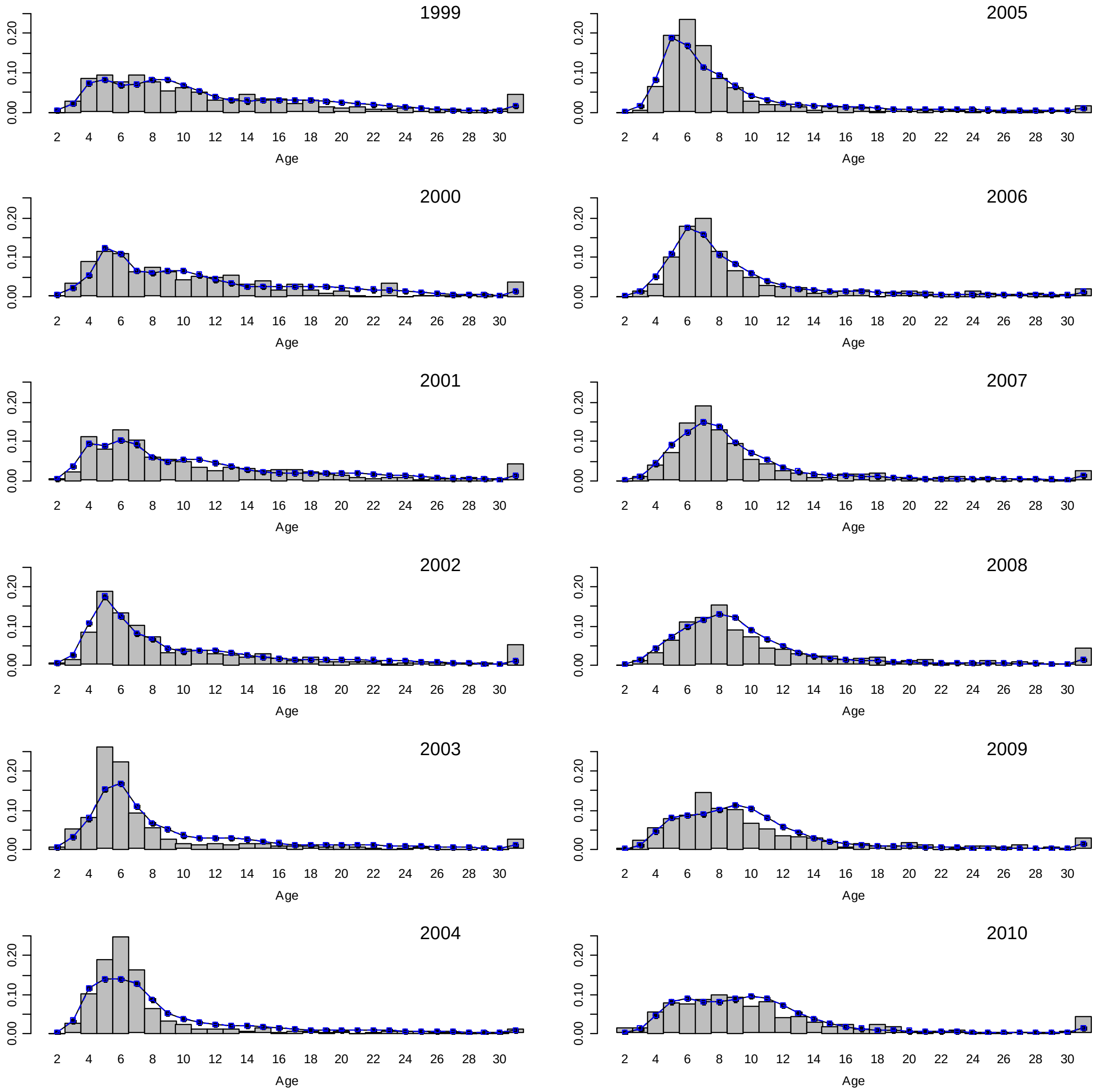


Figure 3.17. Domestic fishery age compositions. Bars are observed frequencies and line is predicted frequencies.

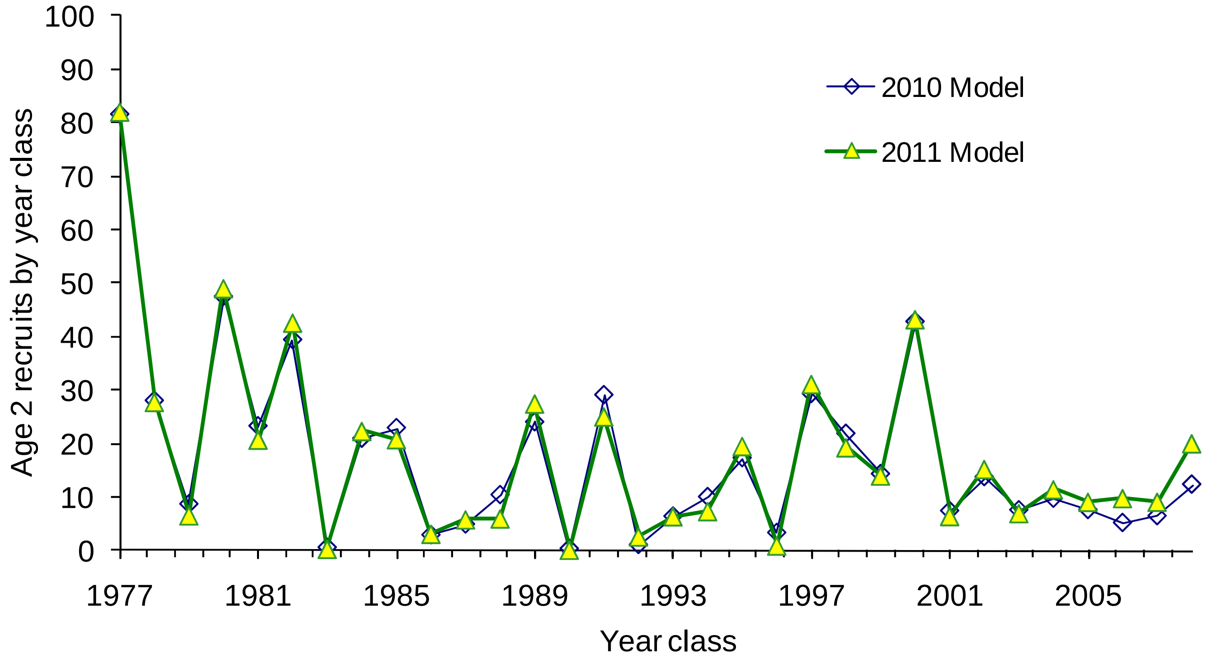


Figure 3.18a. Estimated recruitment (number at age 2, millions) versus year for 2010 and 2011 models.

