3. Assessment of the sablefish stock in Alaska

by
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Executive Summary

Summary of changes in assessment inputs

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

Input data: New data included in the assessment model were relative abundance and length data from the 2012 longline survey, relative abundance and length data from the 2011 longline and trawl fisheries, age data from the 2011 longline survey and 2011 fixed gear fishery, updated 2011 catch and projected 2012 catch.

Model changes: There are no model changes.

Summary of results

Key results for the recommended model compared to last year's recommendations are shown below.

Quantity/Status	As estimated or specified *last* year for: 2012	2013	As estimated or recommended *this* year for: **2013**	2014*
M (natural mortality)	0.10	0.10	0.10	0.10
Tier	3b	3b	3b	3b
Projected total (age 2+) biomass (t)	262,522	268,992	248,473	255,103
Female spawning biomass (t)				
Projected	101,325	98,983	97,193	94,964
$B_{100\%}$	271,436	271,436	266,264	266,264
$B_{40\%}$	108,574	108,574	106,506	106,506
$B_{35\%}$	95,003	95,003	93,192	93,192
F_{OFL}	0.106	0.106	0.102	0.100
$maxF_{ABC}$	0.089	0.089	0.086	0.084
F_{ABC}	0.089	0.089	0.086	0.084
OFL (t)	20,400	20,132	19,180	18,000
max ABC (t)	17,240	17,019	16,230	15,220
ABC (t)	17,240	17,019	**16,230**	15,220
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
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 12,970 t and 12,120 t used in place of maximum permissible ABC for 2013 and 2014. This was done in response to management requests for a more accurate two-year projection.

Assessment results: The fishery abundance index was flat from 2010 to 2011 (the 2012 data are not available yet). The longline survey abundance index decreased 21% from 2011 to 2012 following an 18% increase from 2008 to 2011. Spawning biomass is projected to decrease from 2013 to 2017, and then stabilize.
Sablefish are managed under Tier 3 of NPFMC harvest rules. Reference points are calculated using recruitments from 1979-2011. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 106,506 t (combined across the EBS, AI, and GOA), 0.095, and 0.113, respectively. Projected female spawning biomass (combined areas) for 2013 is 97,193 t (91% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.086, which translates into a 2013 ABC (combined areas) of 16,230 t. The OFL fishing mortality rate is 0.102 which translates into a 2013 OFL (combined areas) of 19,180 t. Model projections indicate that this stock is neither overfished nor approaching an overfished condition.
We recommend a 2013 ABC of 16,230 t. The maximum permissible ABC for 2013 from an adjusted $F_{40\%}$ strategy is 16,230 t. The maximum permissible ABC for 2013 is a 6% decrease from the 2012 ABC of 17,240 t. This decrease is supported by a substantial decrease in the domestic longline survey index in 2012 that offset relatively high survey years in 2010 and 2011. The fishery abundance index was steady which moderated the decrease in ABC. The 2008 year class is appearing in the length and age compositions, but its size was constrained by this year's overall large decrease in the longline survey index. Spawning biomass is projected to decline through 2017, and then is expected to increase, assuming average recruitment is achieved. This year's survey turned the projection downward, predicting maximum permissible ABC to decrease in 2014 at 15,220 t and remain steady at 15,220 t in 2015 (using estimated catches, instead of maximum permissible, see Table 3.18).

Projected 2013 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 2013. The 1997 year class has been an important contributor to the population but has been reduced and should comprise less than 10% of the 2013 spawning biomass. The 2000 year class is still the largest contributor, with 20% of the spawning biomass in 2013. The 2008 year class is beginning to show signs of strength and will comprise 5% of spawning biomass in 2013 even though it is only 40% 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 2013 ABC and OFL.

Apportionments are based on survey and fishery information	**2012 ABC Percent**	**2012 Survey RPW**	**2011 Fishery RPW**	**2013 ABC Percent**	**2012 ABC**	**2013 ABC**	**Change**
Total					17,240	**16,230**	-6%
Bering Sea	13%	5%	9%	10%	2,230	**1,580**	-29%
Aleutians	12%	15%	13%	13%	2,050	**2,140**	4%
Gulf of Alaska	75%	79%	78%	77%	12,960	**12,510**	-4%
Western	14%	15%	13%	14%	1,780	**1,750**	-1%
Central	44%	46%	40%	44%	5,760	**5,540**	-4%
W. Yakutat*	16%	12%	17%	15%	2,080	**1,860**	-11%
E. Yakutat / Southeast*	26%	27%	30%	27%	3,350	**3,360**	0%

*After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the 2013 ABC for West Yakutat is 2,030 t and for East Yakutat/Southeast is 3,190 t. This adjustment projected to 2014 is 1,902 t for W. Yakutat and 2,993 t for E. Yakutat/Southeast.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2013	2,030 t	3,190 t
	2014	1,902 t	2,993 t

Plan team summaries

Area	Year	Biomass (4+)	OFL	ABC	TAC	Catch
GOA	2011	149,000	13,340	11,290	11,290	11,148
	2012	180,000	15,330	12,960	12,960	10,434
	2013	167,000	14,780	12,510		
	2014	164,000	13,871	11,731		
BS	2011	37,000	3,360	2,850	2,850	695
	2012	30,000	2,640	2,230	2,230	559
	2013	19,000	1,870	1,580		
	2014	19,000	1,755	1,482		
AI	2011	25,000	2,250	1,900	1,900	1,019
	2012	26,000	2,430	2,050	2,050	884
	2013	26,000	2,530	2,140		
	2014	28,000	2,374	2,007		

Year	2012				**2013**		2014	
Region	OFL	ABC	TAC	Catch*	OFL	ABC	OFL	ABC
BS	2,640	2,230	2,230	559	1,870	1,580	1,755	1,482
AI	2,430	2,050	2,050	884	2,530	2,140	2,374	2,007
GOA	15,330	12,960	12,960	10,434	14,780	12,510	13,871	11,731
W	--	1,780	1,780	1,179	--	1,750	--	1,641
C	--	5,760	5,760	4,651	--	5,540	--	5,195
WYAK	--	2,247	2,247	1,890	--	2,030	--	1,902
SEO	--	3,173	3,173	2,715	--	3,190	--	2,993
Total	20,400	17,240	17,240	11,877	19,180	16,230	18,000	15,220

*Current as of September 29, 2012 Alaska Fisheries Information Network, (www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

SSC

Halibut fishery incidental catch (December 2011)

The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September: (December 2011)

After discussions with the authors of the HFICE estimates and staff at the Alaska Regional Office, it has been determined that evaluating this overlap is not possible with the available data. After the Observer Program restructuring is implemented, data may become available that will allow evaluation of this overlap.

Joint Plan Team

Total catch accounting (December 2011 and September 2012)

The Plan Teams recommended that the authors consider issues for sablefish where there is overlap between the data sources in these HFICE estimates. In general, for all species, it would be good to understand the unaccounted-for catches and the degree of overlap between the CAS and HFICE estimates and to discuss this at the Plan Team next September.

The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented.

The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal.

The Teams recommend that computation of new HFICE estimates not be continued during the coming year. Once a sufficient amount of observer data are available to compare with HFICE, the time series could be filled out retroactively if comparison suggests this is appropriate. In the meantime, if individual authors want to continue the time series on their own, the code will be made available.

We continue to provide estimates of "other removals" in Appendix 3B. Because of the above Plan Team recommendation, we have not updated the HFICE estimates for 2011.

Retrospective analysis (September 2012)

For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years.

We continue to show retrospective plots, but this year use the working group recommended format for these plots with a plot of female spawning stock biomass and a plot of relative retrospective change and we discuss these in section ***Retrospective Analysis.***

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC

Abundance Indices (December 2011)

The assessment was updated with several new sources of fishery and survey data. Time trends in the fishery abundance index and the trawl survey biomass index decreased, while the longline survey index continued to increase. The SSC encourages the authors to examine trends to discern the cause for these differences.

This year, the author updated the previously approved split-sex stock assessment model. The fit to the domestic longline survey RPN and longline fishery RPW appears to balance different trajectories between the two data sources. The SSC encourages authors to attempt to explain differences.

The nominal fishery CPUE index has been relatively stable throughout its time series after the implementation of the IFQ program. The authors and a postdoctoral researcher are currently exploring generalized linear and additive models, and boosted regression trees to better capture an abundance trend from fishery catch rates. We have isolated a “core fleet” that has fished for at least 15 years and are still actively fishing. We have also incorporated spatial and depth distributions, and catch of four other key species (Greenland turbot, Pacific halibut, Pacific cod, and giant grenadiers) as covariates. We look forward to either incorporating this new index in 2013, or first having it reviewed by an expected CIE review in spring, 2014.

The trawl survey index continues to decline because it reflects has only one potentially large year class since 2000, and the depths of the trawl survey are where these younger fish would be found.

The author plans to refine the survey index model to address whale depredation in the 2012 assessment model and may potentially include gully abundance data and other covariates. The SSC agrees that these would be important improvements to the assessment model.

This work is ongoing and we have had success estimating whale effects with appropriate variance for both killer whale and sperm whale depredation using generalized linear mixed models. Preliminary simulations show that sperm whale effects may be useful to incorporate in an index, but killer whale effects are too variable to use as a correction factor. A forthcoming paper has been drafted that examines killer whale effects on multiple species. We look forward to either incorporating a new survey index in 2013, or first having it reviewed by an expected CIE review in spring, 2014.

The authors reported that a continued investigation into recruitment processes and ecosystem influences (e.g., environmental variables and the Gulf of Alaska Project) is underway. The SSC looks forward to receiving updates on the progress of this research effort. In particular, the SSC would be interested in new information that would inform our understanding of the spawner-recruit relationship for sablefish.

A new publication by Shotwell et al. (2012) investigates the utility of incorporating environmental indices within the sablefish assessment model through multistage hypothesis testing, retrospective predictive modeling, and impact analysis. The best models suggest that advection along large scale oceanographic features such as the North Pacific Polar Front may aid in understanding the spawner-recruit relationship for sablefish. Additionally, the authors provide a conceptual model termed the Ocean Domain Dynamic Synergy (ODDS) that combines three mechanisms influencing sablefish recruitment. This ODDS model may be used for future research on sablefish recruitment and hypothesis testing of potential explanatory variables to be considered for use in the assessment model.

In October 2012, stock assessment authors received updated guidelines for the SAFE reports. However, despite discussion on potential improvements to the Ecosystem Considerations section for the individual SAFE documents, the guidelines for the Ecosystem Considerations section remained unchanged. In an effort to establish a feedback loop between the primary Ecosystem Considerations chapter and the stock-specific sections, discussion concerning a stock-specific ecosystem guidelines report was initiated at the November 2012 Joint Plan Team. This report is likely to include a proposed framework for identifying ecosystem indicators relevant to the stock and provide an example application using the ODDS model for sablefish (Shotwell et al., 2012). A summary of this report is anticipated for the September 2013 Plan Team. An updated version of the sablefish example within this report may be included in next year's assessment dependent on the discussion and recommendations from the September 2013 report.

The SSC thanks the authors for their effort to update the tagging data for BSAI/GOA sablefish. The SSC agrees with the author that these data support the continuation of single-stock management. The SSC continues to encourage the development of a spatial assessment model for research purposes. When developing this model, the authors may wish to consider updated tagging results from tags released off the coast of Canada and along the U.S. west coast.

We are submitting a manuscript for publication of the updated movement model and tagging results. We look forward to expanding the movement model to Canada and the West Coast. In addition, we are working with a new doctoral student at the University of Alaska-Fairbanks that will be examining spatial models and apportionment using these updated movement rates.

Introduction

Distribution: Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), and into the Bering Sea (BS) (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 spend their first two to three years on the continental shelf of the GOA, and occasionally on the shelf of the southeast BS. The BS shelf is utilized significantly in some years and seldom used during other years (Shotwell et al. 2012).

Stock structure: 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. Significant stock structure among the federal Alaska population is unlikely given extremely high movement rates throughout their lives (Heifetz and Fujioka 1991, Maloney and Heifetz 1997, Kimura et al. 1998).

Management units: Sablefish are assessed as a single population in Federal waters off Alaska because of their high movement rates. Sablefish are managed by discrete regions to distribute exploitation throughout their wide geographical range. There are four management areas in the GOA: Western, Central, West Yakutat, and East Yakutat/Southeast Outside (SEO); and two management areas in the Bering Sea/Aleutian Islands (BSAI): the BS and the AI regions.

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). Along the Canadian coast (Mason et al. 1983) and off Southeast Alaska (Jennifer Stahl, February, 2010, ADF&G, pers. comm.) sablefish spawn from January-April with a peak in February. In a survey near Kodiak Island in December, 2011 that targeted sablefish preparing to spawn, spawning appeared to be imminent, but spent fish were not found. It is likely that they would spawn in January or February (Katy Echave, October 2012, AFSC, pers. comm.). Farther down the coast off of central California sablefish spawn earlier, from October-February (Hunter et al. 1989). An analysis of larval otoliths showed that spawning in the Gulf of Alaska may be a month later than southern sablefish (Sigler et al. 2001). 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 GOA (Sigler et al. 2001). Near the end of the first summer, pelagic juveniles less than 20 cm move 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).

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, and tag recovery data from ADF&G for State inside waters (Southern Southeast Inside and Northern Southeast Inside). The previous paradigm was that small fish moved west, and large fish moved east (Hanselman et al. *in review*). 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). Estimates of the probability of small fish moving east are twice as high as previously estimated. In Chatham Strait, sablefish have a precise low probability of moving into federal waters. The sablefish population center seems to be in central GOA, and the one unit stock (AI, BS and GOA) hypothesis is strongly supported by these movement data. There is also the potential in the future for determining age- and sex-specific movement rates for sablefish.

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 GOA; 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 BS in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 t in 1962 (Table 3.1, Figures 3.1, 3.2). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the AI region and the GOA. In the GOA, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 t overall in 1972. Catches in the AI 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 GOA 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 Fishery Conservation and Management Act (MSFCMA).

Japanese trawlers caught sablefish mostly as bycatch in fisheries targeting other species. In the BS, the trawlers were mainly targeting rockfishes, Greenland turbot, and Pacific cod, and only a few vessels targeted sablefish. In the GOA, sablefish were mainly caught as bycatch in the directed Pacific Ocean perch fishery until 1972, when some vessels started targeting sablefish in 1972 (Sasaki 1985).

Other foreign nations besides Japan also caught sablefish. Substantial Soviet Union catches were reported from 1967-73 in the BS (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 gears were 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 GOA, and by 1988, the U.S. harvested all sablefish taken in Alaska, except minor joint venture catches. Following domestication of the fishery, the previously year-round season in the GOA began to shorten in 1984 from 12 months in 1983 to 10 days in 1994, warranting the label “derby” fishery.

In 1995, Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels along with an 8-month season. The IFQ Program is a catch share fishery that issued quota shares to individuals based on sablefish and halibut landings made from 1988-1990. Since the implementation of IFQ’s, the number of longline vessels with sablefish IFQ harvests has experienced a substantial anticipated decline from 616 in 1995 to 362 in 2011 (NOAA 2012). This decrease was expected as shareholders have consolidated their holdings and fish them off fewer vessels to reduce costs (Fina 2011). The sablefish fishery has historically been a small boat fishery; the median vessel length in the 2011 fishery was 56ft. In recent years, approximately 30% of vessels eligible to fish in the IFQ fishery participate in both the halibut and sablefish fisheries and approximately 40% of vessels fish in more than one management area. The season dates have varied by several weeks since 1995, but the monthly pattern has been from March to November with the majority of landings occurring in May - June. The number of landings fluctuates with quota size, but in 2011 there were 1,726 landings recorded in the Alaska fishery (NOAA 2012).

Pot fishing in the IFQ fishery is not allowed in the GOA but is legal in the BSAI regions. In 2000, the pot fishery accounted for less than ten percent of the fixed gear sablefish catch in these areas but effort has increased substantially since in response to killer whale depredation. Since 2004, pot gear has accounted for over 50% of the BS fixed gear IFQ catch and up to 34% of the catch in the AI.

Sablefish also are caught incidentally during directed trawl fisheries for other species groups such as rockfish and deepwater flatfish. Allocation of the TAC by gear group varies by management region and influences the amount of catch in each region (Table 3.1, Figures 3.1, 3.2). 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 GOA and AI. 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.

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. Thus, the stock can provide a greater yield at the same target fishing rate under the IFQ fishery selectivity.

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 on bottom.

Pot fishing for sablefish has increased in the BS and AI as a response to depredation of longline catches by killer whales (Table 3.2). Pots are longlined with approximately 40-135 pots per set.

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 BS in 1958 and the GOA in 1963. Catches rapidly escalated during the mid-1960s. Annual catches in Alaska reached peaks in 1962, 1972, and 1988 (Table 3.1, Figure 3.2). 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.

Exceptional recruitment fueled increased abundance and increased catches during the late 1980's, which coincided with the domestic fishery expansion. Catches declined during the 1990's, increased in the early 2000s, and have since declined to near 12,000 t (Figure 3.1). TACs in the GOA are nearly fully utilized, while TACs in the BS and AI are often not because of depredation and relatively low catch rates.

Bycatch and discards

Sablefish discards by target fisheries are available for hook-and-line gear and other gear combined (Table 3.3). From 1994 to 2004 discards averaged 1,357 t for the GOA and BSAI combined (Hanselman et al. 2008). Since then, discards have been lower, averaging 626 t between 2006 and 2011. The highest discard amounts occur in hook-and-line fisheries in the GOA (Table 3.3).

Table 3.4 shows the bycatch of the GOA and BSAI Fishery Management Plans' (FMP) species in the sablefish target fishery. The largest bycatch is arrowtooth flounder (534 t/year, 456 t discarded). Arrowtooth is the only species that has substantial catch from non-longline gear. Shortspine thornyhead and shortraker rockfish are the 2nd and 3rd most caught species at 366 t/year and 207 t/year. The next three groups are "Other Species", GOA "Other Skate", and GOA longnose skate which total 415 t/year.

Giant grenadiers, a non-target species that is not in either FMP, make up the bulk of the nontarget species bycatch, peaking at 9,315 t in 2007, but decreasing since with a 2011 catch of 6,652 t (Table 3.5). Other nontarget catches that have totals over a ton per year are corals, snails, sponges, sea stars, and miscellaneous fishes and crabs.

Prohibited species catches (PSC) in the targeted sablefish fisheries are dominated by halibut (1,060 t/year) and golden king crab (134,000 individuals/year). Halibut catches seem to be decreasing, while catches of golden king crab are highly variable from year to year, probably as a result of low sampling effort in BSAI sablefish pot fisheries (Table 3.6).

Previous management actions

A summary of historical catch and management measures pertinent to sablefish in Alaska is shown in Table 3.7. Influential management actions regarding sablefish include:

Quota allocation: Amendment 14 to the GOA 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 GOA, and 95% to fixed gear and 5% to trawl in the Eastern GOA, effective 1985. Amendment 15 to the BS/AI Fishery Management Plan, allocated the sablefish quota by gear type, 50% to fixed gear and 50% to trawl in the eastern BS, and 75% to fixed gear and 25% to trawl gear in the Aleutians, effective 1990.

IFQ management: Amendment 20 to the GOA Fishery Management Plan and 15 to the BS/AI 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 BS and AI.

Maximum retainable allowances: Maximum retainable allowances for sablefish were revised in the GOA 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 GOA Fishery Management Plan banned the use of pots for fishing for sablefish in the GOA, 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 BS (57 FR 37906). The prohibition on sablefish longline pot gear use was removed for the BS, 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 AI.

Management areas: Amendment 8 to the GOA 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	1960-2012
Trawl fisheries	Catch	1960-2012
Japanese longline fishery	Catch-per-unit-effort (CPUE)	1964-1981
U.S. fixed gear fishery	CPUE, length	1990-2011
	Age	1999-2011
U.S. trawl fisheries	Length	1990,1991,1999, 2005-2011
Japan-U.S. cooperative longline survey	CPUE, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	CPUE, length	1990-2012
	Age	1996-2011
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, August 25, 1999, Alaska Fisheries Science Center, pers. comm.). 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).

Catch

The catches used in this assessment (Table 3.1) include catches from minor State-managed fisheries in the northern GOA and in the AI 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, July 12, 1999, Alaska Regional Office, pers. comm.,), the source of the catch data used in this assessment. Minor State fisheries catches averaged 180 t from 1995-1998, about 1% of the average total catch. Most of the catch (80%) is from the AI 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 3.8, Figures 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 (Sigler et al. 1999). 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 Limit (ACL) requirements, assessments now document all removals including catch that are not associated with a directed fishery. Research catches of sablefish have been reported in previous stock assessments (Hanselman et al. 2009). Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 3B. 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 312 tons in 2011. This is 1.8% of the 2012 recommended ABC of 17,240 and represents a relatively low risk to the sablefish stock.

Lengths

We use length compositions from the U.S. fixed gear (longline and pot) and U.S. trawl fisheries which are both measured by sex. The fixed gear fishery has large sample sizes and has complete data since 1990. The trawl fishery had low levels of observer sampling in much of the 1990s and early 2000s, and has a much smaller sample size than the fixed gear fishery. We only use years for the trawl fishery that has sample sizes of at least 300 per sex. The length compositions are weighted by catch in each FMP management area to obtain a representative estimate of catch-at-length.