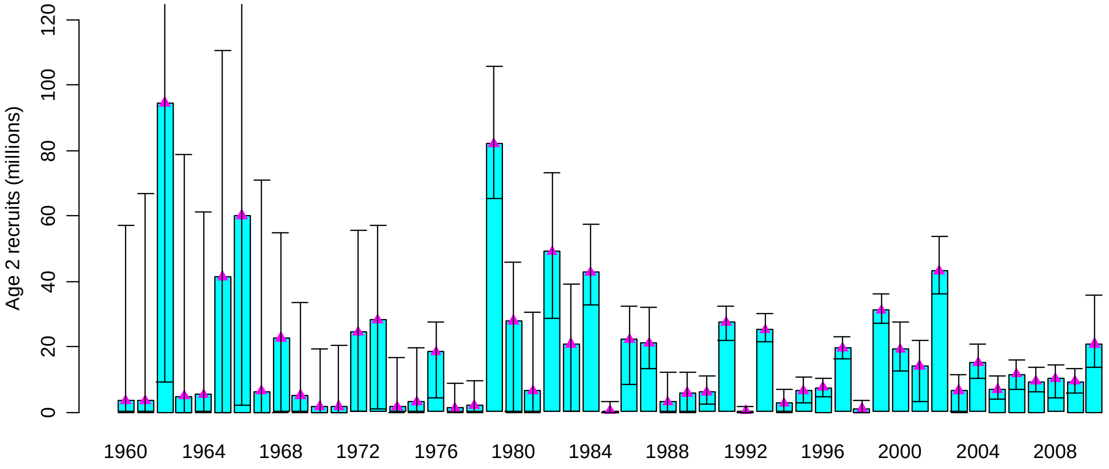


Figure 3.18b. Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on 20,000,000 MCMC runs.

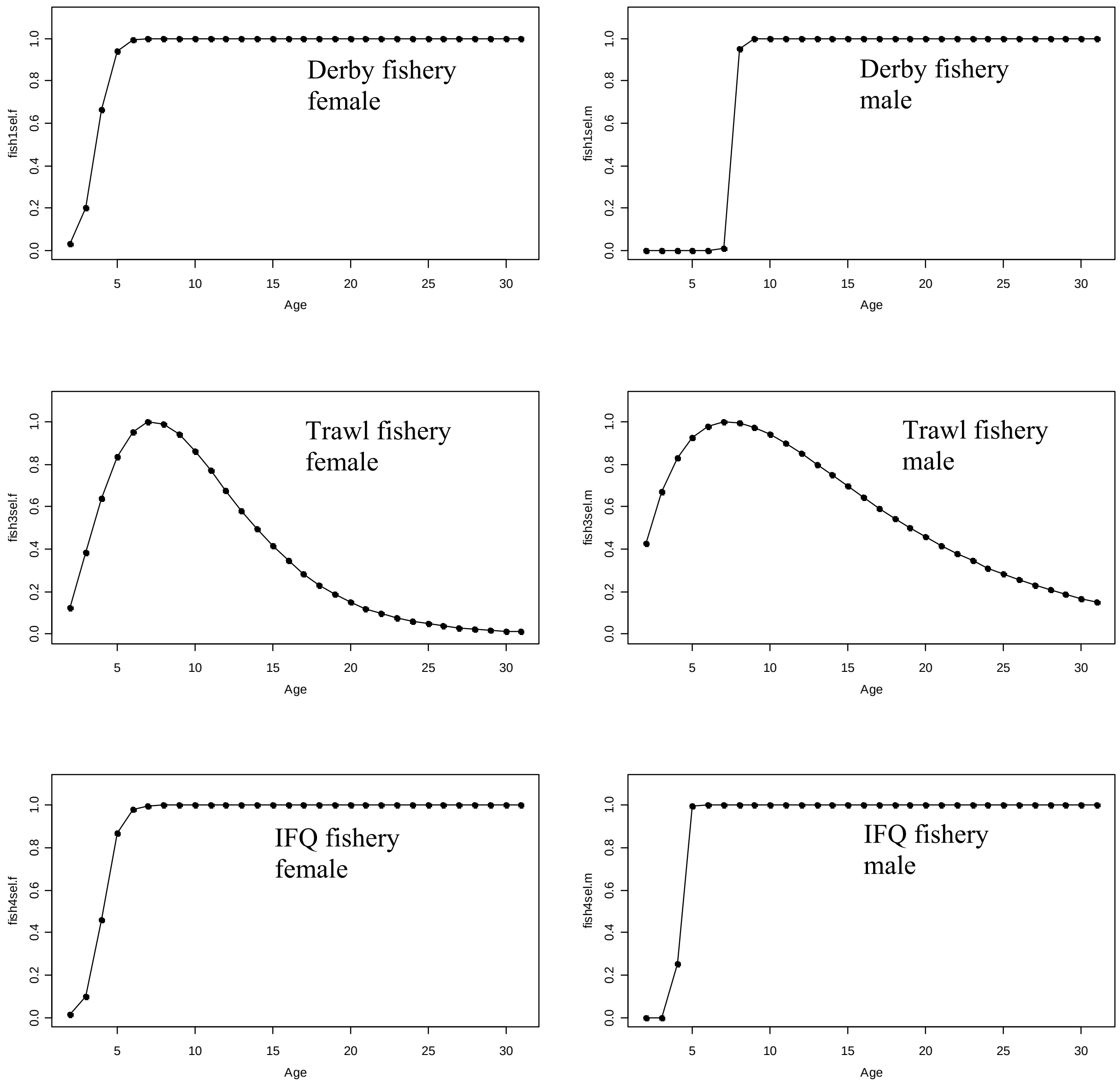


Figure 3.19a. Sablefish selectivities for fisheries.

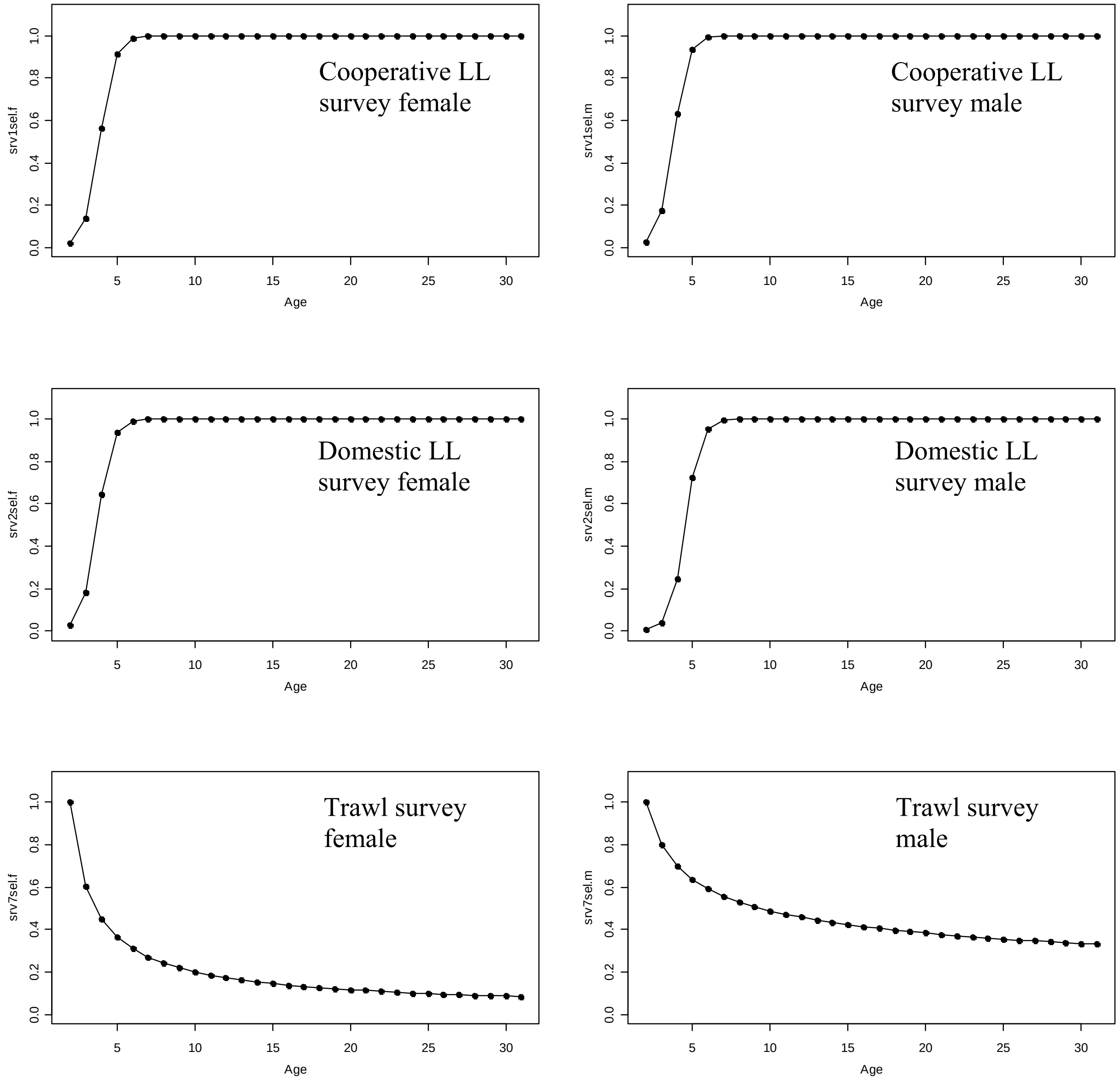


Figure 3.19b. Sablefish selectivities for surveys.

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

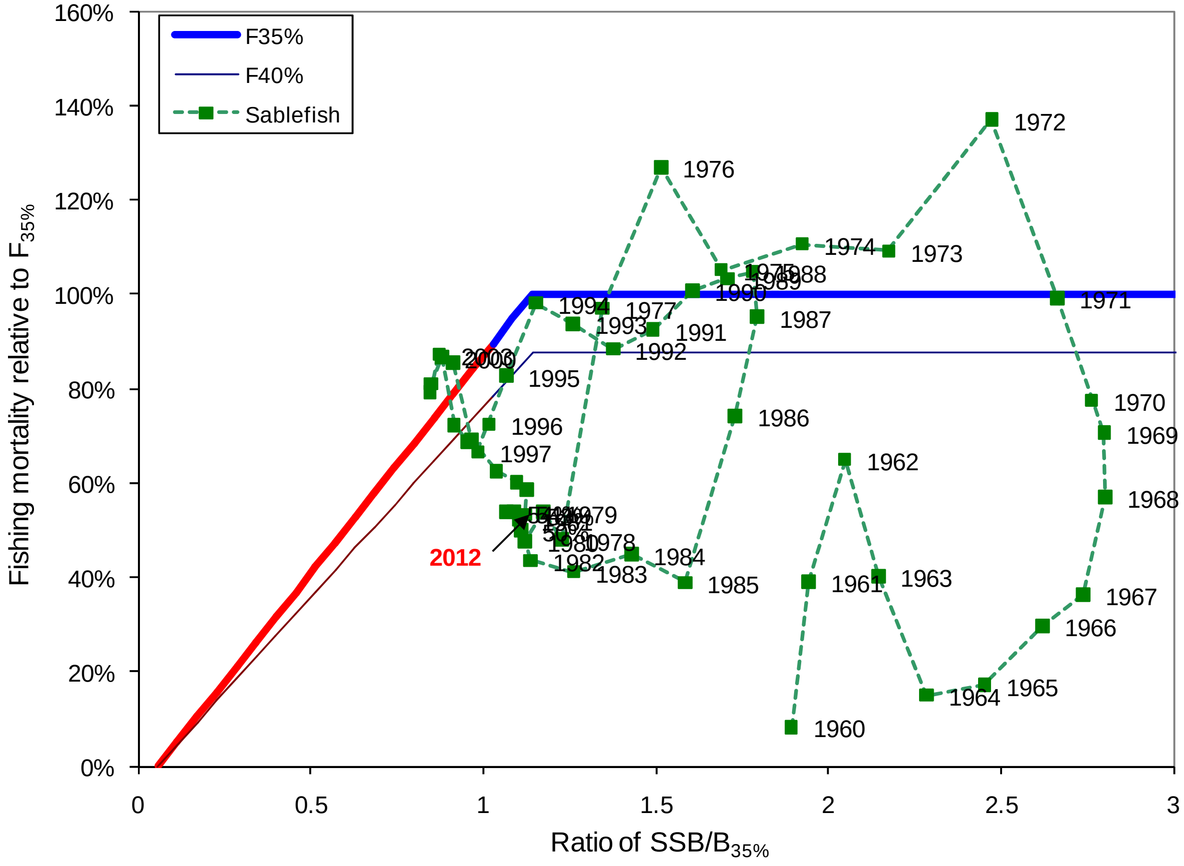
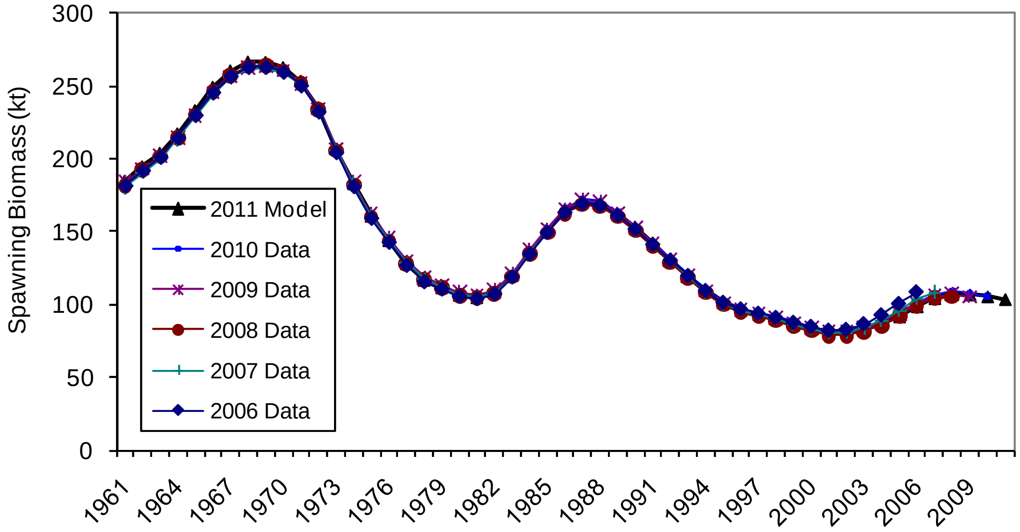


Figure 3.21. Phase-plane diagram of time series of sablefish estimated spawning biomass relative to the unfished level and fishing mortality relative to $F_{OFL}$ for author recommended model.