Ages

We use age compositions from the U.S. fixed gear fishery since 1999. Sample sizes are similar to the longline survey with about 1,000 otoliths aged every year. The age compositions are weighted by the catch in each area to obtain a representative estimate of catch-at-age.

Longline fishery catch rate index

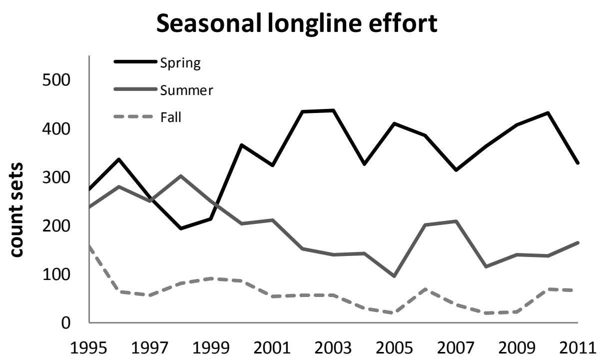
Longline sample sizes: Observer data used in this analysis represent on average 14% of the annual IFQ hook and line catch; in 2011 they covered 10% of the catch (1,319 mt). On average, the percent of the IFQ catch observed is lowest in the East Yakutat/SE (5%), highest in West Yakutat and AI (~22%), and moderate in the BS, 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 BS (Table 3.9). In the BS, the average number of sets observed is only 22. Observer coverage in the AI 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 BS are likely a result of poor observer coverage for sablefish directed trips. Additionally, killer whales impact sablefish catch rates in the BS and AI and these sets are excluded from catch rate analyses.

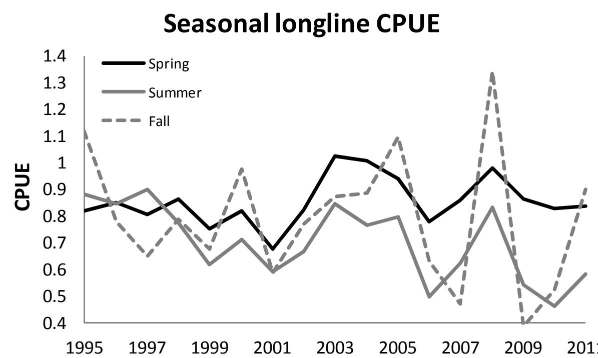
Logbook sample sizes are substantially higher than observer samples sizes, especially since 2004. Logbook samples increased sharply in 2004 in all areas primarily because the International Pacific Halibut Commission (IPHC) was used to collect, edit, and enter logbooks electronically. This increasing 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 2011, the number of sets submitted by vessels <60 ft were similar to the number of sets submitted from vessels >60 ft.

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 BS and AI (Table 3.9, Figures 3.5 and 3.6). Catch rate trends are generally similar for both the observer and logbook data, except in the AI and the BS, areas where sample sizes are relatively small. Since 2004, logbook data have lower variances than observer data, largely due to a greater number of vessels and sets recorded (Table 3.9). Also, logbook data reflects data from the <60 fleet (approximately half of the data in 2011 came from unobserved, small vessels). Minor differences in CPUE trends are expected given the sample sizes of observed sets and the variability in the data, but general trends track closely.

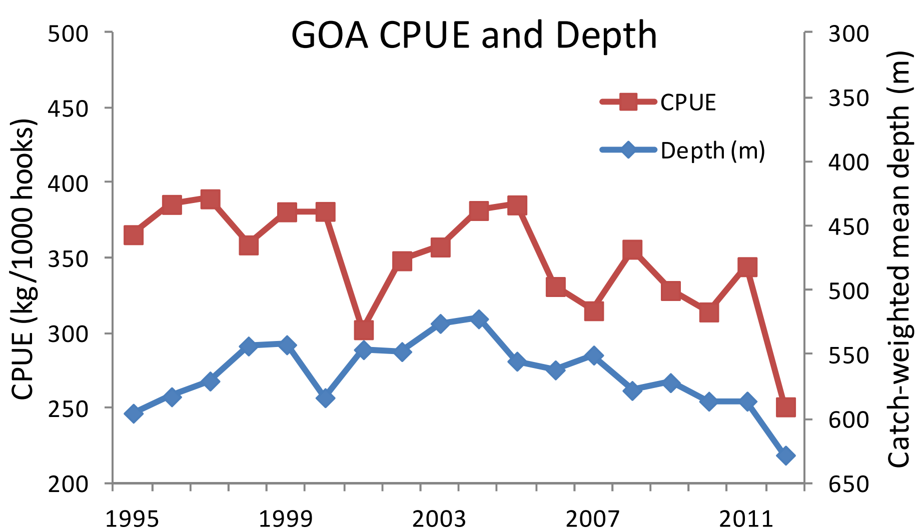
Longline spatial and temporal patterns: Changes in spatial or temporal patterns of the fishery may cause fishery catch rates to be unrepresentative of abundance. For example, fishers sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). This could lead to an incorrect interpretation of fishery catch rates, which could remain stable while the area occupied by the stock was diminishing (Rose and Kulka 1999).

We examined fishery longline data for seasonal and annual differences in effort and catch rate (CPUE, lbs/hook). Such changes may cause fishery catch rates to be unrepresentative of abundance. In the observed longline data since 2000, the majority of effort occurs in the spring and less in the summer and fall (see below). Since 1998, catch rates are also highest in the spring, moderate in the summer, and variable in the fall (due to lower sample sizes in the fall).





Preliminary analysis of the 2012 longline fishery data in the GOA (data is not complete for all of 2012) shows a steep drop in CPUE from 2011 to 2012 (see figure below). This occurred while the catch-weighted mean depth (i.e., each set depth is weighted by the amount of catch that occurred in it) was at its lowest point in the IFQ time series. GOA CPUE has generally declined with mean depth since about 2004.



Pot fishery catch rate analysis

Pot catch rates: There are more vessels in the BS than the AI in the sablefish pot fishery. Thus, the logbook data set is more extensive in the BS than in the AI. Since 2005, in logbook data there have been 5-9 vessels in the BS and only 1-5 in the AI. In 2011, the total number of pots set in the logbook data in the AI was higher than normal (21,550 opposed to an average of 7,574 in other years). In the BS the number of pots set was also above average (66,574 versus 50,329), but was down from a peak in 2008 of 85,412 pots set. From 2005-2011 the average catch rate was 33.6 lbs/pot in the AI and 28.2 in the BS. Because of the high variability and low sample sizes it is difficult to discern any trends in catch rates or to have confidence in these average catch rates. Sample sizes can also be driven by the number of logbooks turned in to IPHC port samplers.

The composition of bycatch species caught in observed pots that retained sablefish in the BS and AI is comprised mostly of arrowtooth/Kamchatka flounder, golden king crab, Greenland turbot, Pacific halibut, and giant grenadier. Almost all of the golden king crab is caught in the AI (Hanselman et al. 2010).

Pot length frequencies: We compared the length frequencies recorded by observers from the 2006-2008 longline and pot fisheries (Hanselman et al. 2008). The average length of sablefish in the AI and in the BS was smaller for sablefish caught by pot gear (63.8 cm) than by 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 BS and catch males and females at the same rates (average % females in BSAI was 58% for both gear types). We concluded that there was no indication that fish selected by pots were significantly different than longline caught fish and should not affect population recruitment. Because few small sablefish are found in pots, there was concern that small sablefish were entering the pots were cannibalized by larger sablefish. In collaboration with the observer program we conducted an experiment examining live deliveries of sablefish from pot fisheries (Hanselman et al. 2008). In the study, 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%).

Surveys

A number of fishery independent surveys catch sablefish. The survey indices included in the model for this assessment are the AFSC longline survey and AFSC GOA bottom trawl survey. For other surveys that occur in the same or adjacent geographical areas, but are not included as separate indices in the model, we provide trends and comparative analyses to the AFSC longline survey. Research catch removals including survey removals are documented in Appendix 3B.

AFSC Surveys

Longline survey

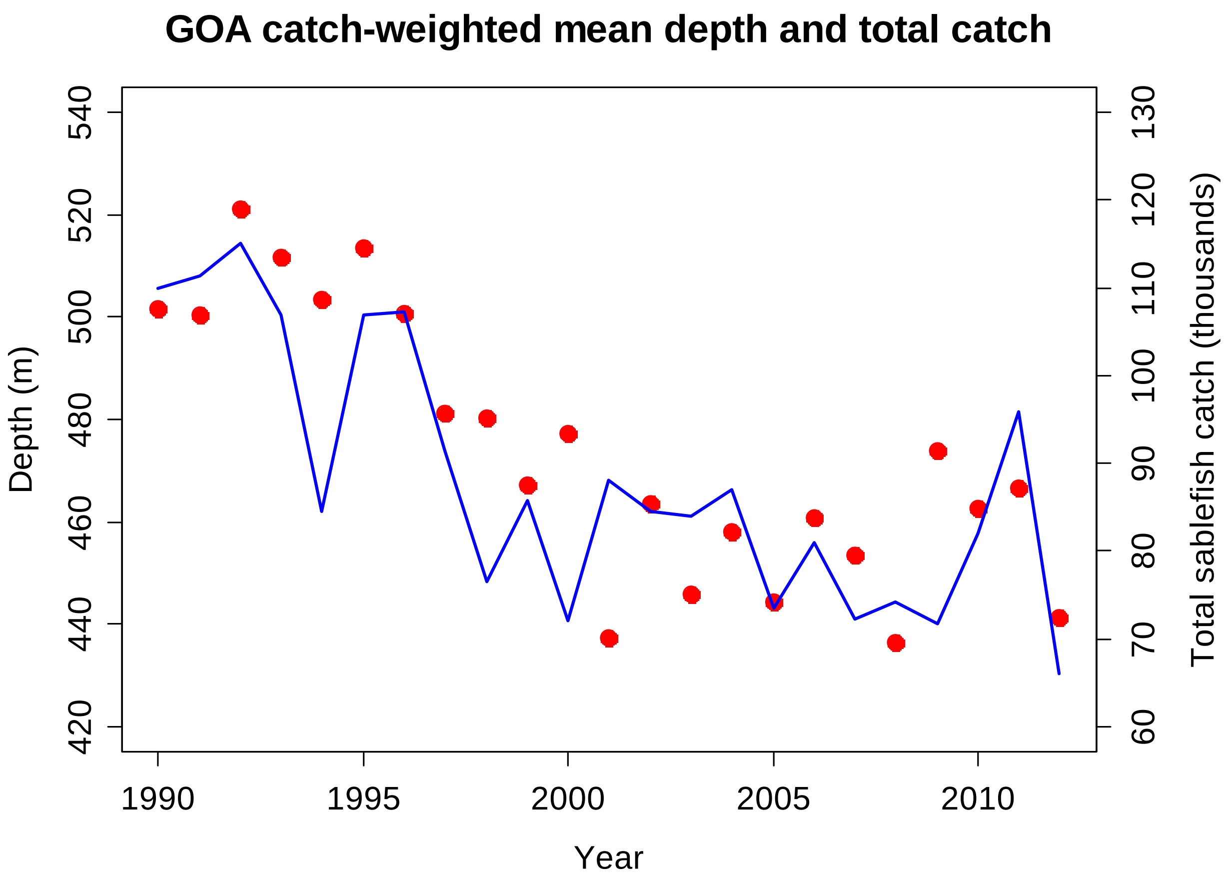
Overview: Catch, effort, age, length, weight, and maturity data are collected during sablefish longline surveys. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000). Japan and the United States conducted a cooperative longline survey for sablefish in the GOA annually from 1978 to 1994, adding the AI region in 1980 and the eastern BS 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 GOA in 1987, biennial sampling of the AI in 1996, and biennial sampling of the eastern BS in 1997 (Rutecki et al. 1997). The domestic survey also samples major gullies of the GOA 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 AI and/or BS, 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 years they were collected. Approximately one-half of the otoliths collected (~1,000) are aged annually. This sample size for age compositions should be large enough to get a precise age composition for the whole survey area, but may be too small to estimate the age composition in smaller areas by sex (P. Hulson, unpublished manuscript).

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. cooperative survey in the mid-1980's, in response to exceptional recruitment in the late 1970's (Figure 3.7). 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 2007-2009. Survey estimates in the Eastern Gulf increased in 2010 and in 2011 the high Central Gulf estimate increased the entire index. Survey abundance estimates in 2010 and 2011 were unexpectedly high, while the 2012 estimate was below expectations.

The 2012 survey estimates were low in all areas except in the AI, with overall indices similar or lower than the 2007-2009 surveys. The AI was higher, despite higher killer whale depredation in the area (killer whale depredated sets are removed). Conversely, the GOA areas were all lower, but with lower sperm whale activity (sperm whale sets are not removed, Table 3.11). Total survey catch rates in the GOA are moderately related (r = 0.77, p<0.01) to the catch-weighted mean depth (see figure below). In 2012, this mean depth was at its shallowest in the time series of the domestic survey. In general, this was a result of catching smaller/younger fish at high rates at shallower depths, while larger/older deeper fish were largely absent (see 2012 length distributions). Relative to the mean from 2000-2012, the 100-200 meter depth stratum was up 9%, depths from 200-600 m were down 7%, and catches from 600-1000 m were down 20%. Bottom temperatures in 2012 were near the mean from 2000-2012 in the GOA, compared to 2011 where temperatures were very high relative to the mean.



Whale Depredation: Killer whale depredation of the survey's sablefish catches has been a problem in the BS since the beginning of the survey (Sasaki 1987). Killer whale depredation primarily occurs in the eastern BS, AI, and Western GOA and to a lesser extent in recent years in the Central GOA. Depredation is easily identified by 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 AI and the BS were added to the survey (Table 3.11). A high of ten BS stations were depredated in 2009, which significantly impacted catch and biased the abundance index leading to using the 2007 BS RPN estimate to interpolate the 2009 and 2010 BS RPNs (Hanselman et al. 2009). In 2011, depredation levels in the BS were similar to previous years with catches at 7 of 16 stations affected. There was higher depredation in the AI in 2012 than most years (5 of 14).

Sperm whale depredation affects longline catches in the GOA, but evidence of depredation is not accompanied by obvious decreases in sablefish catch or common occurrence of lips and jaws or bent and broken hooks. 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 GOA, 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, October, 2009, 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 this small 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 sperm whale presence and depredation at survey stations, as indicated by whale observations and significant results of recent studies, we evaluated a statistical adjustment to survey catch rates using a general linear modeling approach (Appendix 3C, Hanselman et al. 2010). This approach had promise but had issues with variance estimation and autocorrelation between samples. A current approach being evaluated is using a generalized linear mixed model.

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 GOA, AI, or BS.

Previous analyses have shown that on average gully stations catch fewer large fish and more small fish than adjacent slope stations (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). Gully catches may indicate recruitment signals before slope areas because of their shallow depth, where younger, smaller sablefish typically inhabit. Catch rates from these stations have not been included in the historical abundance index calculations because preferred habitat of adult sablefish is on the slope.

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.

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 (Figure 3.8). Overall, gully catches in the GOA from 1990-2012 are poorly correlated with slope catches ($r = 0.31$). 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 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.

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted biennially or triennially since 1980 in the AI, and 1984 in the GOA always to 500 m, and occasionally to 700-1000 m. Trawl surveys of the BS slope were conducted biennially from 1979-1991 and redesigned and standardized for 2002, 2004, 2008, 2010, and 2012. Trawl surveys of the BS shelf are conducted annually but generally catch no sablefish. 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 BS and AI with the GOA 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 GOA trawl survey biomass estimates (<500 m depth, Figure 3.4) and length data (<500 m depth) as a recruitment index for the whole population. The largest proportion of sablefish biomass is in the GOA so it should be indicative of the overall population. Biomass estimates used in the assessment for 1984-2011 are shown in Table 3.10. The GOA trawl survey index is at a low level in 2011, similar to 2009.

AI and BS Slope survey biomass estimates are not used in the assessment model but are tracked in Figure 3.9. Estimates in the two areas have decreased slowly since 2000.

Other surveys/areas

IPHC Longline Surveys

The 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.

We compared the IPHC and the AFSC RPNs for the GOA (Figure 3.10A). 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 and are more patchily distributed. 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 above (Figure 3.4).

Because of the differences in variability between the IPHC and AFSC surveys, we computed Student's t normalized residuals and plotted them for the time series (Figure 3.10B). The trends have begun to diverge and do not track as closely as they did when we started tracking the IPHC data in the 2010 assessment (2012, Pearson's $r = 0.25$, p-value>0.05; 2010 r=0.63, p=0.028). IPHC trends by region were similar but IPHC data was 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 may compute RPNs for these depths for future comparisons with the IPHC RPNs.

Alaska Department of Fish and Game

The Alaska Department of Fish and Game conducts mark-recapture and a longline survey in Northern Southeast Alaska Inside (NSEI) waters. Sablefish in this area are 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 (Figure 3.11), but showing a moderate increase through 2005 and leveling off through 2010. In 2011, there was an increase in sablefish/per hook which may indicate the presence of the 2008 year class (Sherri Dressel, ADFG, October, 2012, pers. comm.).

Department of Fish and Oceans of Canada

The Department of Fish and Oceans of Canada (DFO) conducts a trap survey, conducts tagging studies, and tracks fishery catch rates in British Columbia (B.C.), 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 better understand the contribution to Alaska sablefish productivity from B.C. sablefish. Some ideas we have proposed are to

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

conduct an area-wide study of sablefish tag recoveries, and to attempt to model the population to include B.C. sablefish.

Overall abundance trends

Relative abundance has cycled through three valleys and two peaks near 1970 and 1985 (Table 3.10, Figures 3.3 and 3.4). 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 BS, AI, and western GOA and more slowly in the central and eastern GOA (Figure 3.7). The majority of the surveys show that sablefish were at their lowest levels in the late 1990s, with current abundance only slightly above those levels.

Analytic approach

Model Structure

The sablefish population is assessed 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 GOA Pacific ocean perch model (Hanselman et al. 2005a); it includes split sexes and many more data sources 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 (Fournier et al. 2012).

Parameters Estimated Outside the Assessment Model

The following table lists the parameters estimated independently:

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

Age and Size of Recruitment: Juvenile sablefish rear in nearshore and continental shelf waters, moving to the upper continental slope as adults. Fish first appear on the upper continental slope, where the longline survey and longline fishery 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.

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; Hanselman et al. 2012).

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 (Echave et al. 2012).

New growth relationships were estimated in 2007 because many more age data were available (Hanselman et al. 2007); this analysis was accepted by the Plan Team in November 2007 and published in 2012 (Echave et al. 2012). 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 3.12). 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).

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 3.12). 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, GOA). 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 $m_a = 1/(1+e^{-0.84(a-6.60)})$. In 2011, the AFSC conducted a winter cruise out of Kodiak to sample sablefish when they are preparing to spawn. Ovaries will be examined histologically to determine maturity for a study of the age at maturity and fecundity. Results are expected in 2013.

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). 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 (Sigler et al. 2004). Therefore in 2006, we returned to fixing the parameter at 0.10.

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

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 σ_i is the input sampling log 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

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

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 and rockfish. 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. The data weights in general continue to do well by these objectives (Table 3.13).

Parameters Estimated Inside the Assessment Model

Below is a summary of the parameters estimated within the recommended assessment model:

Parameter name	Symbol	Number of parameters
Catchability	q	6
Log-mean-recruitment	μ_r	1
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_y	80
Average fishing mortality	μ_f	2
Fishing mortality deviations	ϕ_y	106
Fishery selectivity	fs_a	8
Survey selectivity	ss_a	7
Total		213

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:

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 1933-2011.

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 1960-2012 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 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 of reference points

Since the 1999 assessment, we have conducted a limited Bayesian of assessment uncertainty. The posterior distribution was computed based on 10 million MCMC simulations drawn from the posterior distribution. A burn-in of 1 million draws was removed from the beginning of the chain and then thinned to 4,000 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 1979-2011 recruitments.

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

Equations describing state dynamics	**Model Description** (continued)
$N_{1,a} = \begin{cases} R_1, & a = a_0 \\ e^{\left(\mu_r + \tau_{a_0-a+1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ e^{(\mu_r)} e^{-(a-a_0)M} \left(1-e^{-M}\right)^{-1}, & a = a_+ \end{cases}$	Initial year recruitment and numbers at ages.
$N_{y,a} = \begin{cases} R_y, & a = a_0 \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}} + N_{y-1,a} e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$	Subsequent years recruitment and numbers at ages
$R_y = e^{\left(\mu_r + \tau_y\right)}$	Recruitment
Selectivity equations	
$s^g_{a,s} = \left(1 + e^{(-\delta_{g,s}(a - a_{50\%,g,s}))}\right)^{-1}$	Logistic selectivity
$s^g_{a,s} = \dfrac{a^{\delta_{g,s}}}{\max\left(s^g_{a,s}\right)}$	Inverse power family
$s^g_{a,s} = \left(\dfrac{a}{a_{\max}}\right)^{a_{\max,g,s}/p} e^{(a_{\max,g,s} - a)/p}$ $p = 0.5\left[\sqrt{a_{\max,g,s}{}^2 + 4\delta_{g,s}{}^2} - a_{\max,g,s}\right]$	Reparameterized gamma distribution
$s^g_{a,s} = \left(1-\varphi^g_s\right)^{-1} \left(\dfrac{\left(1-\varphi^g_s\right)}{\varphi^g_s}\right)^{\varphi^g_s} \dfrac{\left(e^{(\delta_{g,s}\varphi^g_s (a_{50\%,g,s} - a))}\right)}{\left(1 + e^{(\delta_{g,s}(a_{50\%,g,s} - a))}\right)}$	Exponential-logistic selectivity
Observation equations	
$\hat{C}_{y,g} = \sum_1^g \sum_1^s w_{a,s} N_{y,a,g,s} F_{y,a,g,s} \left(1 - e^{-Z_{y,a,g,s}}\right) Z^{-1}_{y,a,g,s}$	Catch biomass in year y
$\hat{I}_{y,g} = q^g \sum_{a_0}^{a_+} N_{y,a,s} \dfrac{s^g_{a,s}}{\max\left(s^g_{a,s}\right)} w_{a,s}$	Survey biomass index (RPW)
$\hat{I}_{y,g} = q^g \sum_{a_0}^{a_+} N_{y,a,s} \dfrac{s^g_{a,s}}{\max\left(s^g_{a,s}\right)}$	Survey biomass index (RPN)
$\hat{P}^g_{y,\cdot,s} = N_{y,a,s} s^g \left(\sum_{a_0}^{a_+} N_{y,a,s} s^g_{a,s}\right)^{-1} \mathbf{A}_s$	Vector of fishery or survey predicted proportions at age
$\hat{P}^g_{y,\cdot,s} = N_{y,\cdot,s} s^g_s \left(\sum_{a_0}^{a_+} N_{y,a,s} s^g_{a,s}\right)^{-1} \mathbf{A}^l_s$	Vector of fishery or survey predicted proportions at length

Posterior distribution components	**Model Description** (continued)
$L_C = \lambda_c \sum_{1}^{g} \sum_{y} \left(\ln C_{g,y} - \ln \hat{C}_{g,y} \right)^2 / \left(2\sigma_C^2 \right)$	Catch likelihood
$L_I = \lambda_I \sum_{1}^{g} \sum_{y} \left(\ln I_{g,y} - \ln \hat{I}_{g,y} \right)^2 / \left(2\sigma_I^2 \right)$	Survey biomass index likelihood
$L_{age} = \lambda_{age} \sum_{i=1}^{n_g} -\psi_y^g \sum_{a_0}^{a_+} \left(P_{i,a}^g + v \right) \ln \left(\hat{P}_{i,a}^g + v \right)$	Age composition likelihood
$L_{length} = \lambda_{length} \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l}^g + v \right) \ln \left(\hat{P}_{i,l}^g + v \right)$	Length composition likelihood (ψ_y^g=sample size, n_g = number of years of data for gear *g*, *i* = year of data availability, *v* is a constant set at 0.001)
$L_q = \left(\ln \hat{q}^g - \ln q_\mu^g \right)^2 / 2\sigma_q^2$	Prior on survey catchability coefficient for gear *g*
$L_M = \left(\ln \hat{M} - \ln M_\mu \right)^2 / 2\sigma_M^2$	Prior for natural mortality
$L_{\sigma_r} = \left(\ln \hat{\sigma}_r - \ln \sigma_{r_\mu} \right)^2 / 2\sigma_{\sigma_r}^2$	Prior distribution for σ_r
$L_\tau = 0.1 \sum_{y=1}^{T} \frac{\tau_y^2}{2\hat{\sigma}_r^2} + n \ln \hat{\sigma}_r$	Prior on recruitment deviations
$L_f = \lambda_f \sum_{1}^{g} \sum_{y=1}^{T} \phi_{y,g}^2$	Regularity penalty on fishing mortality
$L_{Total} = \sum_{x} L_x$	Total objective function value

Model Evaluation

For this assessment, we present last year's model updated for 2012 with no model changes. A comparison of the model likelihood components and key parameter estimates from 2011 are compared with the 2012 updated model.

Box 2: Model comparison of the 2011 and 2012 models by contribution to the objective function (negative log-likelihood values) and key parameters.

Model Likelihood Components (Data)	**2011**	**2012**
Catch	9	8
Domestic LL survey RPN	43	45
Japanese LL survey RPN	18	18
Domestic LL fishery RPW	8	8
Japanese LL fishery RPW	10	11
NMFS GOA trawl survey	17	16
Domestic LL survey ages	154	159
Domestic LL fishery ages	159	172
Domestic LL survey lengths	52	53
Japanese LL survey ages	144	144
Japanese LL survey lengths	46	45
NMFS trawl survey lengths	269	268
Domestic LL fishery lengths	199	193
Domestic trawl fishery lengths	158	167
Data likelihood	1286	1306
Total objective function value	1307	1326
Key parameters		
Number of parameters	210	213
$B_{next\ year}$ *(Female spawning biomass for next year)*	101	97
$B_{40\%}$ *(Female spawning biomass)*	108	107
B_{1960} *(Female spawning biomass)*	180	176
$B_{0\%}$ *(Female spawning biomass)*	271	266
SPR% current	37.3%	36.5%
$F_{40\%}$	0.096	0.095
$F_{40\%}$ *(adjusted)*	0.089	0.086
ABC	**17.2**	**16.2**
$q_{Domestic\ LL\ survey}$	7.8	7.8
$q_{Japanese\ LL\ survey}$	6.3	6.3
$q_{DomesticLL\ fishery}$	4.1	4.1
$q_{Trawl\ Survey}$	1.3	1.4
$a_{50\%}$ *(domestic LL survey selectivity)*	3.9	3.8
$a_{50\%}$ (LL fishery selectivity)	4.1	4.0
μ_r *(average recruitment)*	18.0	17.8
σ_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 2012 model based on changes in results from 2011. The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. The 2012 update shows a slight decrease in recent recruitment and a slight decrease in spawning and total biomass from previous projections. Therefore the 2012 model is utilizing the new information effectively, and we use it to recommend 2013 ABC and OFL.

Time Series 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 the 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 3.13) 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 3.14, 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 since 2009 (Figure 3.13). The low 2012 longline survey RPN value changed what was a stable trend in 2011 to a slight downward trajectory in 2012.

Projected 2013 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 2013. The 1997 year class has been an important contributor to the population but has been reduced and should comprise less than 10% of the 2013 spawning biomass. The 2000 year class is still the largest contributor, with 20% of the spawning biomass in 2013. The 2008 year class is beginning to show signs of strength and will comprise 5% of spawning biomass in 2013 even though it is only 40% mature.

Figure 3.15 shows the relative contribution of each year class to next year’s spawning biomass.

Recruitment trends

Annual estimated recruitment varies widely (Figure 3.14b). The two recent strong year classes in 1997 and 2000 are evident in all data sources. After 2000, few strong year classes are apparent, but the 2008 year class has potential to be the largest since 2000. Few small fish were caught in the 2005 through 2009 trawl surveys, but the 2008 year class is appearing in the 2011 trawl survey length composition (Figures 3.16, 3.17). The 2010 and 2011 longline survey age compositions show the 2008 year class appearing in all three areas relatively strongly for lightly selected 2 and 3 year old fish (Figures 3.18-3.20). Large year classes often appear in the western areas first and then in subsequent years in the Central and Eastern GOA. While this was true for the 1997 and 2000 year classes, the 2008 year class is appearing in all areas at approximately the same magnitude at the same time (Figure 3.18).

Average recruitment during 1979-2011 was 17.8 million 2-year-old sablefish per year, which is similar to the average recruitment for the 1958-2011 year classes. Estimates of recruitment strength during the 1960s are less certain because they depend on age data from the 1980s with older aged fish that are subject to more ageing error. In addition the size of the early recruitments is based on an abundance index during the 1960s based only on the Japanese fishery catch rate, which may be a weak measure of abundance. The 2008 year class is being estimated at about average in this year’s model. If the 2008 year class is strong, the estimate will increase if the longline survey abundance becomes stronger in future years.

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 have been 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, 1995, NOAA, pers. comm.), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, 2004, ADFG, pers. comm.), the 1998 year class near Kodiak Island (D. Jackson, 2004, ADFG, pers. comm.), and the 2008 year class in Uganik Bay on Kodiak Island (P. Rigby, June, 2009, NOAA, pers. comm.).

Sablefish recruitment varies greatly from year to year (Figure 3.14b), 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 (Figures 3.14, 3.21). 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 (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. Shotwell et al. (2012) used a two-stage model selection process to examine relevant environmental variables that affect recruitment and including them directly into the assessment model. The best model suggested that colder than average wintertime sea surface temperatures in the central North Pacific represent oceanic conditions that create positive recruitment events for sablefish in their early life history.

Goodness of fit

The model generally fit the data well. Abundance indices generally track through the middle of the confidence intervals of the estimates (Figures 3, 4), with the exception of the trawl survey, where predictions are typically lower in the early years and higher in later years. This index is given less weight than the other indices based on higher sampling error so it does not fit as well. All age compositions were predicted well, except for not quite reaching the magnitude of the 1997 and 2000 year classes in several years (Figures 3.19, 3.21, 3.24). The length frequencies from the fixed gear fishery are predicted well in most years, but the model appears to not fit the smallest fish that appear in 2011 (Figure 3.22, 3.23). The fits to the trawl survey and trawl fishery length compositions were generally mediocre, because of the small sample sizes relative to the longline survey and fishery length compositions (Figures 3.16, 3.17., 3.25). The model fit the domestic longline survey lengths poorly in the 1990s, then fit well until 2011 and 2012 where the smallest and largest fish were not fit well (Figures 3.26, 3.27).

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 3.28). The age-of-50% selection is 3.8 years for females in the longline survey and 4.0 years in the IFQ longline fishery. Females are selected at an older age in the

IFQ fishery than in the derby fishery (Figure 3.28). Males were selected at an older age than females in both the derby and IFQ fisheries, likely because they are smaller at the same age. 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 because trawling often occurs on the continental shelf in shallower waters (< 300 m) where young sablefish reside. The trawl fishery selectivities are similar for males and females (Figure 3.28). The trawl survey selectivity curves differ between males and females, where males stay selected by the trawl survey longer (Figure 3.28). 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.

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 3.29). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. In this “management path” we plot estimated fishing mortality relative to the (current) limit value and the estimated spawning biomass relative to limit spawning biomass ($B_{35\%}$). Figure 3.30 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 (Table 3.16). 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 were 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.

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 ten previous assessment years (2002-2011) compared estimates from the current preferred model. This analysis is simply removing all new data that have been added for each consecutive year to 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.

In the first five years of the retrospective plot we see that estimates of spawning biomass were consistently lower for the last few years in the next assessment year (Figure 3.31). In recent years, the retrospective plot of spawning biomass shows only small changes from year to year (e.g., Table 3.17). This retrospective pattern is unlikely to be considered severe, but at issue is the "one-way" pattern in the early part of the time series. The model appears to have an inertia that is difficult to overcome. It is difficult to isolate the cause of this pattern but several possibilities exist. For example, hypotheses could include environmental changes in catchability, time-varying natural mortality, or changes in selectivity of the fishery or survey. One other issue is that fishery abundance and lengths, and all age compositions are added into the assessment with a one year lag to the current assessment.

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.

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. We examined this in the 2011 SAFE and concluded that despite many model changes, including growth updates and a split-gender model, the management advice would have been similar (Hanselman et al. 2011).

Harvest Recommendations

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. Reference points are calculated using recruitments from 1979-2011. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 106,506 t (combined across the EBS, AI, and GOA), 0.095, and 0.113, respectively. Projected female spawning biomass (combined areas) for 2013 is 97,193 t (91% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.086, which translates into a 2013 ABC (combined areas) of 16,230 t. The OFL fishing mortality rate is 0.102 which translates into a 2013 OFL (combined areas) of 19,180 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 2012 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2012. 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 2012 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 2013, 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 2013 and 2014, 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 2009-2011 to the TAC 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 2008-2012 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 2012 or 2) above ½ of its MSY level in 2012 and above its MSY level in 2022 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2013 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 2025 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 3.18). 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 2013 and 2014. 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 2013, it does not provide the best estimate of OFL for 2014, because the mean 2013 catch under Scenario 6 is predicated on the 2013 catch being equal to the 2013 OFL, whereas the actual 2013 catch will likely be less than the 2012 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 (2011) is 12,863 t. This is less than the 2011 OFL of 18,950 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 (Table 3.18) 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 2012:

a. If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2012 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2012 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 3.18). If the mean spawning biomass for 2022 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 (Table 3.18):

a. If the mean spawning biomass for 2015 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2015 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2025 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 the results of the seven scenarios in Table 3.18, the stock is not overfished and is not approaching an overfished condition.

Specified catch estimation

In response to GOA 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. We explained the methods and gave examples in the 2011 SAFE (Hanselman et al. 2011). 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. 2009-2011 for this year).

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 on the amount of catch taken before spawning in the projection two years out.

Bayesian analysis

The model estimates of projected spawning biomass fall near the center of the posterior distribution of spawning biomass. Most of the probability lies between 90,000 and 110,000 t (Figure 3.32). 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 3.33). The plots indicate that the parameters are reasonably well defined by the data. As expected, catchabilities, $F_{40\%}$, and ending spawning biomass were 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 0.17. During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of falling below $B_{35\%}$ is 0.7 (up from 0.6 last year), and the probability of staying below $B_{40\%}$ is near 100% (Figure 3.34).

Alternate Projection

We also use an alternate projection that considers uncertainty from the whole model by running projections within the model. This projection propagates uncertainty throughout the entire assessment procedure and is based on 10,000,000 MCMC (burnt-in and thinned) using the standard Tier 3 harvest rules. The projection shows wide credible intervals on future spawning biomass (Figure 3.35). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1979-2011 recruitments, and this projection predicts that the mean and median spawning biomass will dip below $B_{35\%}$ by 2015, and then return to $B_{40\%}$ if average recruitment is attained. This projection is run with the same ratio for catch as described in Alternative 2 above, except for all future years instead of the next two.

Acceptable biological catch

We recommend a 2013 ABC of 16,230 t. The maximum permissible ABC for 2013 from an adjusted $F40_{\%}$ strategy is 16,230 t. The maximum permissible ABC for 2013 is a 6% decrease from the 2012 ABC of 17,240 t. This decrease is supported by a substantial decrease in the domestic longline survey index in 2012 that offset relatively high survey years in 2010 and 2011. The fishery abundance index was steady which moderated the decrease in ABC. The 2008 year class is appearing in the length and age compositions, but its size was constrained by this year's overall large decrease in the longline survey index. Spawning biomass is projected to decline through 2017, and then is expected to increase, assuming average recruitment is achieved. This year's survey turned the projection downward, predicting maximum permissible ABC to decrease in 2014 at 15,220 t and remain steady at 15,220 t in 2015 (using estimated catches, instead of maximum permissible, see Table 3.18).

Area allocation of harvests

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of inter-annual changes in the apportionment. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of the biomass distribution, while adapting to current information about the 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, where x is the year index, reduced annual fluctuations in regional ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model (J. Heifetz, 1999, NOAA, 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 2013 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, but we continue to weight in the 2:1 ratio because of the potential biases with the use of fishery catch rate data discussed earlier.

Apportionments are based on survey and fishery information	**2012 ABC Percent**	**2012 Survey RPW**	**2011 Fishery RPW**	**2013 ABC Percent**	**2012 ABC**	**2013 ABC**	**Change**
Total					17,240	**16,230**	-6%
Bering Sea	13%	5%	9%	10%	2,230	**1,580**	-29%
Aleutians	12%	15%	13%	13%	2,050	**2,140**	4%
Gulf of Alaska	75%	79%	78%	77%	12,960	**12,510**	-4%
Western	14%	15%	13%	14%	1,780	**1,750**	-1%
Central	44%	46%	40%	44%	5,760	**5,540**	-4%
W. Yakutat*	16%	12%	17%	15%	2,080	**1,860**	-11%
E. Yakutat / Southeast*	26%	27%	30%	27%	3,350	**3,360**	0%

*After the adjustment for the 95:5 hook-and-line:trawl split in the Eastern Gulf of Alaska, the 2013 ABC for West Yakutat is 2,030 t and for East Yakutat/Southeast is 3,190 t. This adjustment projected to 2014 is 1,902 t for W. Yakutat and 2,993 t for E. Yakutat/Southeast.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2013	2,030 t	3,190 t
	2014	1,902 t	2,993 t

This year's apportionment reflects a substantial decrease in the longline survey index in all areas except the AI. The BS fishery RPW decreased substantially, while all other areas remained steady or increased (Figure 3.36a). The standard weighted average approach, described above, which includes values from 2008-2012 for survey RPWs and 2007-2011 for fishery RPWs, greatly alleviates the effect of an individual year's change in RPW (Figure 3.36b). The BS saw the largest change in apportionment, with the BS ABC declining another 29% as high years dropped out of the moving average and low survey and fishery indices become the most recent strongly weighted indices in the average. Thus, the GOA continues to gain a larger share of the apportionment (Figure 3.36c).

Overfishing level (OFL)

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b, results in a value of 19,180 t for the combined stock. The OFL is apportioned by region, Bering Sea (1,870 t), AI (2,530 t), and GOA (14,780 t), by the same method as the ABC apportionment.

Ecosystem considerations

Ecosystem considerations for the Alaska sablefish fishery are summarized in Table 3.19.

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 consume more euphausiids, shrimp, and cephalopods, while sablefish > 60 cm consume more fish (Yang and Nelson 2000). In the GOA, 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 GOA is Pacific halibut; however, sablefish comprised less than 1% of their stomach contents (M. Yang, October 14, 1999, NOAA, pers. comm.). 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 potential predators such as arrowtooth flounder, halibut, Pacific cod, bigmouth sculpin, big skate, and Bering skate, which are the main piscivorous groundfishes in the GOA (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 AI and GOA. Although fish species were not identified in sperm whale diets in Alaska, sablefish were found in 8.3% of sperm whale stomachs off of California (Kawakami 1980).

Sablefish distribution is typically thought to be on the upper continental slope in deeper waters than most groundfish. However, during the first two to three years of their life sablefish inhabit the continental shelf. Length samples from the NMFS bottom trawl survey suggest that the range of juvenile sablefish on the shelf varies dramatically from year to year. In particular, juveniles utilize the Bering Sea shelf extensively in some years, while not at all in others (Shotwell et al. 2012). Juvenile sablefish (< 60 cm FL) prey items overlap with the diet of small arrowtooth flounder. On the continental shelf of the GOA, 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). Shotwell et al. (2012) showed that colder than average wintertime sea surface temperatures in the central North Pacific may represent oceanic conditions that create positive recruitment events for sablefish in their early life history.

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 partly 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.

Fishery effects on the ecosystem

Fishery-specific contribution to bycatch of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species: The sablefish fishery catches significant portions of the spiny dogfish and unidentified shark total catch, but there is no distinct trend through time (Table 3.4). The sablefish fishery catches the majority of grenadier total catch, but 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 (1,090 t/year) and golden king crab (134,000 individuals/year). Halibut catches were steady in 2011, while golden king crab catches jumped from 26,000 to 191,000 individuals in 2011 (Table 3.6).

The shift from an open-access to an IFQ fishery has increased 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 (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 trawl gear, a significant effect of longlines on bedrock, cobbles, or sand is unlikely.

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.

Future sablefish research is going to focus on several directions:

1) Refine survey abundance index model for inclusion in the 2012 assessment model that accounts for whale depredation and potentially includes gully abundance data and other covariates.
2) Refine fishery abundance index to utilize a core fleet, and identify covariates that affect catch rates.
3) Improve knowledge of sperm whale and killer whale depredation in the fishery and begin to quantify depredation effects on fishery catch rates.
4) Continue to explore the use of environmental data to aid in determining recruitment
5) An integrated GOA 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.
6) 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.
7) Improve knowledge of maturity and fecundity. In 2011, the AFSC conducted a winter cruise out of Kodiak to sample sablefish when they are preparing to spawn. Ovaries will be examined histologically to determine maturity for a study of the age at maturity and fecundity. Results are expected in 2013.

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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 West Yakutat and East Yakutat / Southeast. 2012 catch as of September 29, 2012 (www.akfin.org).

		BY AREA								BY GEAR	
Year	Grand total	Bering Sea	Aleu-tians	Western	Central	Eastern	West Yakutat	East Yak/SEO	Un-known	Fixed	Trawl
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	12,863	695	1,019	1,398	4,855	4,895	1,886	3,010	0	11,691	1,172
2012	11,877	559	884	1,179	4,651	4,605	1,890	2,715	0	10,950	927

Table 3.2. 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. 2012 catch as of September 29, 2012 (www.akfin.org).

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	141	47	831	1019
2012	36	140	708	884
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	405	44	246	695
2012	295	87	177	559

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 2006-2011. Source: NMFS Alaska Regional Office via AKFIN, October 12, 2012.