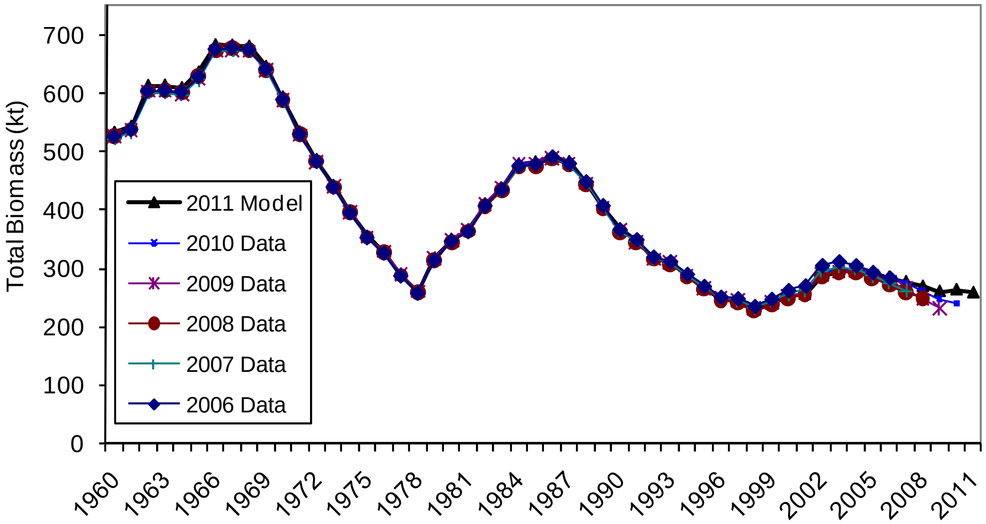


Figure 3.22a. Retrospective trends for spawning biomass (top) and total biomass (bottom) from 2006-2011.

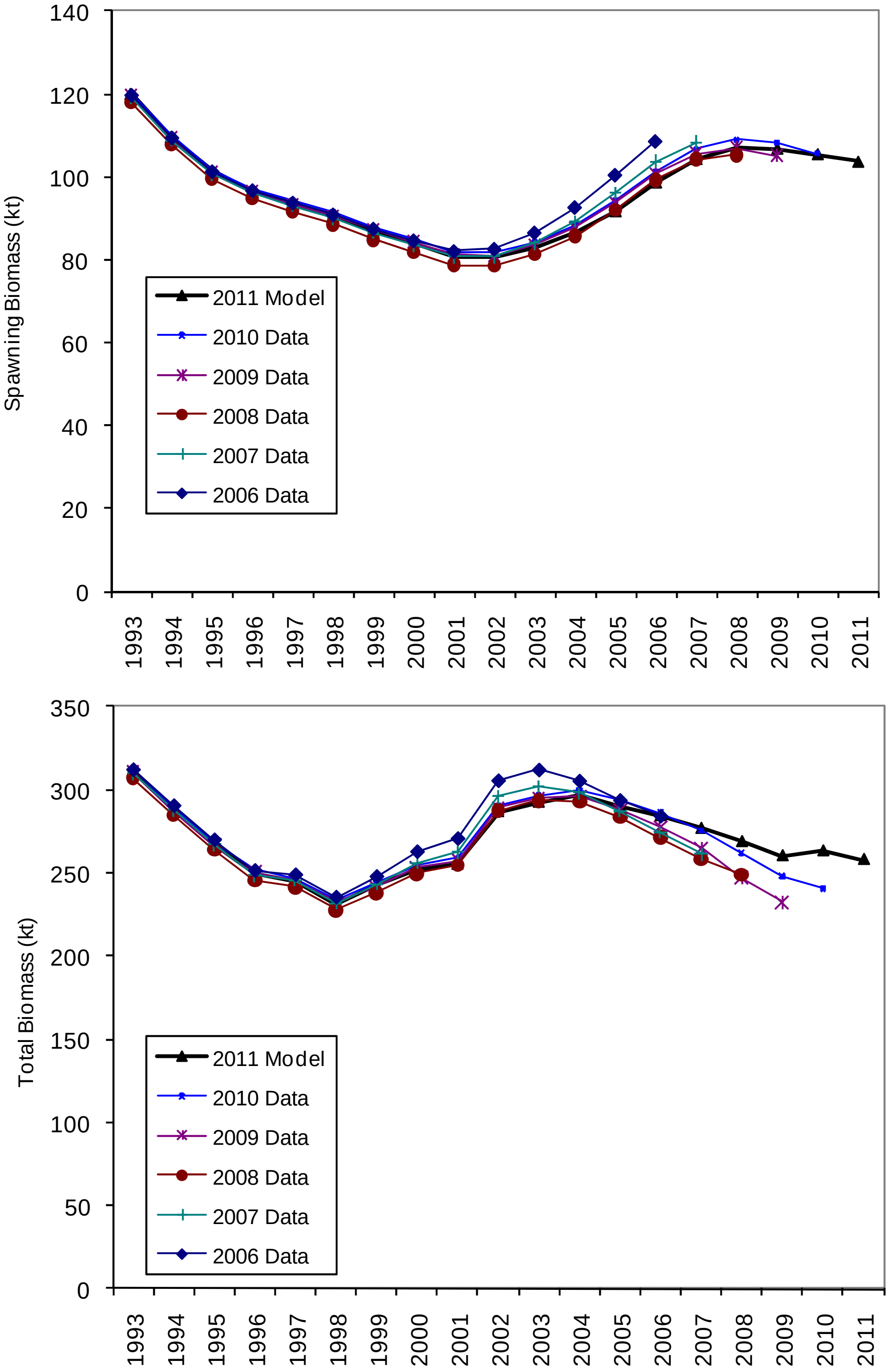


Figure 3.22b. Recent retrospective trends for spawning biomass and total biomass 2006-2011.