		BSAI			GOA			Combined		
YEAR	Gear	Discard	%Discard	Catch	Discard	%Discard	Catch	Discard	%Discard	Catch
2006	Total	62	2.87%	2,168	556	4.22%	13,171	618	4.03%	15,339
	H&L	46	4.68%	982	286	2.37%	12,073	332	2.55%	13,055
	Other	16	1.38%	1,186	269	24.55%	1,098	286	12.51%	2,284
2007	Total	70	3.01%	2,322	419	3.30%	12,692	489	3.26%	15,014
	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
2008	Total	98	4.83%	2,035	810	6.43%	12,591	908	6.21%	14,626
	H&L	92	10.86%	845	737	6.29%	11,727	829	6.60%	12,573
	Other	7	0.55%	1,190	72	8.36%	864	79	3.83%	2,053
2009	Total	26	1.28%	1,986	709	6.45%	10,997	734	5.66%	12,983
	H&L	18	1.49%	1,183	628	6.21%	10,108	646	5.72%	11,291
	Other	8	0.98%	803	81	9.10%	889	89	5.25%	1,692
2010	Total	41	2.26%	1,830	415	4.12%	10,086	457	3.83%	11,916
	H&L	34	2.81%	1,215	368	4.01%	9,186	402	3.87%	10,401
	Other	7	1.19%	615	47	5.26%	900	55	3.61%	1,515
2011	Total	24	1.40%	1,714	529	4.74%	11,148	553	4.30%	12,863
	H&L	16	1.52%	1,077	350	3.48%	10,058	367	3.29%	11,136
	Other	41	6.44%	637	178	16.36%	1,090	186	10.77%	1,727
2006-2011	Total	54	2.67%	2,009	573	4.86%	11,781	626	4.54%	13,790
Average	H&L	37	3.70%	997	435	4.03%	10,790	472	4.01%	11,787
	Other	22	2.19%	1,012	138	13.88%	991	154	7.70%	2,003

Table 3.4. Bycatch (t) of FMP Groundfish species in the targeted sablefish fishery averaged from 2007-2011. Other = Pot and trawl combined because of confidentiality. Other Species is 2007-2010, and Sharks is only 2011. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN, October 12, 2012.

	Hook and Line			Other Gear			All Gear		
Species	Discard	Retained	Total	Discard	Retained	Total	Discard	Retained	Total
Arrowtooth Flounder	320	66	385	137	12	148	456	78	534
Thornyhead rockfish	49	292	341	3	21	25	53	313	366
Shortraker Rockfish	81	93	173	7	26	34	89	119	207
Other Species	180	2	181	3	1	4	183	3	185
GOA Other Skate	135	4	139	1	0	1	137	4	141
GOA Longnose Skate	119	4	122	2	1	3	121	5	126
Other Rockfish	41	77	118	2	1	4	43	78	121
Greenland Turbot	37	54	91	16	2	18	53	56	109
Rougheye Rockfish	38	57	99	16	4	20	54	60	119
Pacific Cod	25	58	83	1	7	8	26	65	91
Shark	234	0	234	1	0	1	235	0	235
GOA Deep Water Flatfish	8	0	8	15	4	19	24	4	28
Pacific ocean perch	7	0	7	2	16	18	9	16	25
BSAI Skate	18	0	18	0	-	0	18	0	18
BSAI Shortraker Rockfish	8	8	15	0	0	0	8	8	16
GOA Demersal Shelf Rockfish	0	11	11	-	-	-	0	11	11
BSAI Other Flatfish	7	2	9	1	0	1	8	2	10
Pollock	0	0	1	5	3	9	5	4	9
GOA Shallow Water Flatfish	7	1	8	1	0	1	8	1	9
GOA Rex Sole	0	0	0	5	3	8	5	3	8
Total	1,315	728	2,046	220	102	322	1,535	830	2,369

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 12, 2012. Conf. = confidential.

	Estimated Catch (t)					
Group Name	2006	2007	2008	2009	2010	2011
Benthic urochordata	0.08	0.00	-	0.01	0.12	0.13
Birds	0.91	1.59	0.55	0.40	0.35	1.43
Bivalves	0	Conf.	-	0	0.00	0.06
Brittle star unidentified	0.05	0.10	0.06	0.33	0.10	0.38
Corals Bryozoans	1.57	0.16	1.56	1.62	2.45	4.90
Dark Rockfish	-	-	Conf.	0	Conf.	-
Eelpouts	1.30	2.26	9.04	1.76	1.34	0.54
Eulachon	-	0	Conf.	0	Conf.	-
Giant Grenadier	4,030	9,315	8,897	5,369	4,402	6,652
Greenlings	-	76	0.02	0.02	-	0
Grenadier	4,907	109	128	961	749	810
Hermit crab unidentified	0.05	0.05	0.07	0.09	0.19	0.21
Invertebrate unidentified	0.07	0.02	0.01	0.42	0.76	1.88
Misc crabs	0.47	1.12	0.94	3.20	1.90	1.16
Misc crustaceans	-	-	-	2	0.00	0.00
Misc deep fish	0	0.00	-	0	-	0
Misc fish	18.34	17.10	21.19	4.72	4.01	7.96
Misc inverts (worms etc)	0	Conf.	0	0.01	0.00	0.00
Other osmerids	-	-	Conf.	-	-	-
Pandalid shrimp	0	0.00	0.00	0.01	0.00	0.00
Polychaete unidentified	-	-	0	0.00	0.00	0.00
Scypho jellies	0.10	0.00	Conf.	0	0	1
Sea anemone unidentified	0.29	3.34	0.69	1.99	1.32	3.06
Sea pens whips	0.19	0.08	0.32	0.49	0.03	1.52
Sea star	5.23	35.29	1.56	2.45	2.53	3.24
Snails	9.41	8.09	6.43	11.22	11.56	19.70
Sponge unidentified	0.71	0.16	14.65	1.92	0.76	1.99
Urchins, dollars, cucumbers	0.15	0.14	0.48	1.03	0.55	0.24

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 (BSAI or GOA) area for the sablefish fishery. Other = Pot and trawl combined because of confidentiality. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN, October 12, 2012.

	2008			2009			2010			2011			Average
	BSAI	GOA	Total	BSAI	GOA	Total	BSAI	GOA	Total	BSAI	GOA	Total	
Hook and Line													
Bairdi Crab	0.00	0.01	0.01	0.03	0.24	0.28	0.00	0.07	0.07	0.00	0.00	0.00	0.09
Golden K. Crab	0.17	0.08	0.25	0.32	0.03	0.35	0.97	0.00	0.97	0.50	0.13	0.63	0.55
Halibut	151	953	1,104	186	1,023	1,209	220	760	980	135	813	948	1,060
Other Salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Opilio Crab	0.01	0.23	0.24	0.01	0.21	0.22	0.00	0.16	0.16	0.00	0.29	0.29	0.23
Red K. Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.02	0.00	0.02	0.02
Other													
Bairdi Crab	0.14	0.18	0.32	1.65	0.08	1.74	0.00	0.06	0.06	0.94	0.00	0.00	0.53
Golden K. Crab	182	0	182	139	0	139	26	0	26	191	0	191	134
Halibut	28	7	35	17	3	20	39	4	43	17	6	23	30
Herring	0.00	0.03	0.03	0.00	0.00	0.00	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	0.02	0.02	0.00	0.00	0.00	0.00
Opilio Crab	0.25	0.00	0.25	0.01	0.10	0.11	2.15	0.03	2.18	0.33	0.00	0.33	0.72
Red K. Crab	0.42	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.41	0.21

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

Year	Catch(t)	OFL	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	27,900	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	26,500	16,800	16,800	
1999	13,575	24,700	15,900	15,900	
2000	15,919	21,400	17,300	17,300	
2001	14,097	20,700	16,900	16,900	
2002	14,789	26,100	17,300	17,300	
2003	16,371	28,900	18,400	20,900	
2004	17,720	30,800	23,000	23,000	
2005	16,619	25,400	21,000	21,000	
2006	15,417	25,300	21,000	21,000	
2007	15,011	23,750	20,100	20,100	
2008	14,335	21,310	18,030	18,030	Pot fishing ban repealed in Bering Sea for June 1-30 (74 FR 28733).
2009	13,206	19,000	16,080	16,080	
2010	11,916	21,400	15,230	15,230	
2011	12,863	20,700	16,040	16,040	
2012	11,877	20,400	17,240	17,240	

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	32,936	78,794	101,530			
1991				721	28,182	69,653	95,364	902		
1992				0	20,929	79,210	104,786			
1993	7,282			468	21,943	80,596	94,699	1,178		
1994				89	11,914	74,153	70,431			
1995				87	17,735		80,826			
1996	4,650			239	14,416		72,247		1,176	
1997				0	20,330		82,783		1,214	
1998				35	8,932		57,773		1,191	
1999	4,408			1,268	28,070		79,451		1,186	1,141
2000				472	32,208		62,513		1,236	1,152
2001	*partial			473	30,315		83,726		1,214	1,003
2002				526	33,719		75,937		1,136	1,059
2003	5,039			503	36,077		77,678		1,128	1,185
2004				694	31,199		82,767		1,185	1,145
2005	4,956			2,306	36,213		74,433		1,074	1,164
2006				721	32,497		78,625		1,178	1,154
2007	3,804			860	29,854		73,480		1,174	1,115
2008				2,018	23,414		71,661		1,184	1,164
2009	3,975			1,837	24,674		67,978		1,197	1,126
2010				1,634	24,530		75,010		1,176	1,159
2011	2,118			1,877	22,659		87,498		1,199	1,190
2012							63,116			

Table 3.9. Average catch rate (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. The standard error is not available when vessel sample size equals one.

Observer Fishery Data

Aleutian Islands-Observer						Bering Sea-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.53	0.05	0.10	193	8	1990	0.72	0.11	0.15	42	8
1991	0.50	0.03	0.07	246	8	1991	0.28	0.06	0.20	30	7
1992	0.40	0.06	0.15	131	8	1992	0.25	0.11	0.43	7	4
1993	0.28	0.04	0.14	308	12	1993	0.09	0.03	0.36	4	3
1994	0.29	0.05	0.18	138	13	1994	0.35	0.16	0.45	2	2
1995	0.30	0.04	0.14	208	14	1995	0.41	0.07	0.17	38	10
1996	0.23	0.03	0.12	204	17	1996	0.63	0.19	0.30	35	15
1997	0.35	0.07	0.20	117	9	1997				0	0
1998	0.29	0.05	0.17	75	12	1998	0.17	0.03	0.18	28	9
1999	0.38	0.07	0.17	305	14	1999	0.29	0.09	0.32	27	10
2000	0.29	0.03	0.11	313	15	2000	0.28	0.09	0.31	21	10
2001	0.26	0.04	0.15	162	9	2001	0.31	0.02	0.07	18	10
2002	0.32	0.03	0.11	245	10	2002	0.10	0.02	0.22	8	4
2003	0.26	0.04	0.17	170	10	2003	0.16	0.05	0.29	8	2
2004	0.21	0.04	0.21	138	7	2004	0.17	0.05	0.31	9	4
2005	0.15	0.05	0.34	23	6	2005	0.23	0.02	0.16	9	6
2006	0.23	0.04	0.16	205	11	2006	0.17	0.05	0.21	68	15
2007	0.35	0.10	0.29	198	7	2007	0.28	0.05	0.18	34	8
2008	0.37	0.04	0.10	247	6	2008	0.38	0.22	0.58	12	5
2009	0.29	0.05	0.22	335	10	2009	0.14	0.04	0.21	24	5
2010	0.27	0.04	0.14	459	12	2010	0.17	0.03	0.19	42	8
2011	0.25	0.05	0.19	401	9	2011	0.10	0.01	0.13	12	4

Western Gulf-Observer						Central Gulf-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.64	0.14	0.22	178	7	1990	0.54	0.04	0.07	653	32
1991	0.44	0.06	0.13	193	16	1991	0.62	0.06	0.09	303	24
1992	0.38	0.05	0.14	260	12	1992	0.59	0.05	0.09	335	19
1993	0.35	0.03	0.09	106	12	1993	0.60	0.04	0.07	647	32
1994	0.32	0.03	0.10	52	5	1994	0.65	0.06	0.09	238	15
1995	0.51	0.04	0.09	432	22	1995	0.90	0.07	0.08	457	41
1996	0.57	0.05	0.10	269	20	1996	1.04	0.07	0.07	441	45
1997	0.50	0.05	0.10	349	20	1997	1.07	0.08	0.08	377	41
1998	0.50	0.03	0.07	351	18	1998	0.90	0.06	0.06	345	32
1999	0.53	0.07	0.12	244	14	1999	0.87	0.08	0.10	269	28
2000	0.49	0.06	0.13	185	12	2000	0.93	0.05	0.06	319	30
2001	0.50	0.05	0.10	273	16	2001	0.70	0.04	0.06	347	31
2002	0.51	0.05	0.09	348	15	2002	0.84	0.07	0.08	374	29
2003	0.45	0.04	0.10	387	16	2003	0.99	0.07	0.07	363	34
2004	0.47	0.08	0.17	162	10	2004	1.08	0.10	0.09	327	29
2005	0.58	0.07	0.13	447	13	2005	0.89	0.06	0.07	518	32
2006	0.42	0.04	0.13	306	15	2006	0.82	0.06	0.08	361	33
2007	0.37	0.04	0.11	255	12	2007	0.93	0.06	0.07	289	30
2008	0.46	0.07	0.16	255	11	2008	0.84	0.07	0.08	207	27
2009	0.44	0.09	0.21	208	11	2009	0.77	0.06	0.07	320	33
2010	0.42	0.06	0.14	198	10	2010	0.80	0.05	0.07	286	31
2011	0.54	0.12	0.22	196	12	2011	0.85	0.08	0.10	213	28

Table 3.9 (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
2011	1.18	0.09	0.07	186	24	2011	0.98	0.09	0.10	196	16

Table 3.9 (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
2011	0.23	0.07	0.30	609	12

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	0.08	0.27	766	12
2011	0.22	0.03	0.13	500	24

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
2011	0.50	0.05	0.10	1148	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
2011	0.80	0.06	0.07	1065	71

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
2011	0.95	0.07	0.07	1377	75

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
2011	1.01	0.04	0.04	877	112

Table 3.10. 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, 2009 and 2011, and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2009, 2010, and 2012. NMFS trawl survey biomass estimates (kilotons) 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			1,683	1,048	84
2012		438			1,280		

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". Killer whale depredation did not always occur on all skates of gear, and only those skates with depredation were cut from calculations of RPNs and RPWs.

	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
2012			1	5	1	5	2	0	4	0	3	0

Table 3.12. Sablefish fork length (cm), weight (kg), and proportion mature by age and sex (weights from 1996-2004 age-length data from the AFSC longline survey).

	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	0.999	0.998
27	67.8	80.1	3.2	5.4	0.999	0.999
28	67.8	80.1	3.2	5.4	0.999	0.999
29	67.8	80.1	3.2	5.5	0.999	0.999
30	67.8	80.2	3.2	5.5	0.999	0.999
31+	67.8	80.2	3.2	5.5	1.000	1.000

Table 3.13. Input and output sample sizes and standard deviation of normalized residuals (SDNR) for data sources in the sablefish assessment model.

Multinomial Compositions	Input N/CV	SDNR	Effective N
Domestic LL Fishery Ages	200	1.00	188
Domestic LL Fishery Lengths	120	0.82	357
Trawl Fishery Lengths	50	0.88	90
LL Survey Ages	160	0.86	217
NMFS Trawl Survey Lengths	140	0.98	146
Domestic LL Survey Lengths	20	0.29	237
Japanese/Coop LL Survey Lengths	20	0.32	200
Lognormal abundance indices			
Domestic RPN	5%	3.91	
Japanese/Coop RPN	5%	2.98	
Domestic Fishery RPW	10%	0.84	
Foreign Fishery RPW	10%	1.16	
NMFS Trawl Survey	10-20%	1.78	

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	4	0	32	531	471	637	176	140	244
1961	5	0	36	544	480	651	182	155	239
1962	90	49	143	611	550	716	193	171	243
1963	7	0	50	612	556	719	203	179	250
1964	7	0	50	610	553	720	217	190	264
1965	41	0	87	637	559	724	233	205	280
1966	58	19	128	682	621	770	249	222	296
1967	9	0	48	683	626	770	260	234	307
1968	20	0	51	679	630	757	266	240	312
1969	6	0	26	645	599	715	266	240	308
1970	2	0	12	593	549	657	262	237	300
1971	2	0	13	533	491	592	253	229	289
1972	25	8	47	487	449	543	235	213	268
1973	28	9	48	442	413	487	206	187	236
1974	2	0	12	399	373	438	183	165	210
1975	4	0	16	356	333	392	161	145	185
1976	18	7	27	330	310	359	144	130	166
1977	1	0	8	291	273	317	128	115	148
1978	2	0	10	261	243	284	117	106	134
1979	82	67	100	318	300	344	112	102	127
1980	28	10	46	351	333	374	107	98	120
1981	7	0	23	368	349	391	105	97	117
1982	49	29	74	412	395	446	109	101	120
1983	21	1	41	439	420	463	120	113	131
1984	42	32	58	481	464	509	136	129	148
1985	0	0	3	484	467	513	151	144	164
1986	22	10	31	493	476	518	165	157	178
1987	20	14	30	483	468	507	171	163	184
1988	4	0	10	449	435	470	170	163	183
1989	5	0	11	407	393	426	163	156	175
1990	6	3	10	366	353	382	153	146	165
1991	28	24	33	349	337	364	143	136	153
1992	0	0	2	319	308	333	132	126	142
1993	25	21	30	312	301	326	121	115	130
1994	3	0	9	291	279	304	110	105	119
1995	6	1	10	270	258	284	102	97	111
1996	8	5	11	252	241	265	97	92	105
1997	19	15	23	247	236	262	94	89	102
1998	1	0	4	233	221	247	92	87	99
1999	31	28	36	244	232	259	88	83	95
2000	19	14	26	253	241	269	85	80	92
2001	13	4	20	255	242	271	82	77	88
2002	43	36	52	286	273	303	81	76	88
2003	8	2	14	292	278	311	84	78	90
2004	15	10	20	296	282	314	87	82	94
2005	7	4	11	289	274	308	92	86	99
2006	12	7	15	283	268	301	98	92	106
2007	9	6	13	275	259	293	104	97	112
2008	10	5	14	267	251	284	106	99	114
2009	9	6	14	258	242	276	106	99	114
2010	17	11	25	258	243	277	104	97	113
2011	4	1	8	250	233	268	102	95	110
2012	18	-	-	244	221	257	99	92	107
2013							97	85	105

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	103	142	48	132	40	65	531
1961	106	146	49	135	41	66	544
1962	119	164	56	152	46	75	611
1963	119	164	56	152	46	75	612
1964	119	163	55	152	46	75	610
1965	124	171	58	158	48	78	637
1966	133	183	62	170	52	83	682
1967	133	183	62	170	52	84	683
1968	132	182	62	169	51	83	679
1969	125	173	59	161	49	79	645
1970	115	159	54	148	45	72	593
1971	104	143	48	133	40	65	533
1972	95	130	44	121	37	59	487
1973	86	118	40	110	33	54	442
1974	78	107	36	99	30	49	399
1975	69	95	32	88	27	44	356
1976	64	88	30	82	25	40	330
1977	57	78	26	72	22	36	291
1978	51	70	24	64	20	33	261
1979	62	84	28	83	23	37	318
1980	68	97	31	84	27	44	351
1981	72	96	37	77	33	52	368
1982	82	92	52	96	39	52	412
1983	91	94	65	108	35	46	439
1984	107	110	71	116	31	46	481
1985	120	109	65	114	32	43	484
1986	126	102	65	115	38	48	493
1987	91	104	63	125	46	55	483
1988	55	96	60	139	44	56	449
1989	63	82	48	126	39	50	407
1990	64	62	38	108	39	55	366
1991	44	43	37	109	43	73	349
1992	26	36	28	102	47	79	319
1993	17	38	31	102	49	76	312
1994	19	37	36	94	40	65	291
1995	29	31	33	87	33	56	270
1996	27	28	31	88	28	49	252
1997	25	28	32	90	27	46	247
1998	20	37	32	76	24	44	233
1999	22	49	34	72	21	45	244
2000	25	50	40	73	21	45	253
2001	33	48	48	68	17	41	255
2002	46	48	48	82	20	41	286
2003	44	46	44	92	24	42	292
2004	42	44	42	100	25	43	296
2005	49	38	45	90	22	45	289
2006	54	40	45	80	20	44	283
2007	54	41	35	79	23	43	275
2008	56	38	32	78	21	41	267
2009	54	36	37	76	19	37	258
2010	55	30	33	74	24	43	258
2011	35	25	34	87	26	43	250
2012	15	35	42	92	21	41	244

Table 3.16. Key parameter estimates and their uncertainty and Bayesian credible intervals (BCI). Recruitment is in millions.

Parameter	μ (MLE)	μ (MCMC)	Median (MCMC)	σ (Hessian)	σ (MCMC)	BCI-Lower	BCI-Upper
$q_{domesticLL}$	7.75	7.74	7.74	0.11	0.22	7.33	8.17
q_{coopLL}	6.29	6.27	6.27	0.11	0.20	5.85	6.67
q_{trawl}	1.37	1.35	1.35	0.31	0.09	1.17	1.54
$F_{40\%}$	0.095	0.110	0.104	0.023	0.032	0.062	0.195
2012 SSB (kt)	99.4	99.7	99.8	4.0	4.0	92.2	107.5
2000 Year Class	42.6	43.8	44.0	4.1	3.8	36.7	51.7
2008 Year Class	17.2	18.3	17.8	3.70	3.65	11.0	25.2

Table 3.17. Comparison of 2011 results versus 2012 results. Biomass is in kilotons.

Year	2011 SAFE Spawning Biomass	2012 SAFE Spawning Biomass	2011 SAFE Total Biomass	2012 SAFE Total Biomass
1960	180	176	533	531
1961	185	182	543	544
1962	195	193	613	611
1963	204	203	614	612
1964	217	217	609	610
1965	233	233	636	637
1966	249	249	683	682
1967	260	260	682	683
1968	266	266	680	679
1969	266	266	646	645
1970	262	262	593	593
1971	253	253	533	533
1972	235	235	486	487
1973	207	206	442	442
1974	183	183	398	399
1975	161	161	355	356
1976	144	144	329	330
1977	128	128	290	291
1978	117	117	260	261
1979	112	112	316	318
1980	107	107	349	351
1981	105	105	366	368
1982	108	109	410	412
1983	120	120	437	439
1984	136	136	479	481
1985	151	151	482	484
1986	164	165	492	493
1987	171	171	483	483
1988	169	170	449	449
1989	162	163	408	407
1990	153	153	367	366
1991	142	143	348	349
1992	131	132	318	319
1993	120	121	310	312
1994	110	110	288	291
1995	101	102	267	270
1996	97	97	249	252
1997	94	94	245	247
1998	91	92	231	233
1999	87	88	242	244
2000	84	85	252	253
2001	81	82	255	255
2002	80	81	287	286
2003	83	84	292	292
2004	87	87	297	296
2005	92	92	290	289
2006	99	98	284	283
2007	104	104	277	275
2008	107	106	269	267
2009	107	106	260	258
2010	105	104	263	258
2011	104	102	258	250
2012		99		244

Table 3.18. 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)				
2012	99.4	99.4	99.4	99.4	99.4	99.4	99.4
2013	97.2	97.2	97.2	97.2	97.2	97.2	97.2
2014	93.4	95.0	97.0	95.4	101.3	91.9	93.4
2015	90.5	93.3	96.7	94.0	105.7	87.9	90.5
2016	88.9	91.4	96.0	93.6	111.0	85.6	87.7
2017	89.4	91.4	95.3	95.0	118.1	85.4	87.1
2018	91.5	93.2	95.7	98.1	127.0	86.9	88.2
2019	94.3	95.7	97.7	101.9	136.8	89.1	90.2
2020	97.2	98.3	99.9	105.9	146.8	91.4	92.2
2021	100.0	100.8	103.2	109.7	156.6	93.6	94.2
2022	102.4	103.0	108.3	113.3	165.9	95.4	95.9
2023	104.5	105.0	112.0	116.5	174.7	97.1	97.4
2024	106.5	106.9	114.6	119.5	183.0	98.6	98.8
2025	108.2	108.5	119.3	122.2	190.8	99.9	100.1
			Fishing mortality				
2012	0.063	0.063	0.063	0.063	0.063	0.063	0.063
2013	0.086	0.068	0.043	0.063	-	0.102	0.102
2014	0.082	0.066	0.043	0.063	-	0.097	0.097
2015	0.080	0.082	0.043	0.063	-	0.092	0.092
2016	0.078	0.080	0.042	0.063	-	0.089	0.089
2017	0.077	0.078	0.042	0.063	-	0.088	0.088
2018	0.076	0.077	0.042	0.063	-	0.087	0.087
2019	0.076	0.077	0.043	0.063	-	0.086	0.086
2020	0.076	0.077	0.044	0.063	-	0.086	0.086
2021	0.076	0.077	0.046	0.063	-	0.087	0.087
2022	0.077	0.077	0.047	0.063	-	0.088	0.088
2023	0.078	0.078	0.047	0.063	-	0.088	0.088
2024	0.078	0.079	0.047	0.063	-	0.089	0.089
2025	0.079	0.080	0.047	0.063	-	0.091	0.091
			Yield (kt)				
2012	12.0	12.0	12.0	12.0	12.0	12.0	12.0
2013	16.2	16.2	8.3	12.1	-	19.2	16.2
2014	14.7	15.2	8.1	11.7	-	16.9	14.7
2015	14.4	15.2	8.4	11.9	-	16.1	17.0
2016	14.9	15.6	9.1	12.6	-	16.6	17.2
2017	15.7	16.2	9.7	13.2	-	17.2	17.7
2018	16.2	16.6	10.2	13.7	-	17.8	18.2
2019	16.9	17.2	10.7	14.2	-	18.5	18.7
2020	17.4	17.6	11.2	14.7	-	19.0	19.2
2021	17.9	18.1	11.6	15.0	-	19.5	19.6
2022	18.4	18.5	12.0	15.4	-	20.0	20.1
2023	18.8	18.9	12.4	15.8	-	20.4	20.5
2024	19.3	19.3	12.7	16.1	-	20.8	20.9
2025	19.8	19.9	13.1	16.4	-	21.4	21.4

* Projections in Author's F (Alternative 2) are based on estimated catches of 12,970 t and 12,120 t used in place of maximum permissible ABC for 2013 and 2014. This was done in response to management requests for a more accurate two-year projection.

Table 3.19. 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

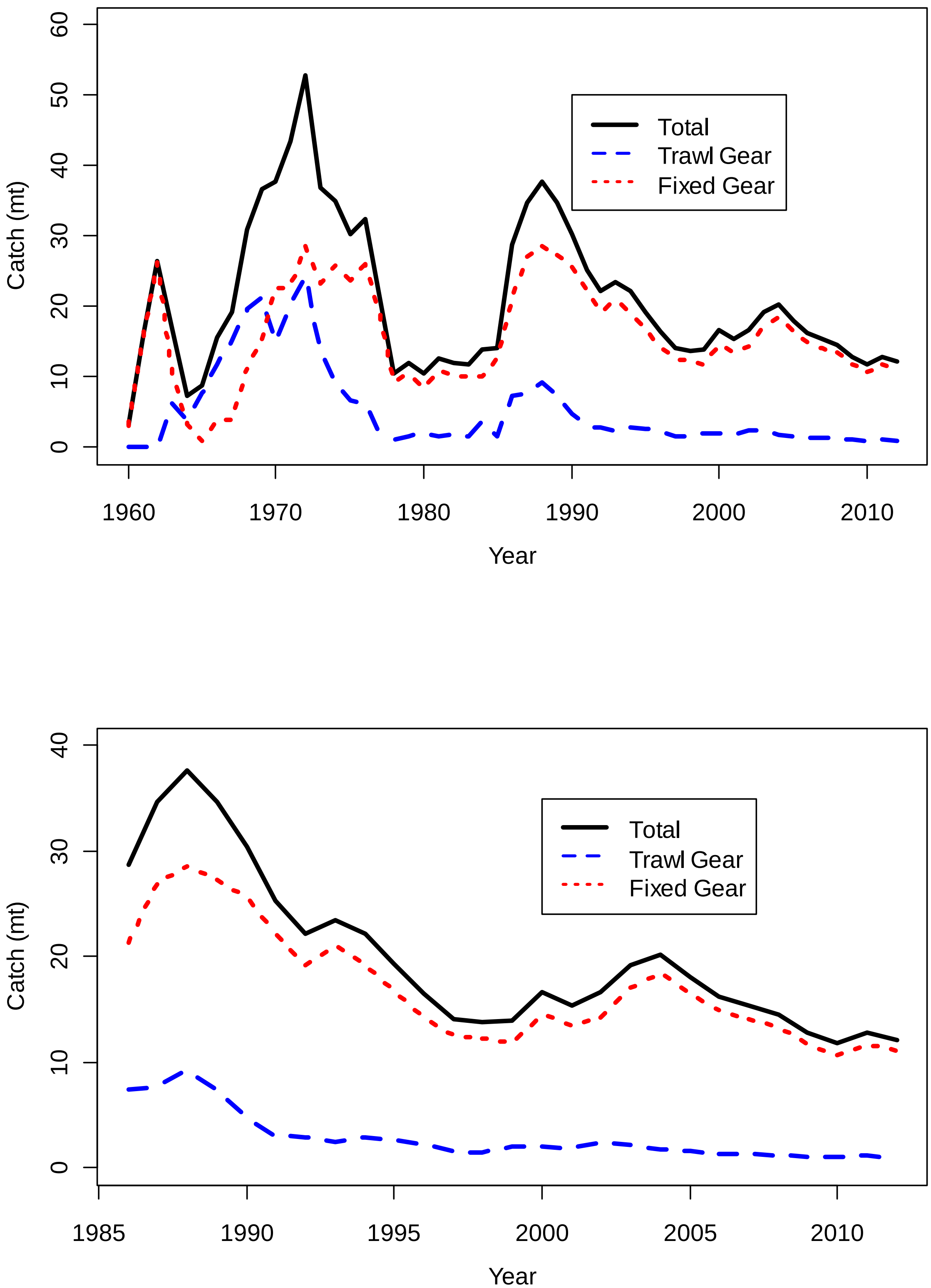

Figure 3.1. Long term and short term sablefish catch by gear type.

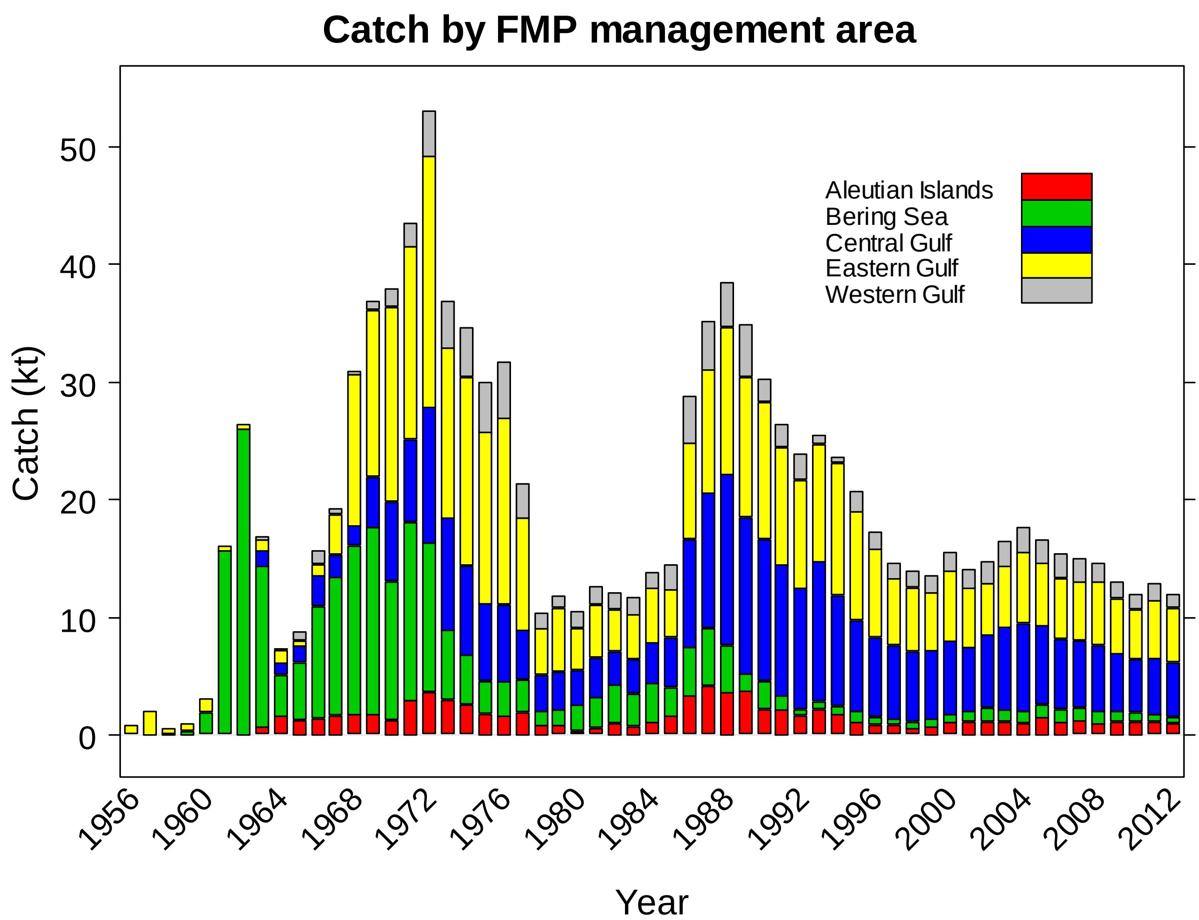

Figure 3.2. Sablefish fishery total reported catch (kt) by North Pacific Fishery Management Council area and year.

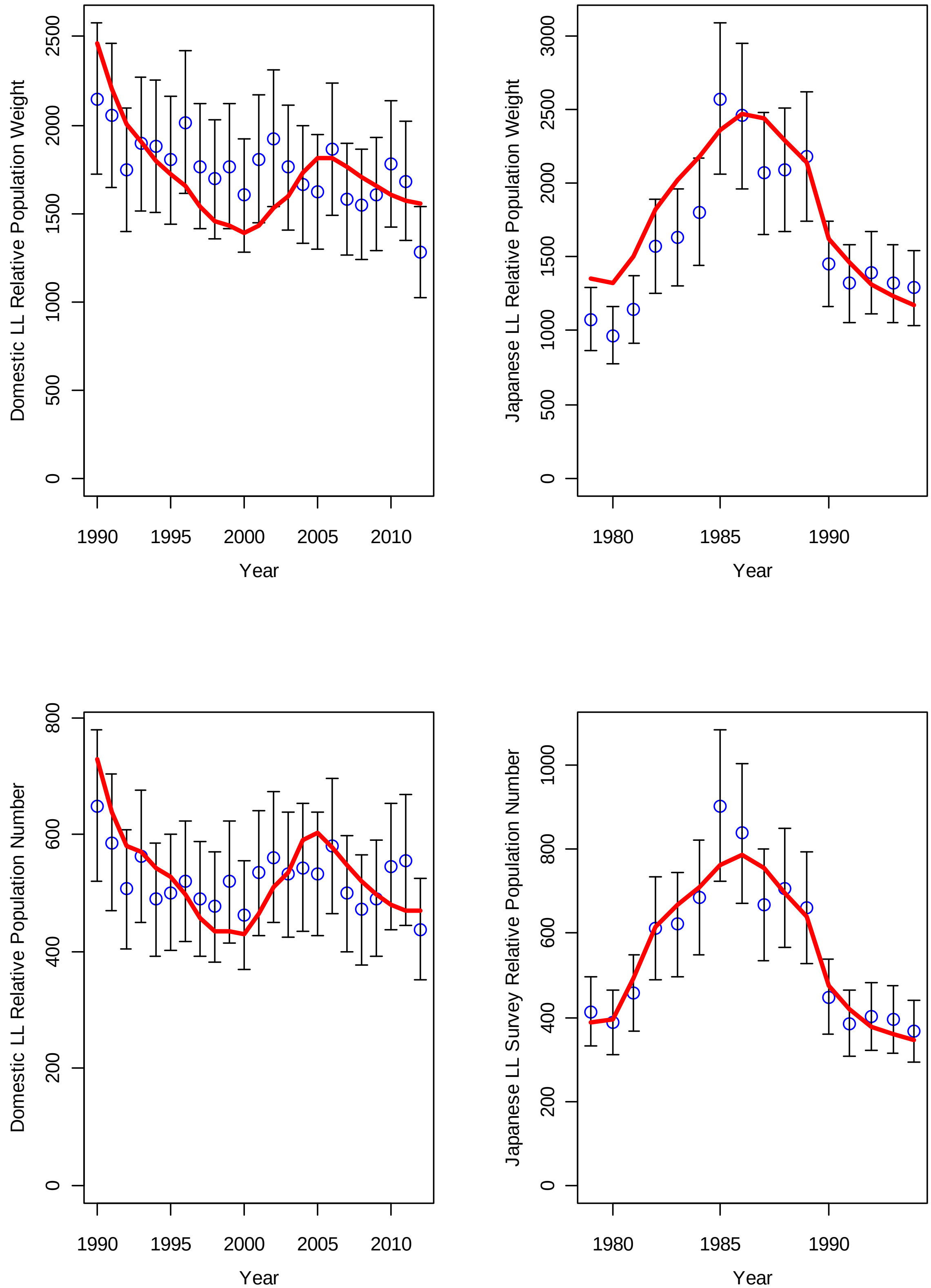

Figure 3.3. Observed and predicted sablefish relative population weight and numbers versus year. Points are observed estimates with approximate 95% confidence intervals, solid red line is model predicted. The relative population weights are not fit in the models, but are presented for comparison.

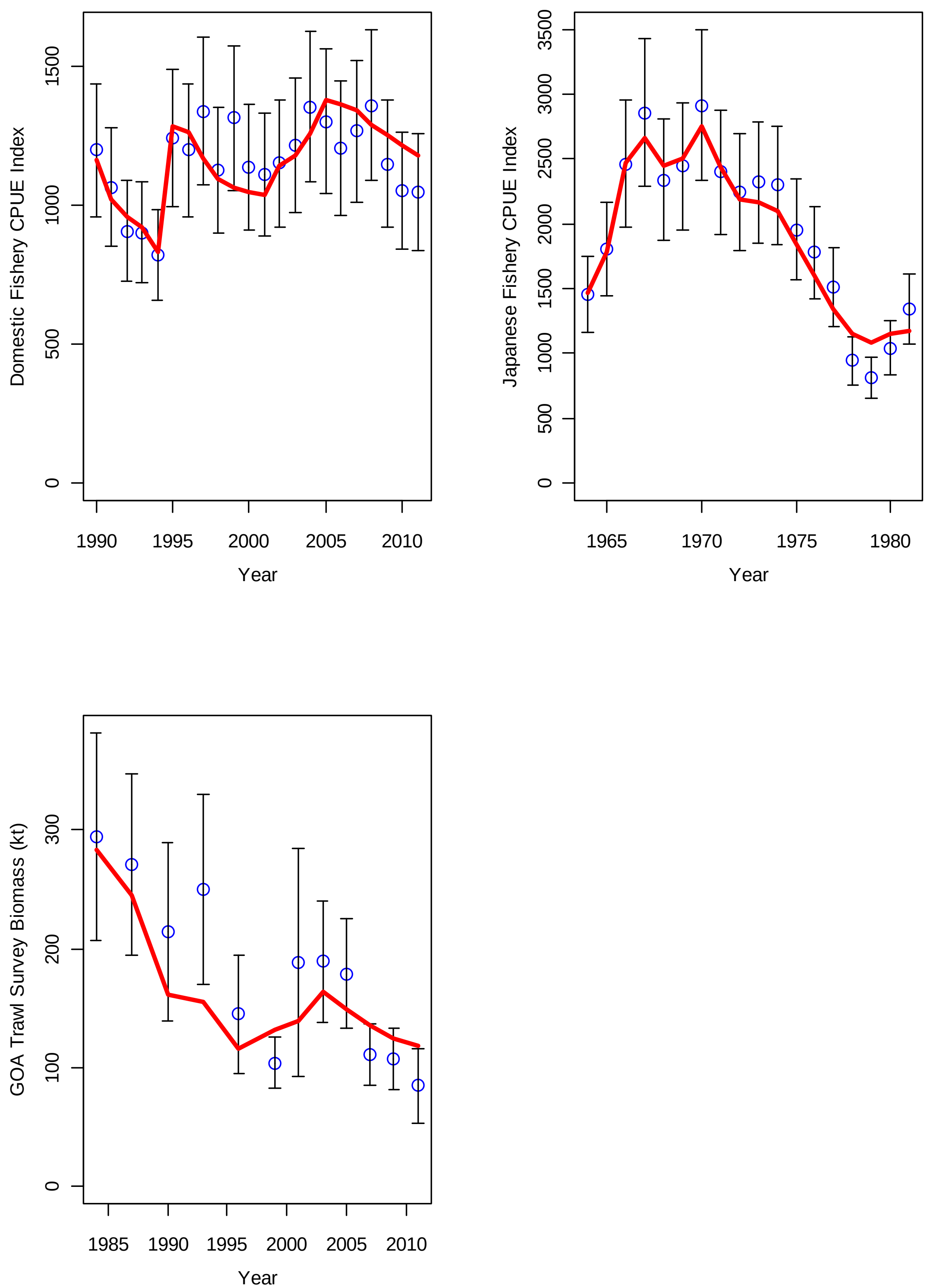

Figure 3.4. Observed and predicted sablefish abundance indices. Fishery indices are on top two panels, GOA trawl survey is on the bottom left panel. Points are observed estimates with approximate 95% confidence intervals while solid red lines are model predictions.