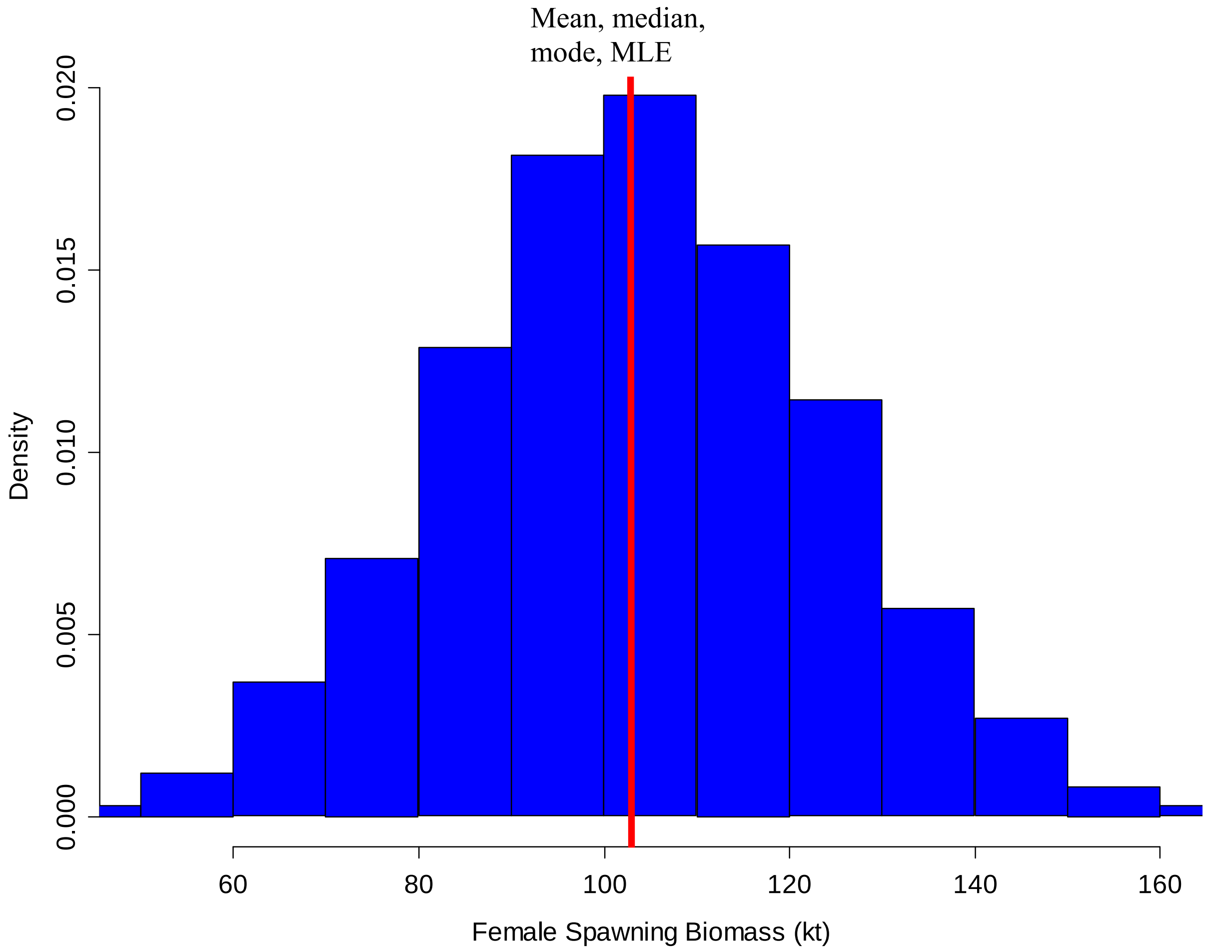


Figure 3.23. Posterior probability distribution for projected spawning biomass (thousands t) in 2012.

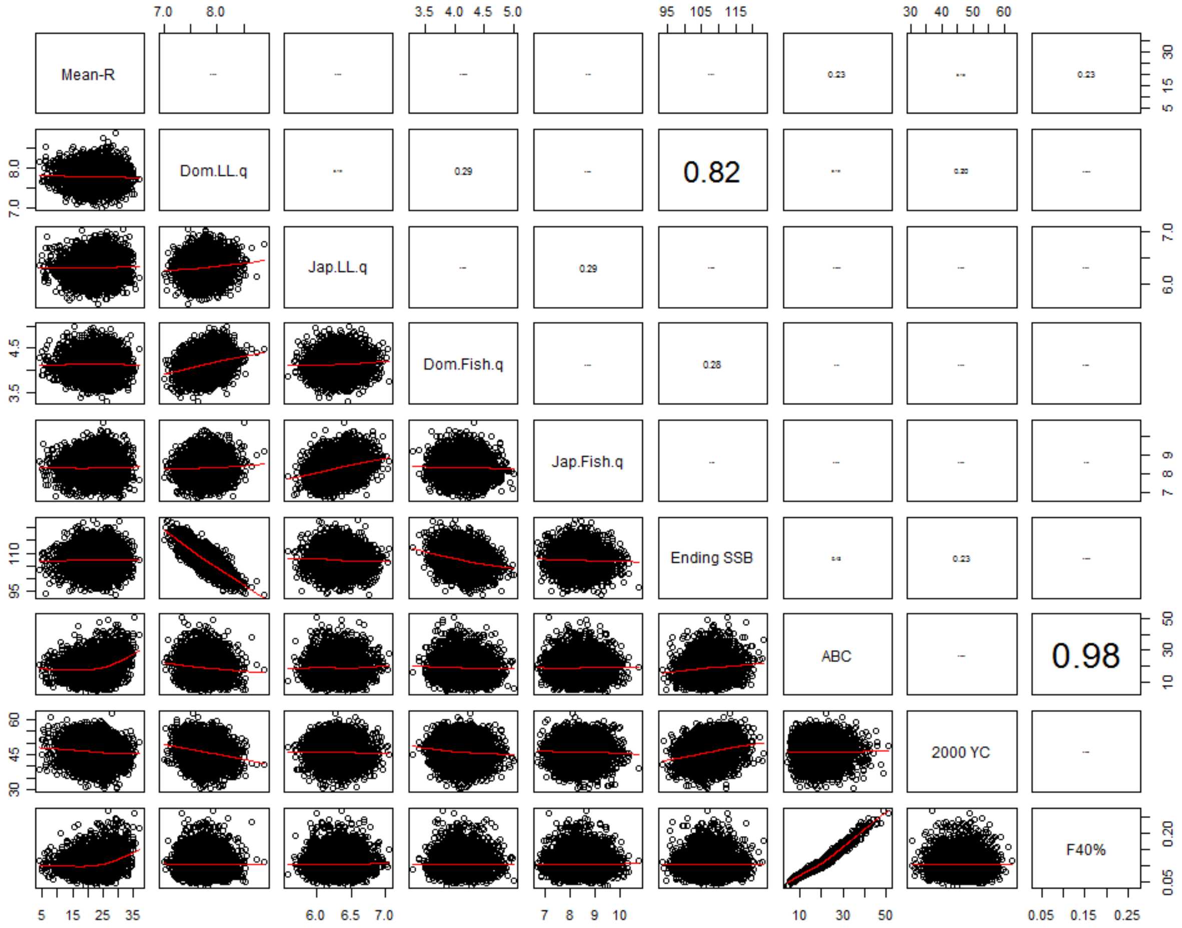


Figure 3.24. Pairwise scatterplots of key parameter MCMC runs. Red curve is loess smooth. Numbers in upper right hand panel are correlation coefficients between parameters.