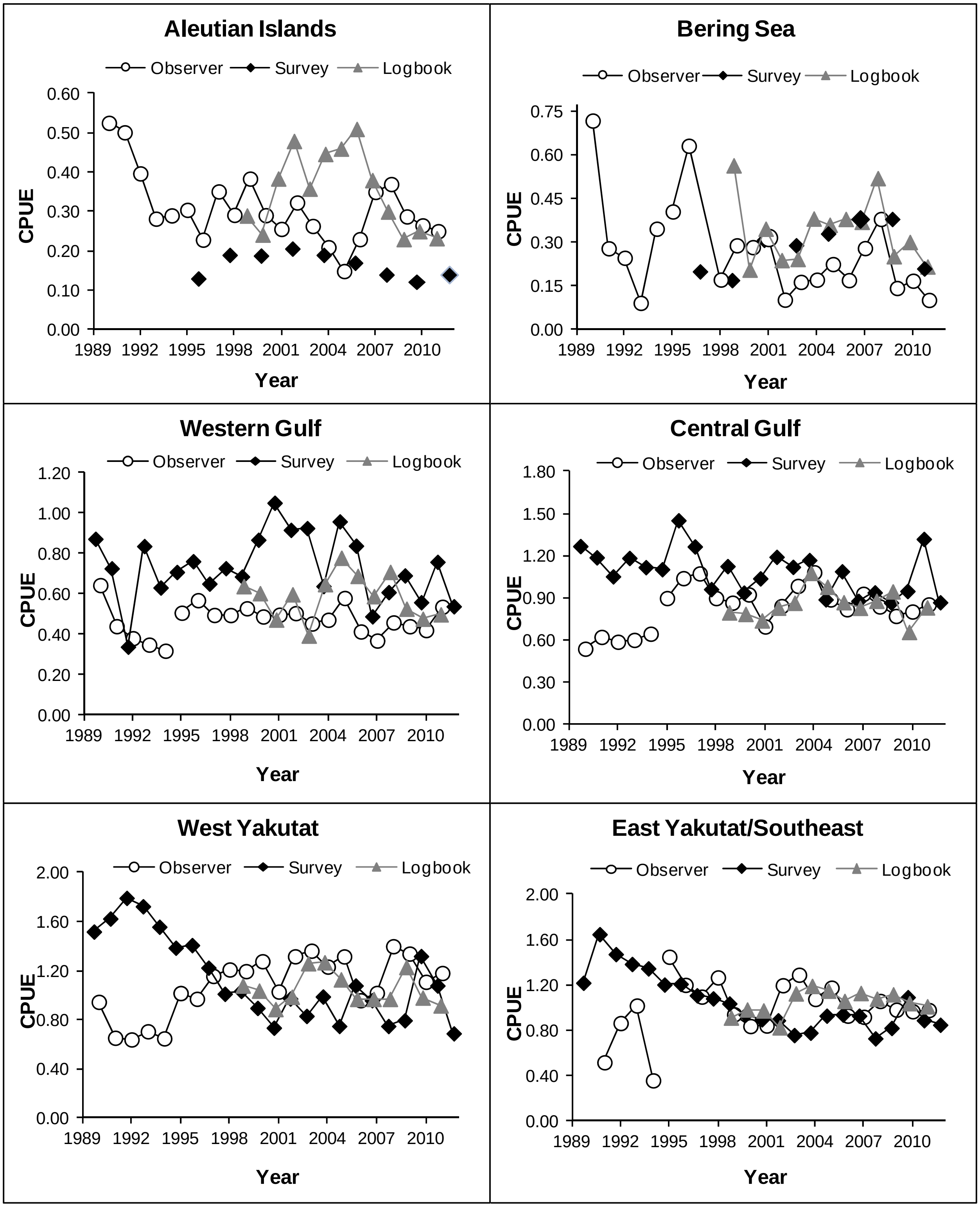

Figure 3.5. Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995.

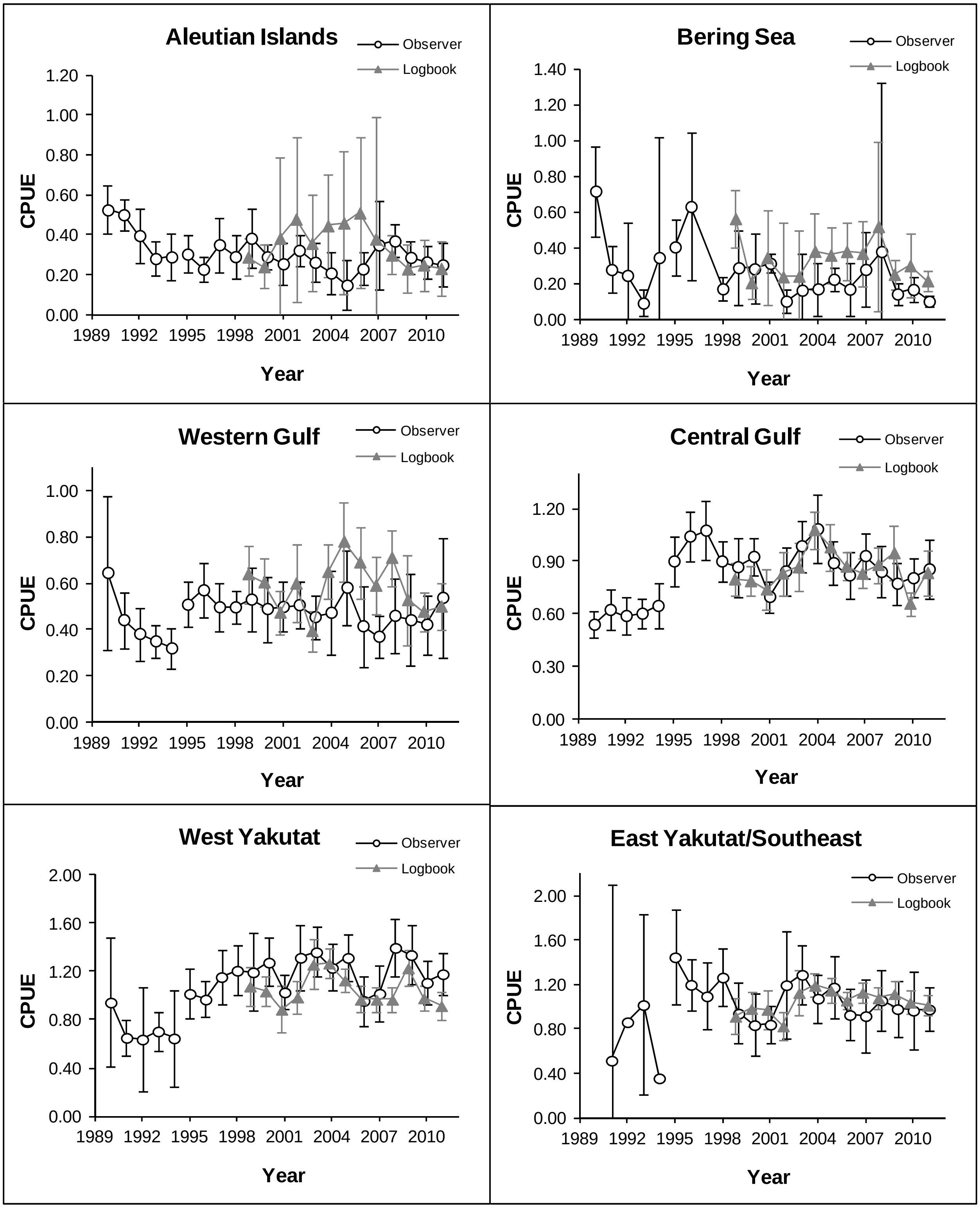

Figure 3.6. Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995.

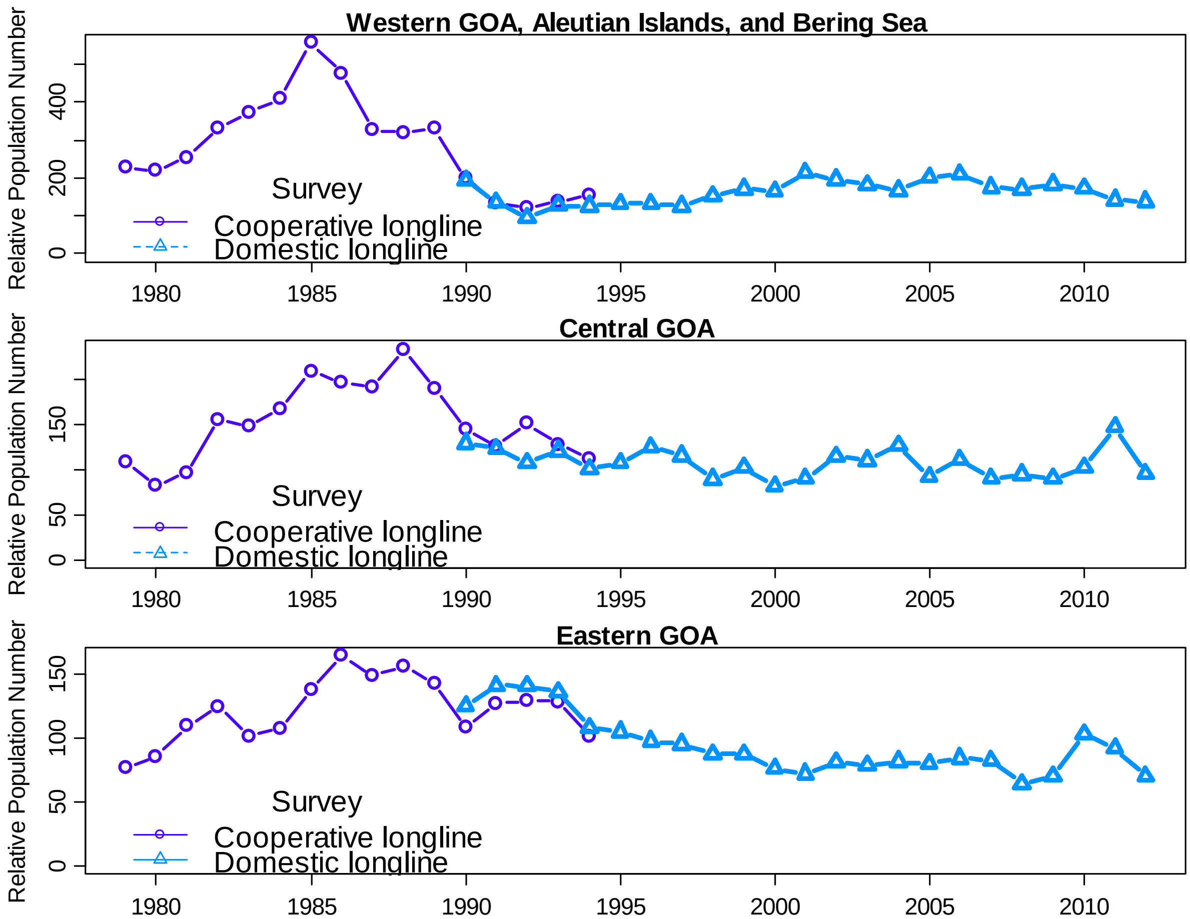

Figure 3.7. Relative abundance (numbers) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear.

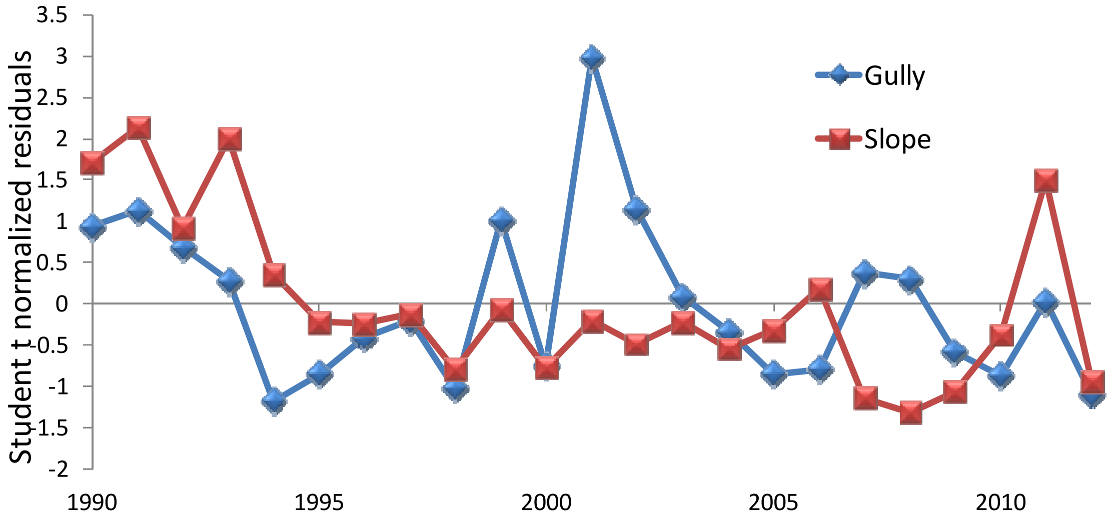

Figure 3.8 Comparison of abundance trends in GOA gully stations versus GOA slope stations.

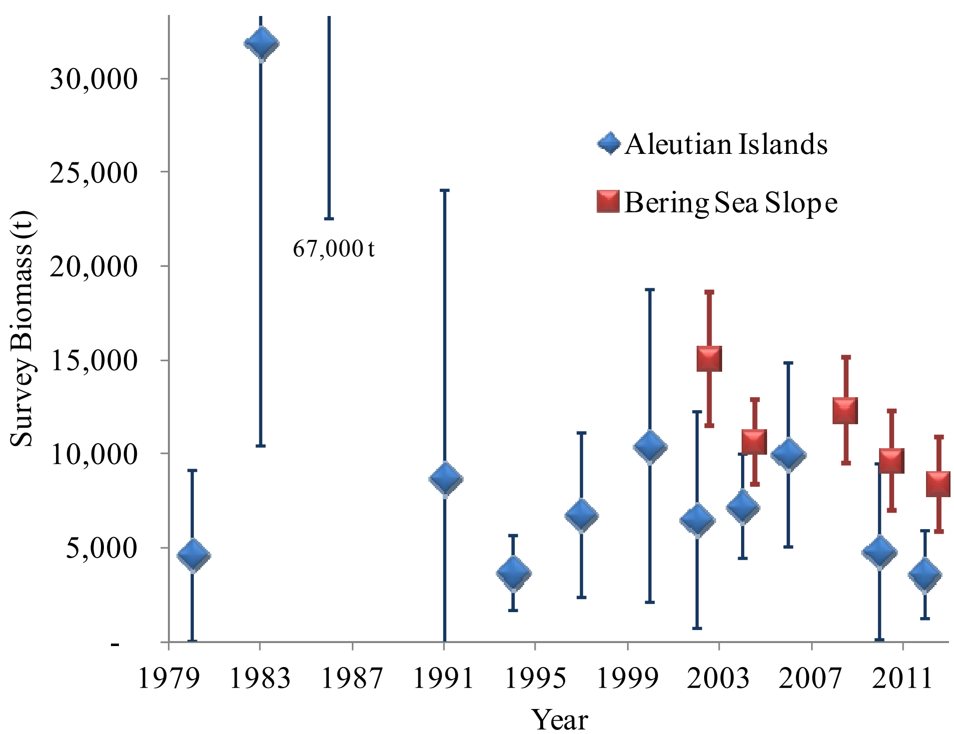

Figure 3.9. NMFS Bering Sea Slope and Aleutian Island trawl survey biomass estimates. Bering Sea Slope years are jittered so that intervals do not overlap.

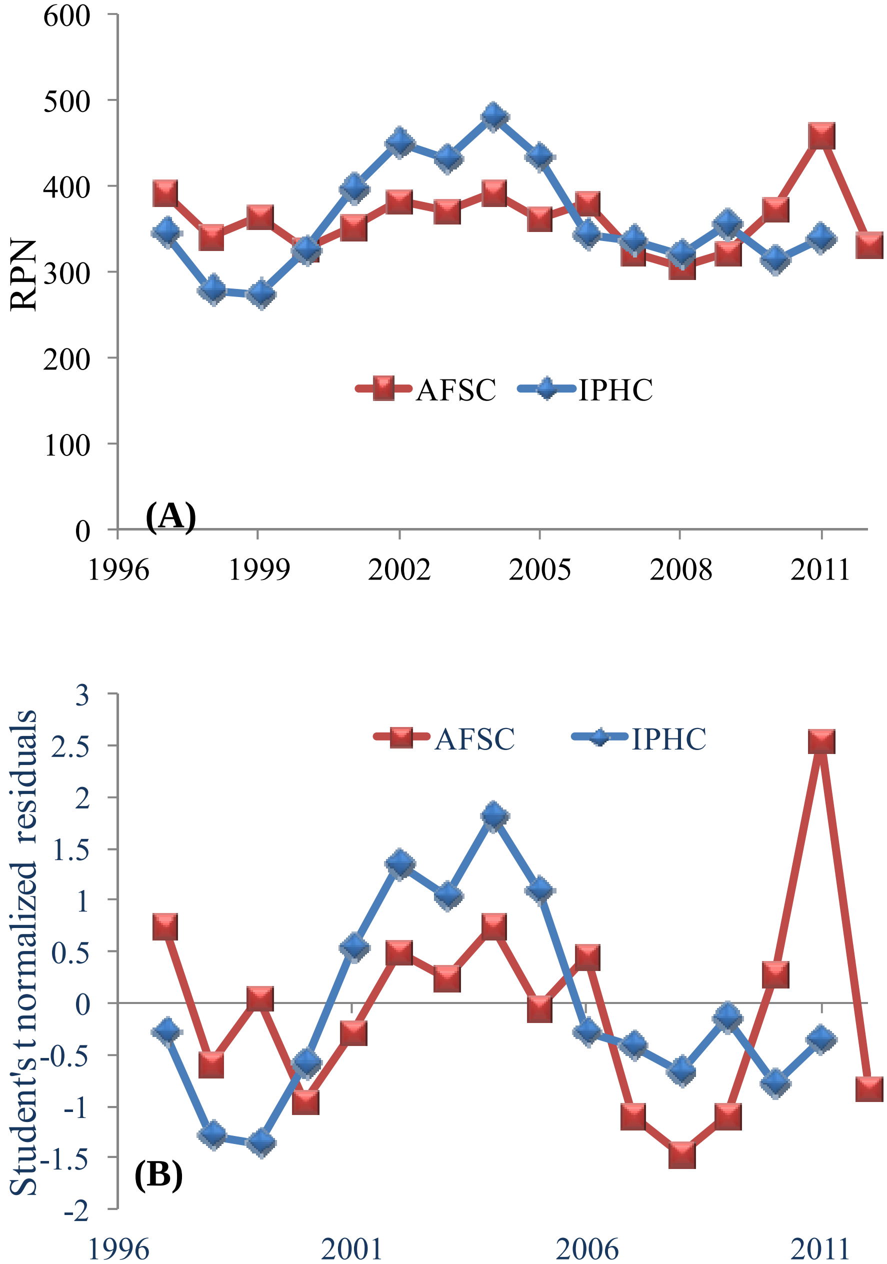

Figure 3.10. Comparisons of IPHC and AFSC longline survey trends in relative population number of sablefish in the Gulf of Alaska.

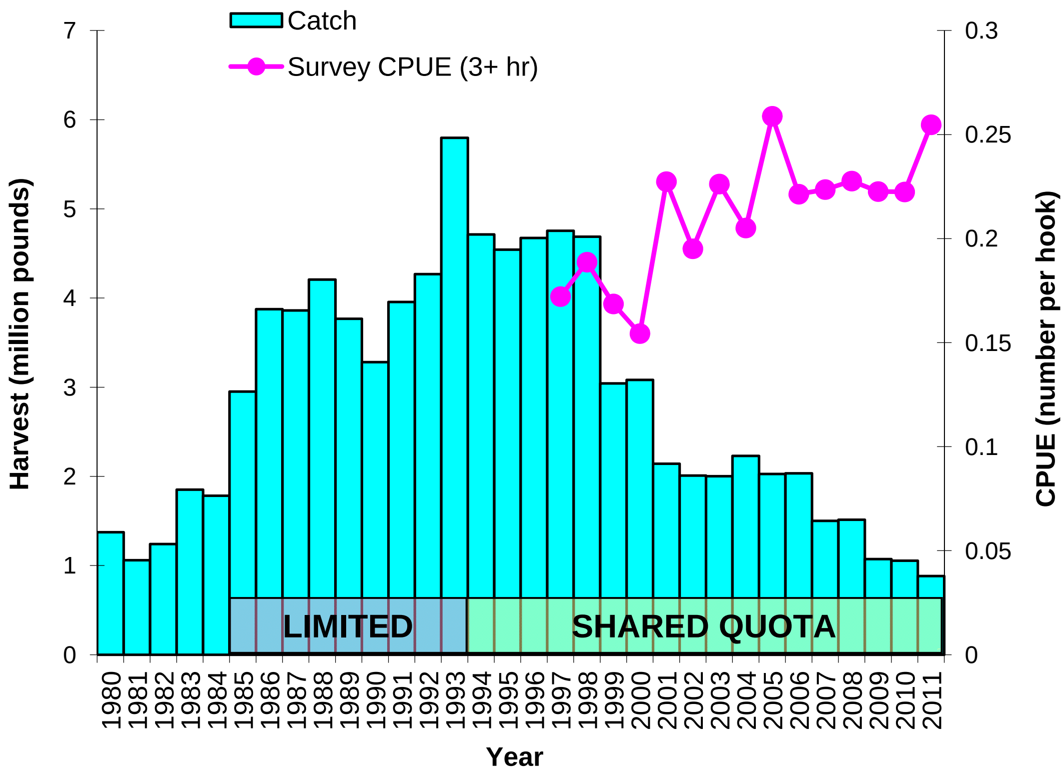

Figure 3.11. Northern Southeast Inside sablefish long line survey catch per unit effort (number per hook) in sablefish per hook and harvest over time (from Dressel per. comm. 2012).