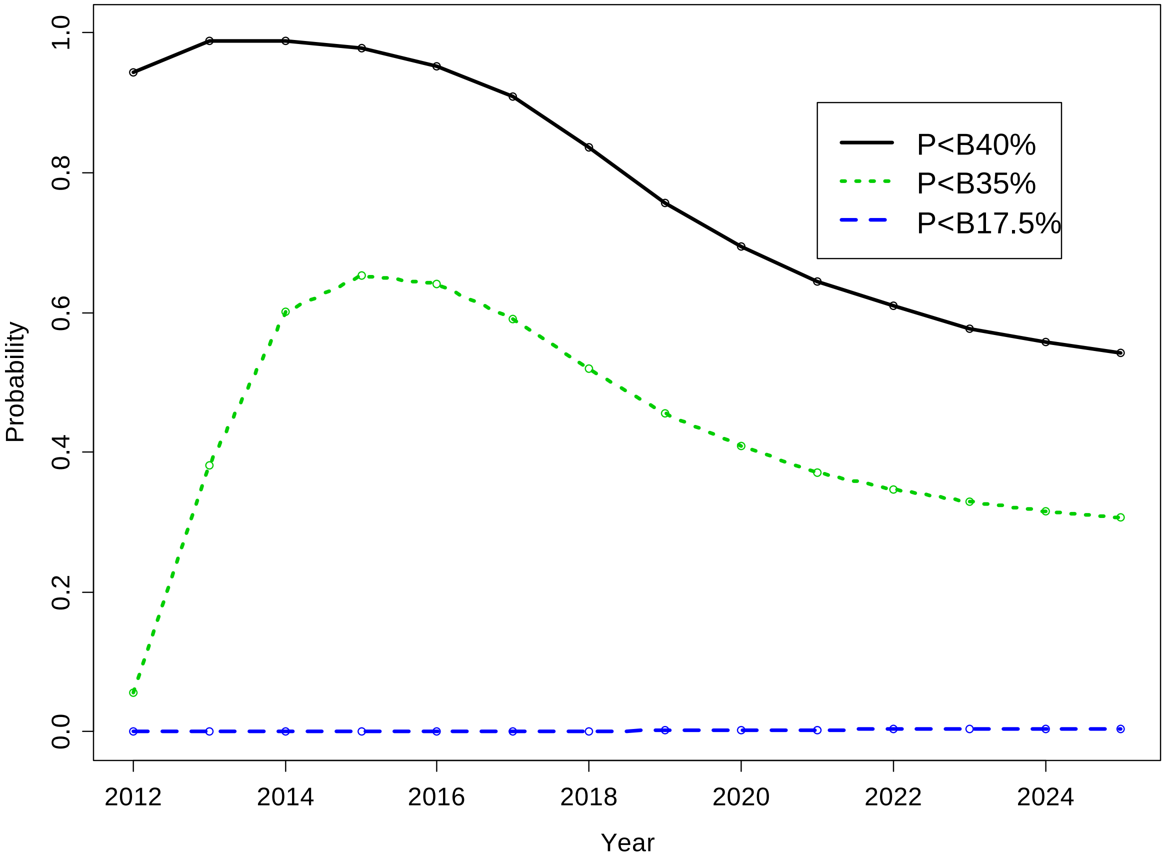


Figure 3.25. Probability that projected spawning biomass (from MCMC) will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

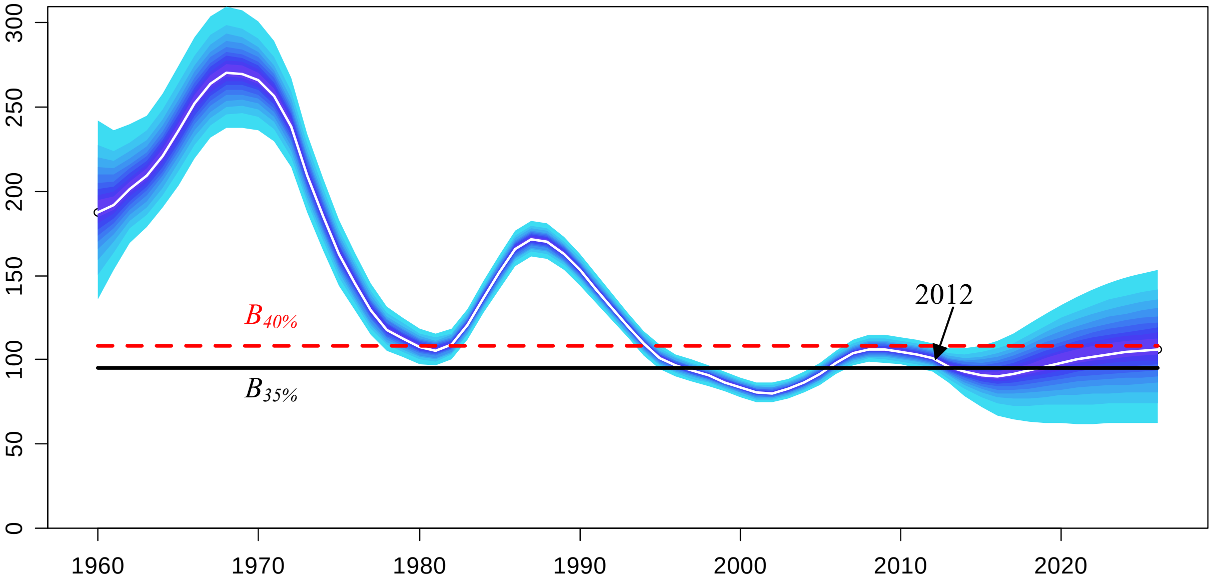


Figure 3.26. Estimates of female spawning biomass (thousands t) and their uncertainty. White line is the median and shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 20,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval. Harvest policy is least conservative with catch at maximum permissible ABC.