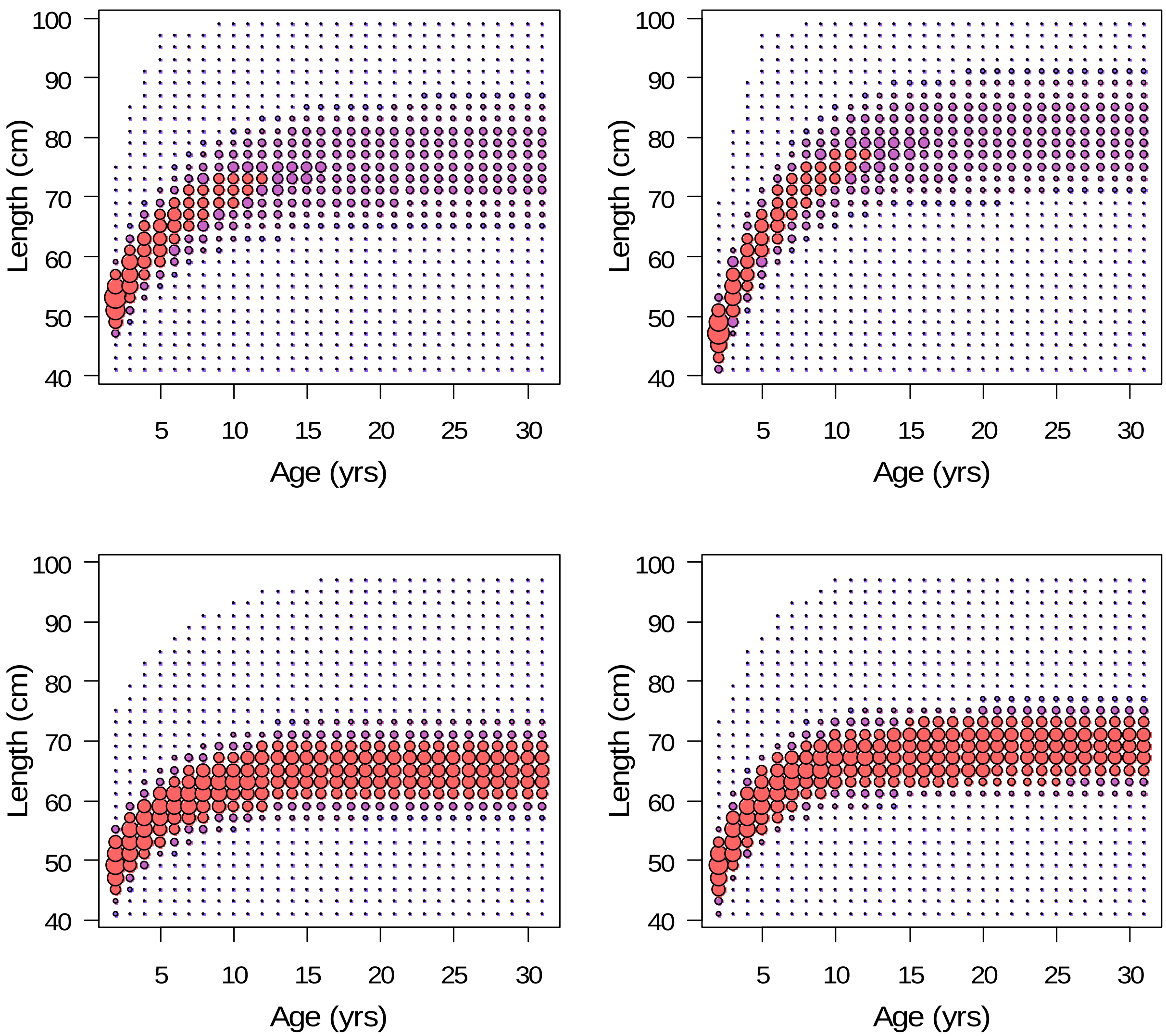

Figure 3.12. Age-length conversion matrices for sablefish. Top panels are female, bottom panel are males, left is 1981-1993, and right is 1996-2012.

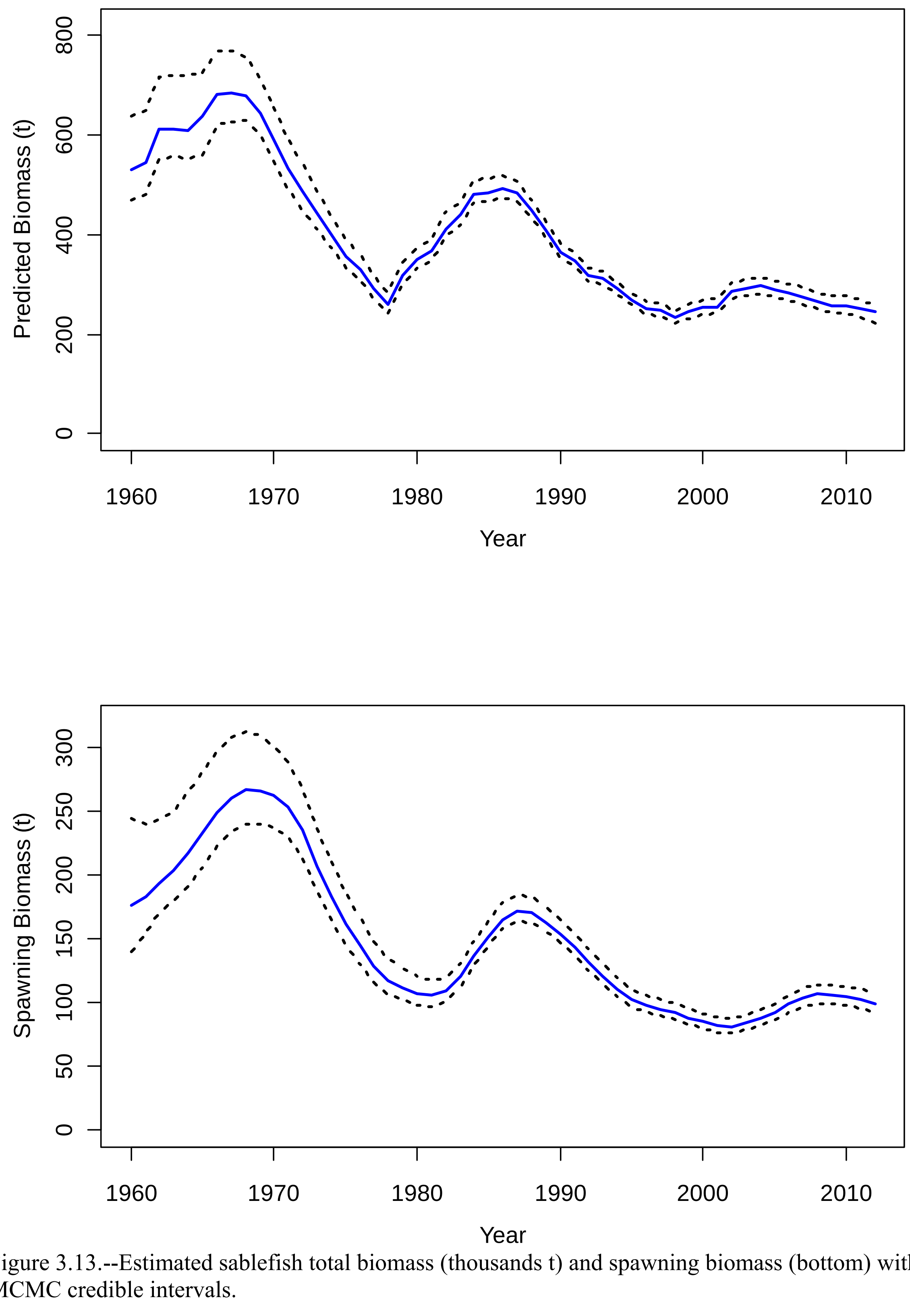

Figure 3.13.--Estimated sablefish total biomass (thousands t) and spawning biomass (bottom) with 95% MCMC credible intervals.

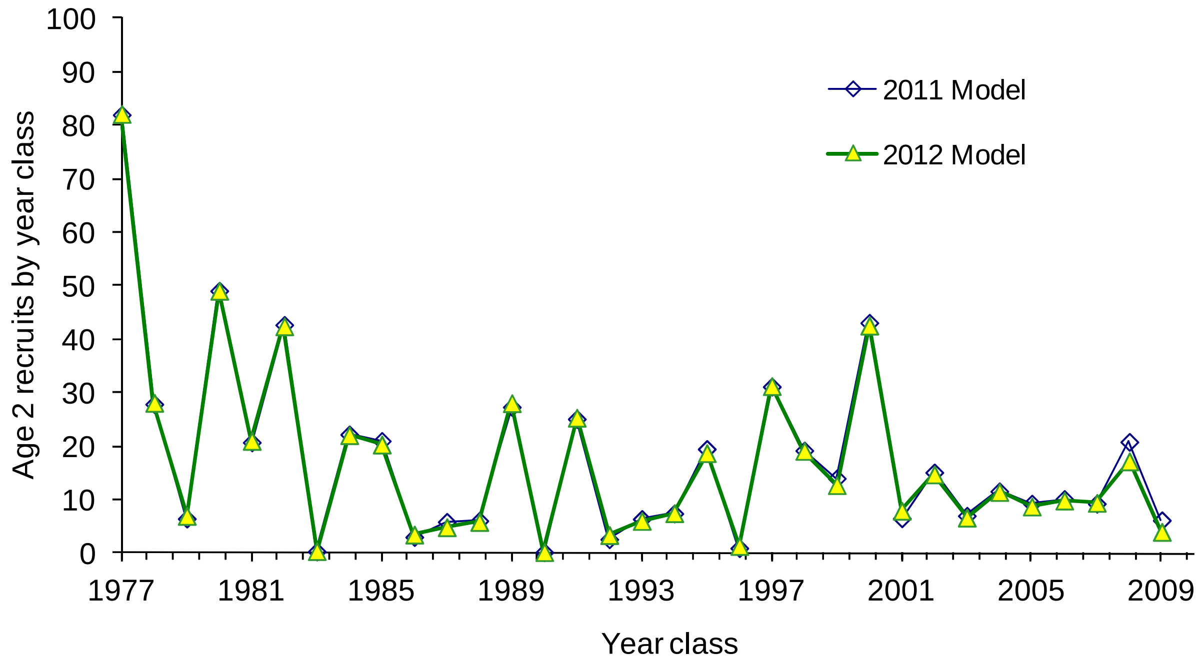

Figure 3.14a. Estimated recruitment (number at age 2, millions) versus year for 2011 and 2012 models.

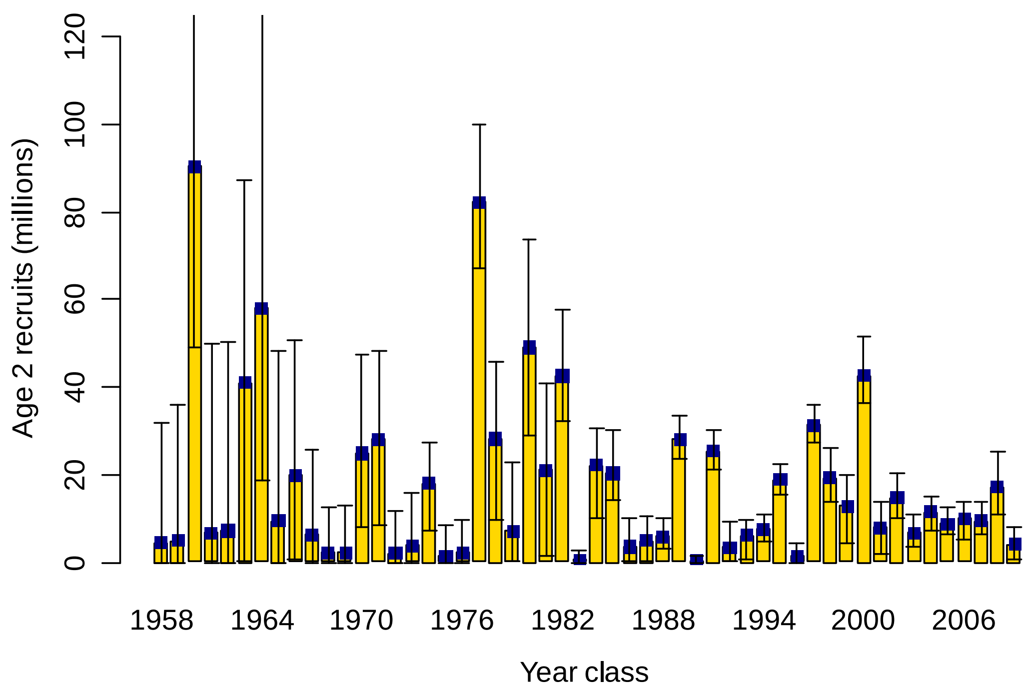

Figure 3.14b. Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on 20,000,000 MCMC runs.

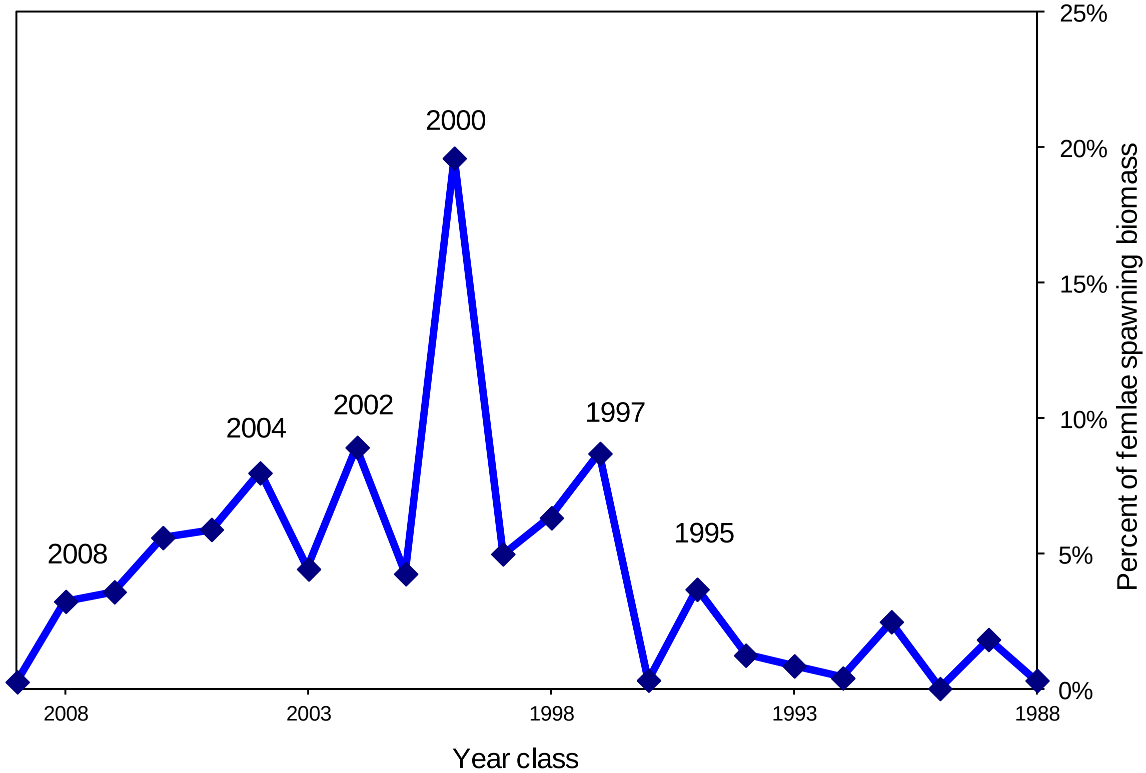

Figure 3.15. Relative contribution of the last 20 year classes to next year's female spawning biomass.

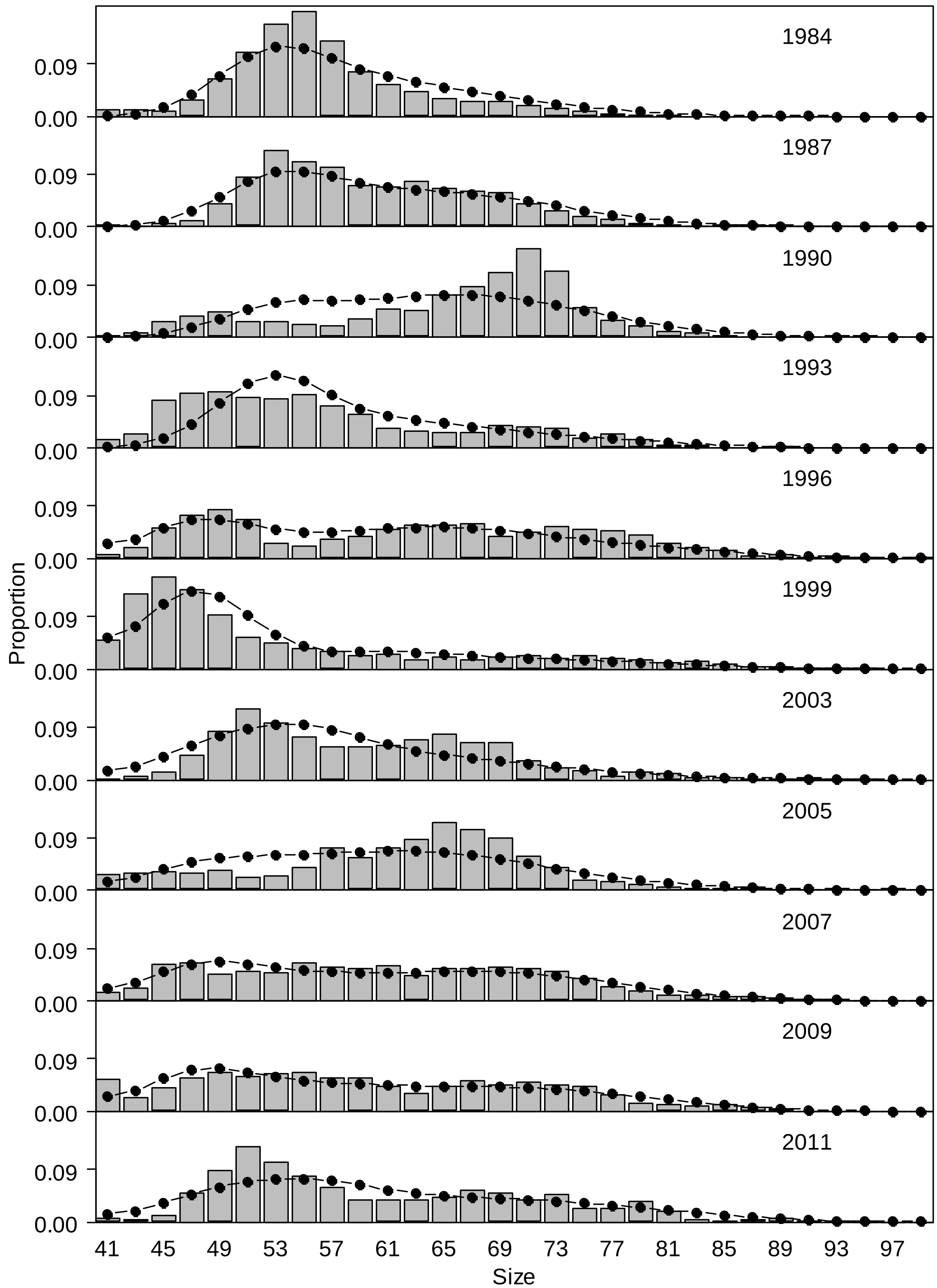

Figure 3.16. Gulf of Alaska bottom trawl survey length (cm) compositions for female sablefish at depths <500 m. Bars are observed frequencies and lines are predicted frequencies.