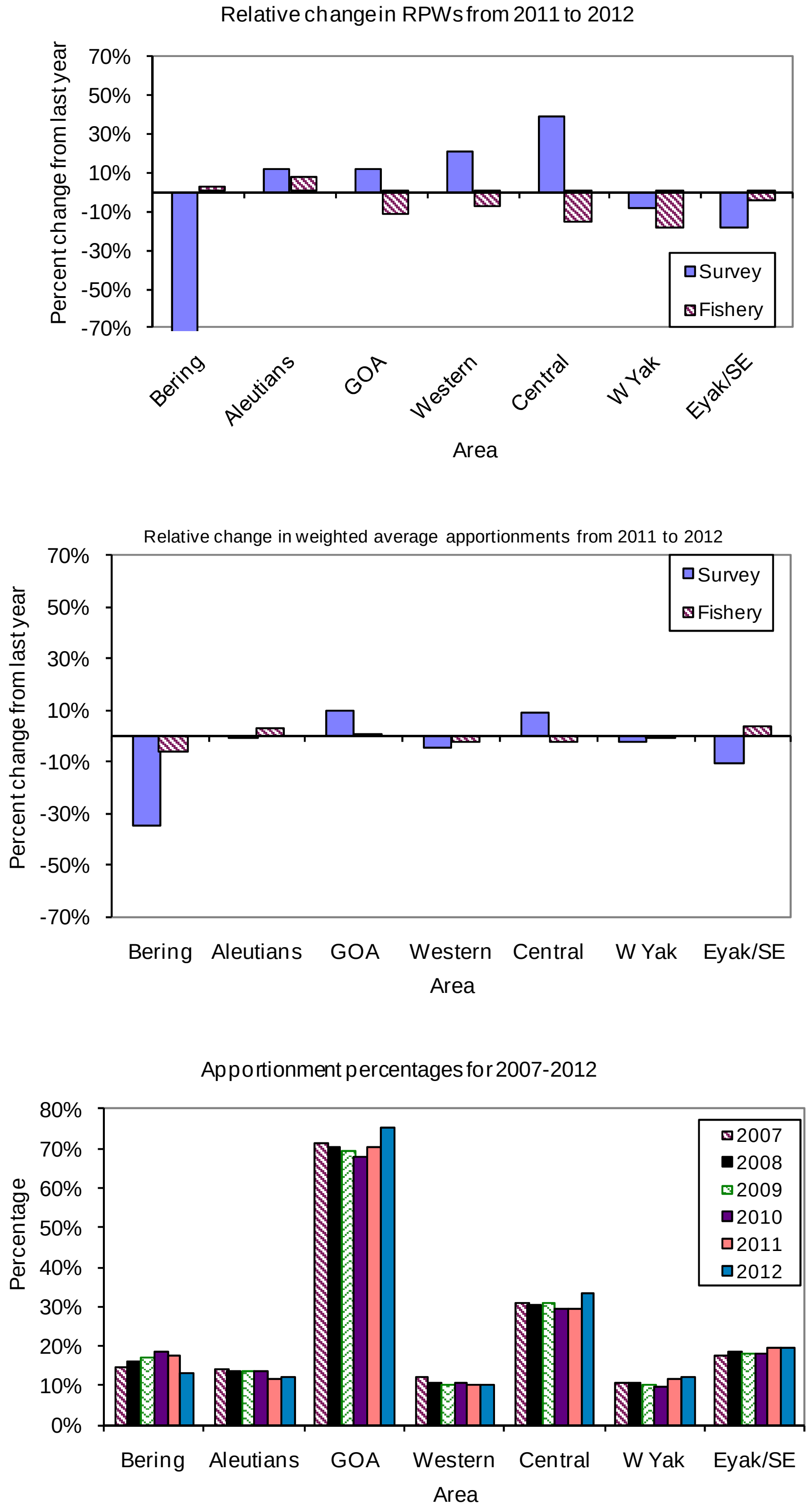


Figure 3.27. (a) The percentage change of each Relative Population Weight (RPW) index by area from 2011 apportionment to the 2012 apportionment. (b) The percentage change of the weighted average of apportionment by area. (c) The apportionment percentages by area of ABCs for 2007-2012.

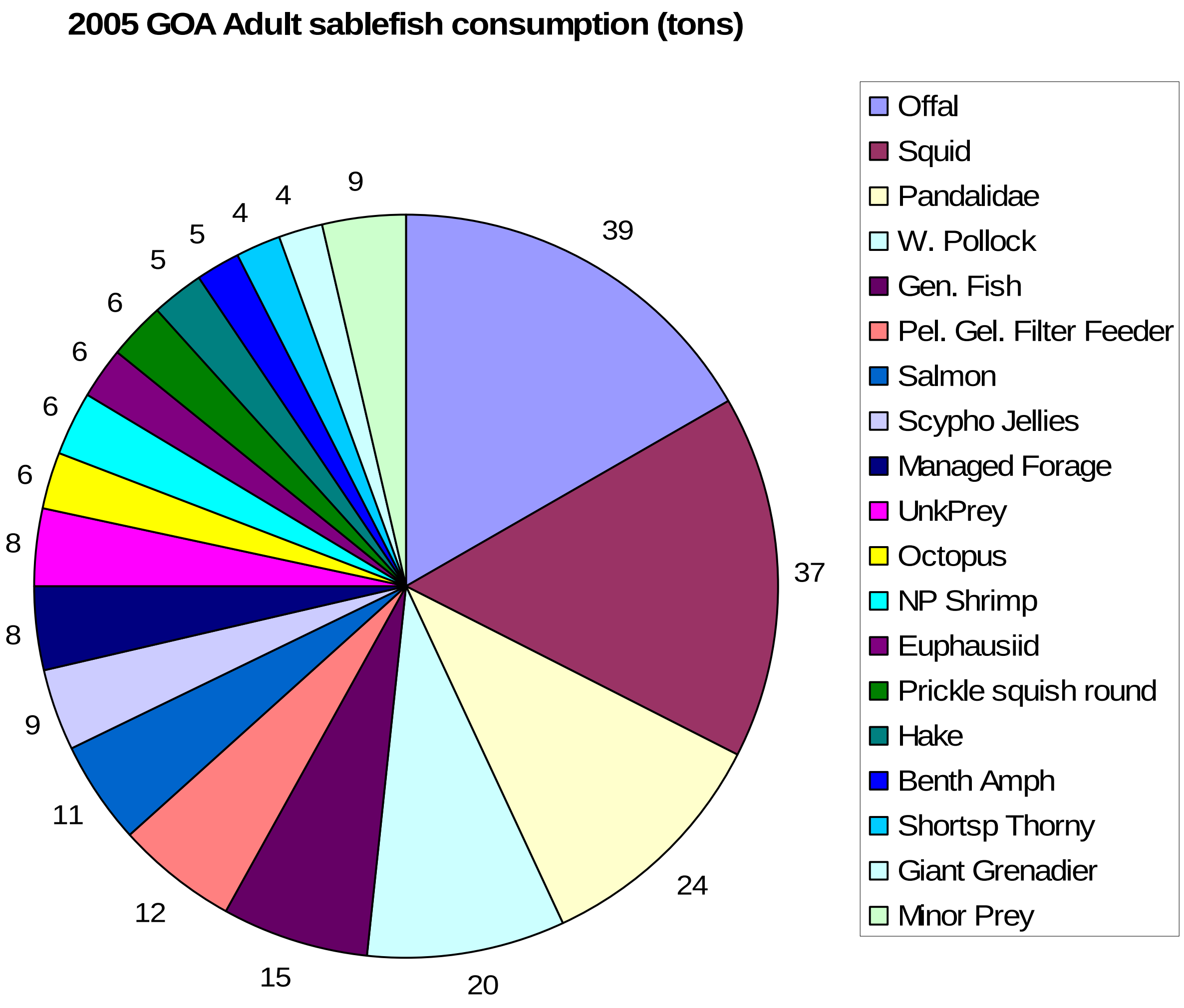


Figure 3.28. Consumption of prey in tons by sablefish in the Gulf of Alaska in 2005. Minor prey category are prey that totaled less than 4 tons of consumption.

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

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

## *History of interactions*

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

Since 2000, the number of vessels fishing near survey stations has remained relatively low. During the past several surveys, many fishing vessels were contacted by the survey vessel and in most cases fishermen were aware of the survey or willing to help out by fishing other grounds to avoid potential survey interactions.

Longline Survey-Fishery Interactions

| | Longline | | Trawl | | Pot | | Total | |
|---|---|---|---|---|---|---|---|---|
| Year | Stations | Vessels | Stations | Vessels | Stations | Vessels | Stations | Vessels |
| 1995 | 8 | 7 | 9 | 15 | 0 | 0 | 17 | 22 |
| 1996 | 11 | 18 | 15 | 17 | 0 | 0 | 26 | 35 |
| 1997 | 8 | 8 | 8 | 7 | 0 | 0 | 16 | 15 |
| 1998 | 10 | 9 | 0 | 0 | 0 | 0 | 10 | 9 |
| 1999 | 4 | 4 | 2 | 6 | 0 | 0 | 6 | 10 |
| 2000 | 10 | 10 | 0 | 0 | 0 | 0 | 10 | 10 |
| 2001 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 |
| 2002 | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 |
| 2003 | 4 | 4 | 2 | 2 | 0 | 0 | 6 | 6 |
| 2004 | 5 | 5 | 0 | 0 | 1 | 1 | 6 | 6 |
| 2005 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 |
| 2006 | 6 | 6 | 1 | 2 | 0 | 0 | 7 | 8 |
| 2007 | 8 | 6 | 2 | 2 | 0 | 0 | 10 | 8 |
| 2008 | 2 | 2 | 2 | 2 | 0 | 0 | 4 | 4 |
| 2009 | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 |
| 2010 | 2 | 2 | 1 | 1 | 0 | 0 | 3 | 3 |
| 2011 | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 |

## *Recommendation*

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

# Appendix 3B.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For sablefish, these estimates can be compared to the research removals reported in previous assessments (Hanselman et al. 2010) (Table 3B.1). The sablefish research removals are substantial relative to the fishery catch and compared to the research removals for many other species. These research removals support a dedicated longline survey. Additional sources of significant removals are bottom trawl surveys and the International Pacific Halibut Commissions longline survey. Recreational removals are relatively minor for sablefish. Total removals from activities other than directed fishery were near 359 tons in 2010. This is 2.2% of the 2011 recommended ABC of 16,040 and represents a relatively low risk to the sablefish stock. In general, if these removals were accounted for in the stock assessment model, it would likely result in an increase in ABC of comparable magnitude.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between “retained” or “discarded” catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of sablefish catch by the halibut fishery are substantial and represent approximately 10% of the annual sablefish ABC (Table 3B.2). Sablefish and halibut are often caught and landed in association with each other by the IFQ fishery. It is unknown what level of sablefish catch reported here is already accounted for as IFQ harvest in the CAS system because the HFICE estimates do not separate retained and discarded catch. If these were strictly additive removals, 10% would represent a significant amount of additional mortality and a potential risk to the stock, but how much is additive is unknown. The HFICE estimates may represent some valuable discard information for sablefish, but that level is unknown until these estimates are separated from the IFQ landings and CAS system.

**References:**

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Hanselman, D. H., C. Lunsford, and C. Rodgveller. 2010. Alaskan Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.pp.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 3B.1 Total removals of sablefish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, GOA, AI, and BS Slope bottom trawl surveys, and occasional short-term research projects. Other is recreational, personal use, and subsistence harvest.

| Year | Source | Trawl | Japan US longline survey | Domestic longline survey | IPHC longline survey* | Other | Total |
|---|---|---|---|---|---|---|---|
| 1977 | | 3 | | | | | 3 |
| 1978 | | 14 | | | | | 14 |
| 1979 | | 27 | 104 | | | | 131 |
| 1980 | | 70 | 114 | | | | 184 |
| 1981 | | 88 | 150 | | | | 238 |
| 1982 | | 108 | 240 | | | | 348 |
| 1983 | | 46 | 236 | | | | 282 |
| 1984 | | 127 | 284 | | | | 412 |
| 1985 | | 186 | 390 | | | | 576 |
| 1986 | | 123 | 396 | | | | 519 |
| 1987 | | 117 | 349 | | | | 466 |
| 1988 | **Assessment of the sablefish stock in Alaska (Hanselman et al. 2010)** | 15 | 389 | 303 | | | 707 |
| 1989 | | 4 | 393 | 367 | | | 763 |
| 1990 | | 26 | 272 | 366 | | | 664 |
| 1991 | | 3 | 255 | 386 | | | 645 |
| 1992 | | 0 | 281 | 393 | | | 674 |
| 1993 | | 39 | 281 | 408 | | | 728 |
| 1994 | | 1 | 271 | 395 | | | 667 |
| 1995 | | 0 | | 386 | | | 386 |
| 1996 | | 13 | | 430 | | | 443 |
| 1997 | | 1 | | 396 | | | 397 |
| 1998 | | 26 | | 325 | 50 | | 401 |
| 1999 | | 43 | | 311 | 49 | | 403 |
| 2000 | | 2 | | 290 | 53 | | 345 |
| 2001 | | 11 | | 326 | 48 | | 386 |
| 2002 | | 3 | | 309 | 58 | | 370 |
| 2003 | | 16 | | 280 | 98 | | 393 |
| 2004 | | 2 | | 288 | 98 | | 387 |
| 2005 | | 18 | | 255 | 92 | | 365 |
| 2006 | | 2 | | 287 | 64 | | 352 |
| 2007 | | 17 | | 266 | 48 | | 331 |
| 2008 | | 3 | | 262 | 46 | | 310 |
| 2009 | | 14 | | 242 | 47 | | 257 |
| 2010 | AKRO | 3 | | 291 | 50 | 15 | 359 |

* IPHC survey sablefish removals are released and estimates from mark-recapture studies suggest that these removals are expected to produce low mortality. Some state removals are included.

Table 3B.2. Estimates of Alaska sablefish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. AI = Aleutian Islands, WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

| Area | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Western/Central AI | 27 | 19 | 34 | 18 | 14 | 11 | 36 | 44 | 17 | 23 |
| Eastern AI | 18 | 16 | 46 | 26 | 20 | 6 | 4 | 13 | 6 | 7 |
| WGOA | 10 | 9 | 12 | 22 | 21 | 16 | 7 | 12 | 3 | 12 |
| CGOA-Shumagin | 184 | 27 | 36 | 65 | 60 | 47 | 21 | 38 | 10 | 37 |
| CGOA-Kodiak/ PWS* | 802 | 107 | 96 | 89 | 82 | 49 | 57 | 33 | 69 | 63 |
| EGOA-Yakutat | 110 | 324 | 291 | 258 | 240 | 149 | 175 | 103 | 207 | 195 |
| EGOA-Southeast | 339 | 335 | 389 | 315 | 269 | 242 | 230 | 184 | 242 | 262 |
| Southeast Inside* | 459 | 1,018 | 1,181 | 917 | 786 | 739 | 701 | 574 | 731 | 805 |
| Total | 1,948 | 2,231 | 2,346 | 2,469 | 2,194 | 2,476 | 1,937 | 1,874 | 1,921 | 1,594 |

*These areas include removals from the state of Alaska.

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