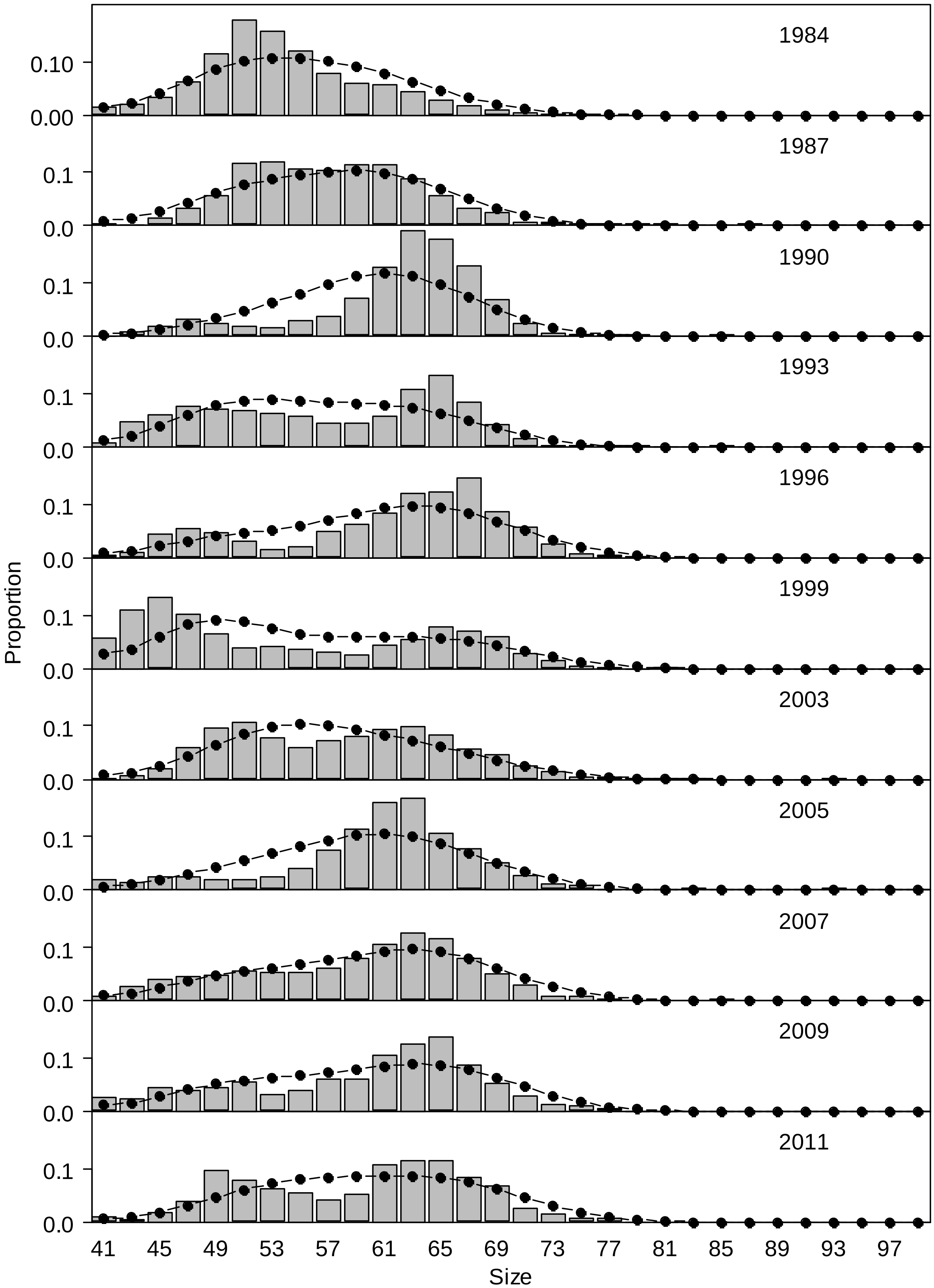

Figure 3.17. Gulf of Alaska bottom trawl survey length (cm) compositions for male sablefish at depths <500 m. Bars are observed frequencies and lines are predicted frequencies.

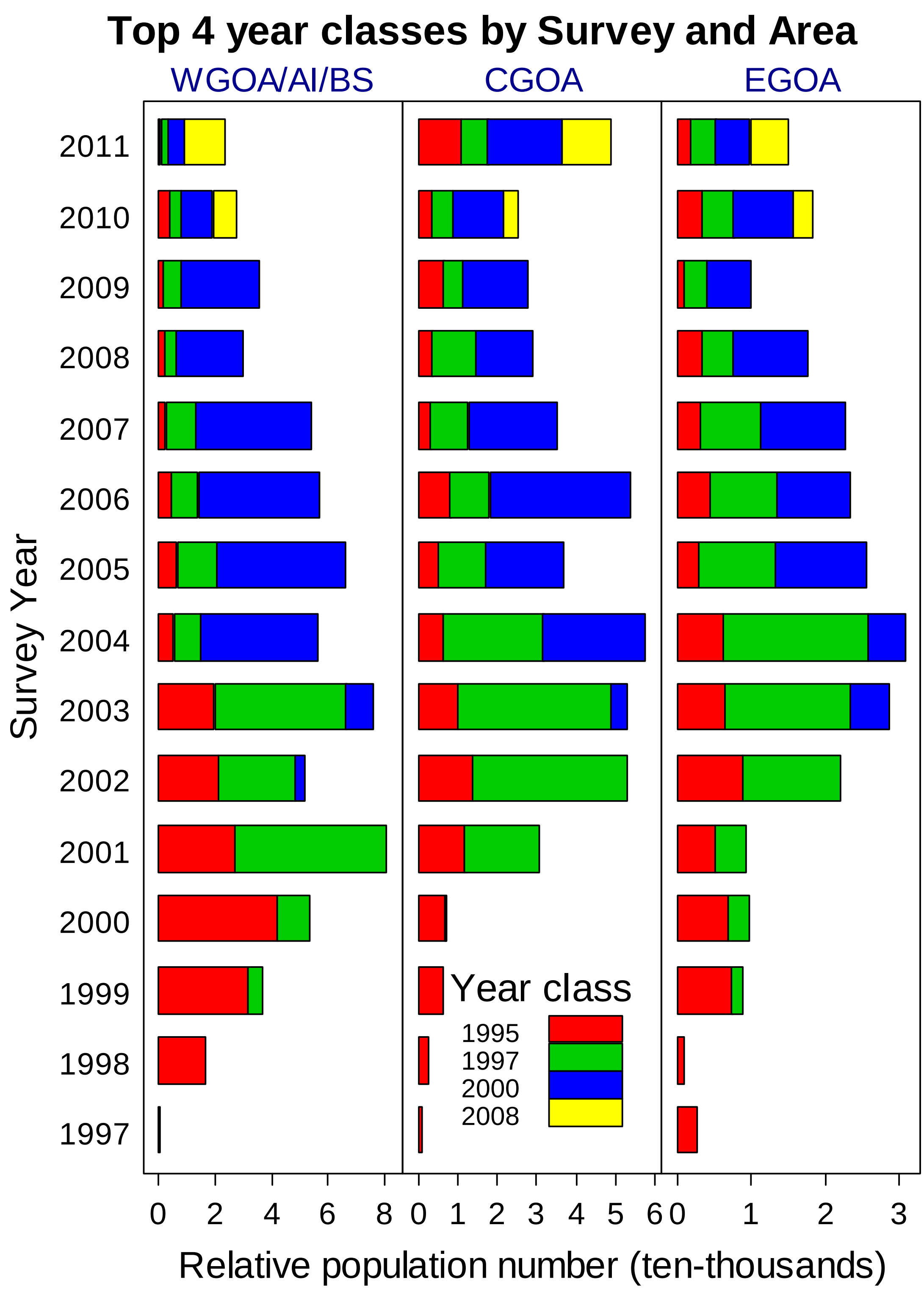

Figure 3.18. Above average 1995, 1997, 2000 and potential above-average 2008 year classes' relative population abundance in each survey year and area.

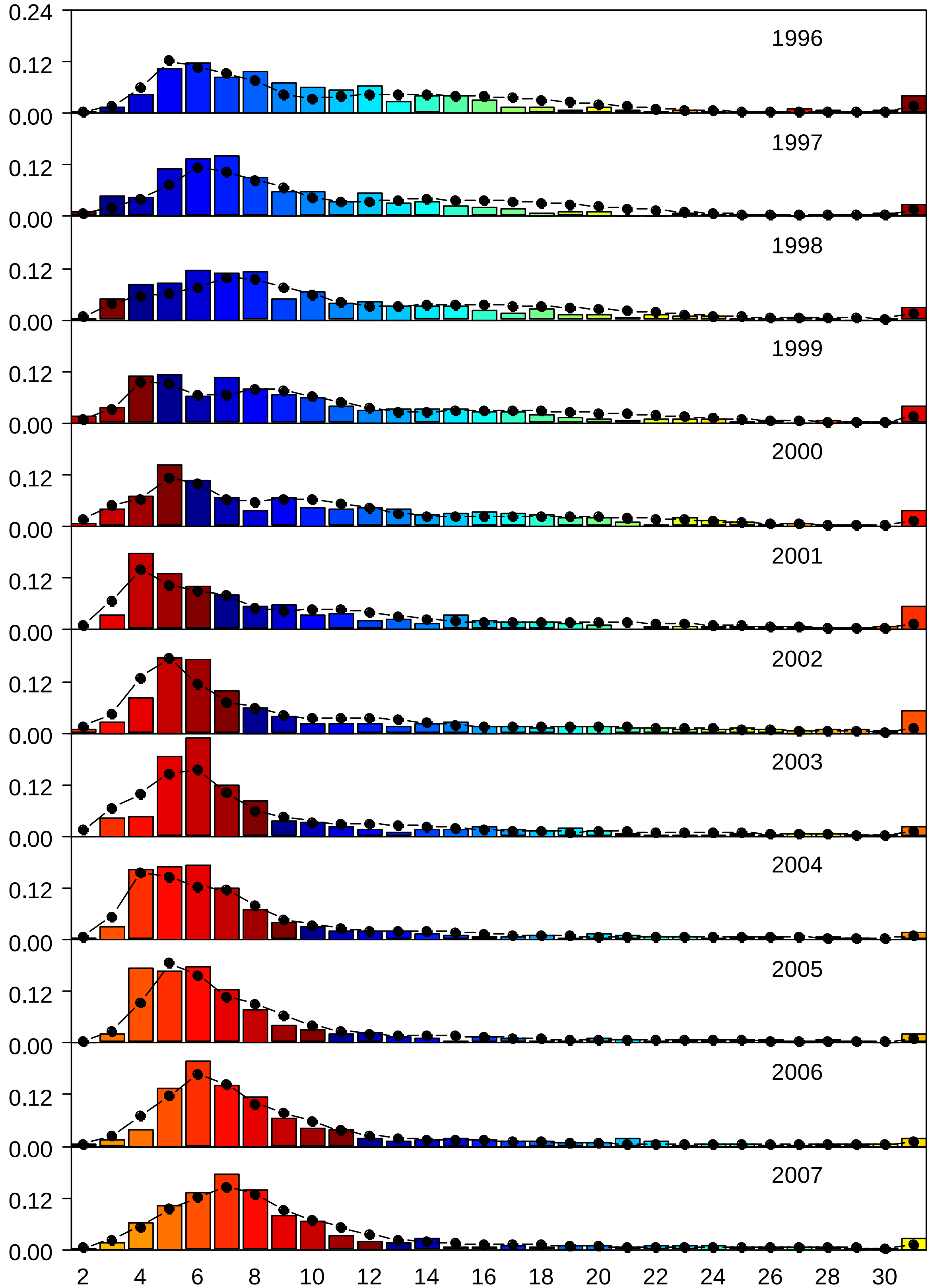

Figure 3.19. Domestic longline survey age compositions. Bars are observed frequencies and lines are predicted frequencies.

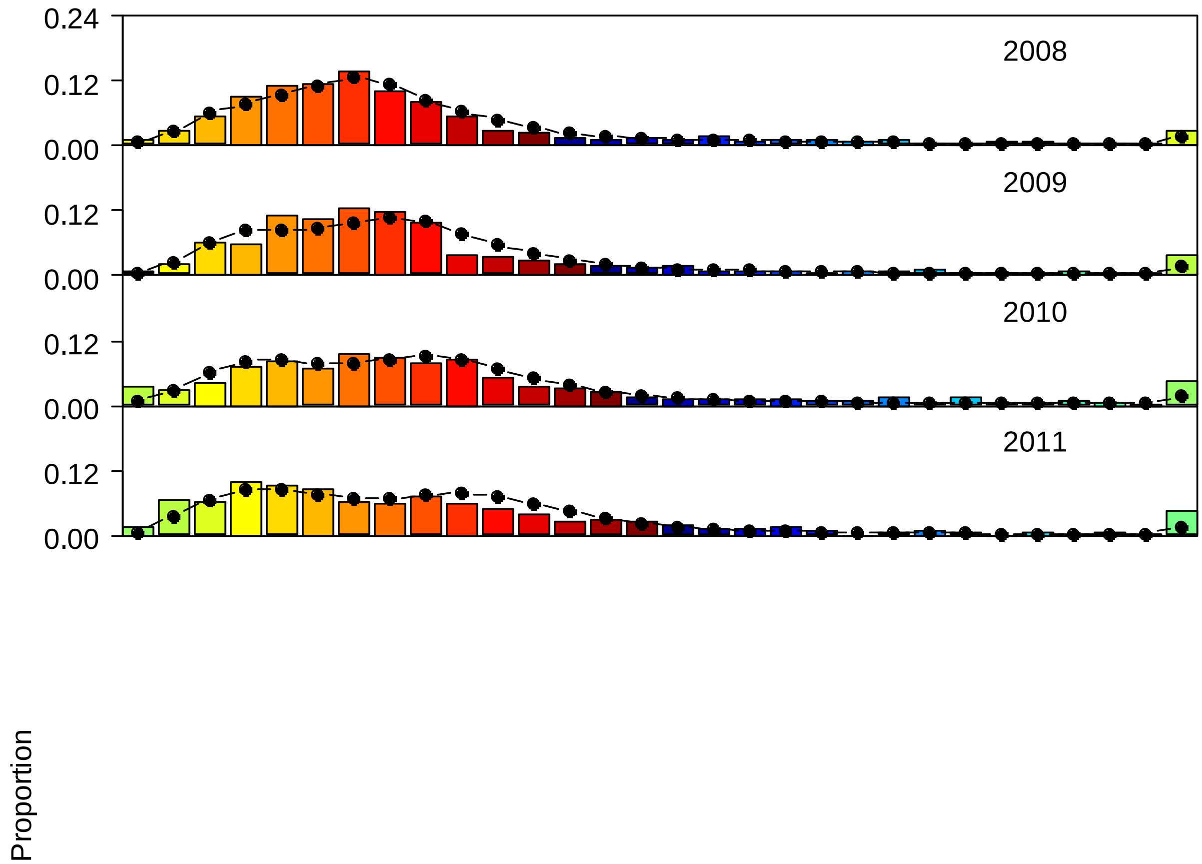

Figure 3.19 (cont.). Domestic longline survey age compositions. Bars are observed frequencies and lines are predicted frequencies.

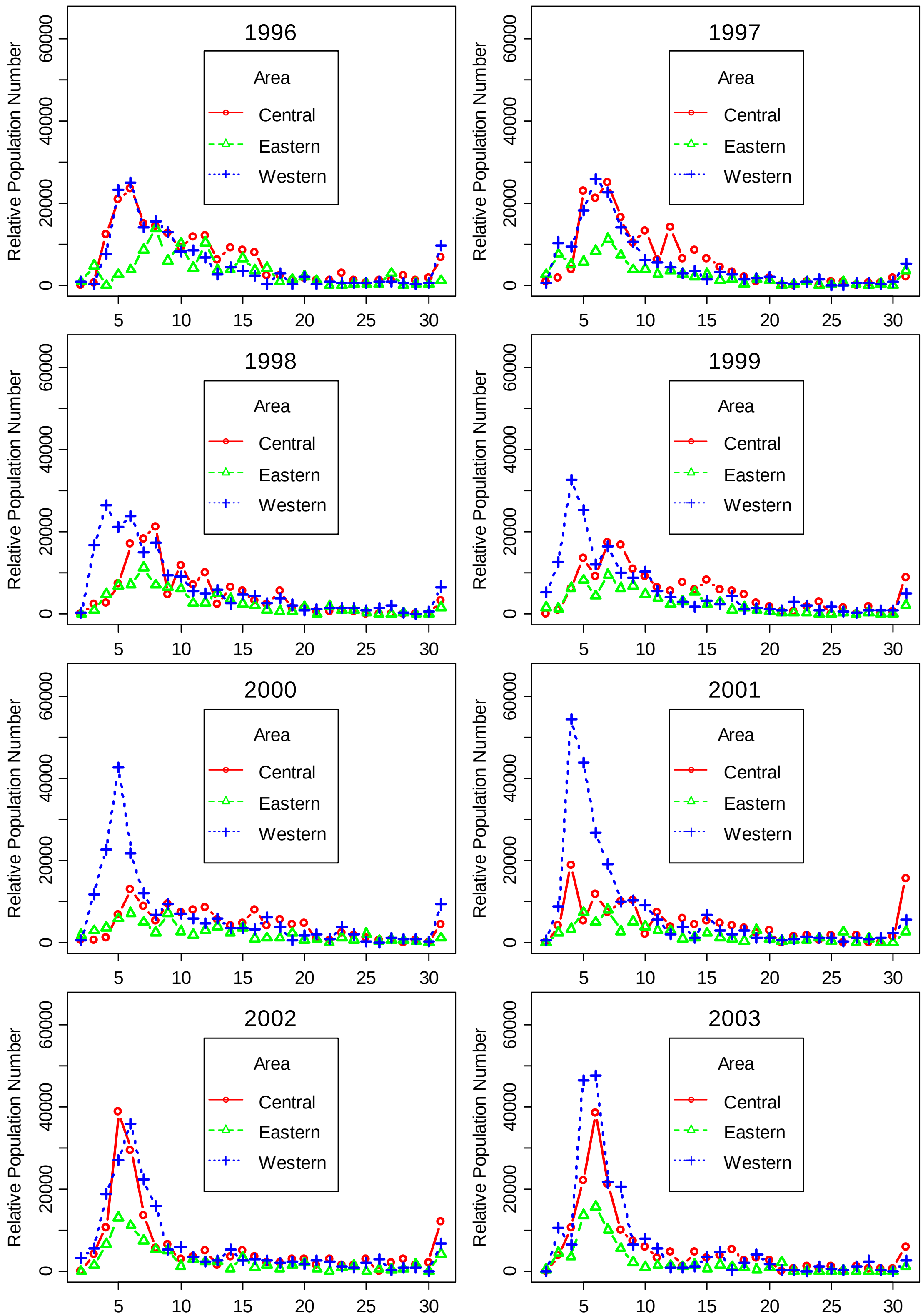

Figure 3.20. Relative abundance (number in thousands) by age and region from the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

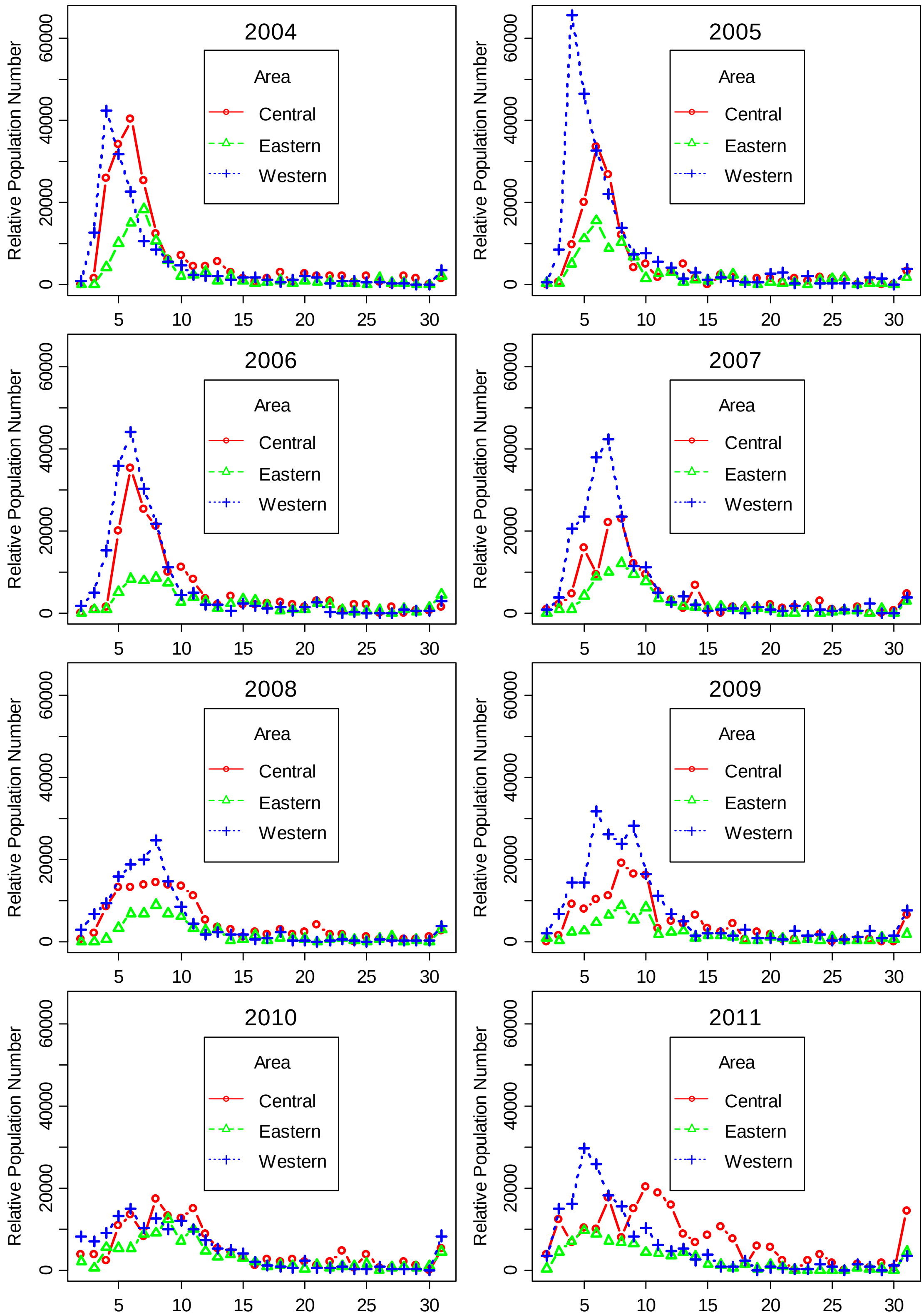

Figure 3.20 (cont.). Relative abundance (number in thousands) by age and region from the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

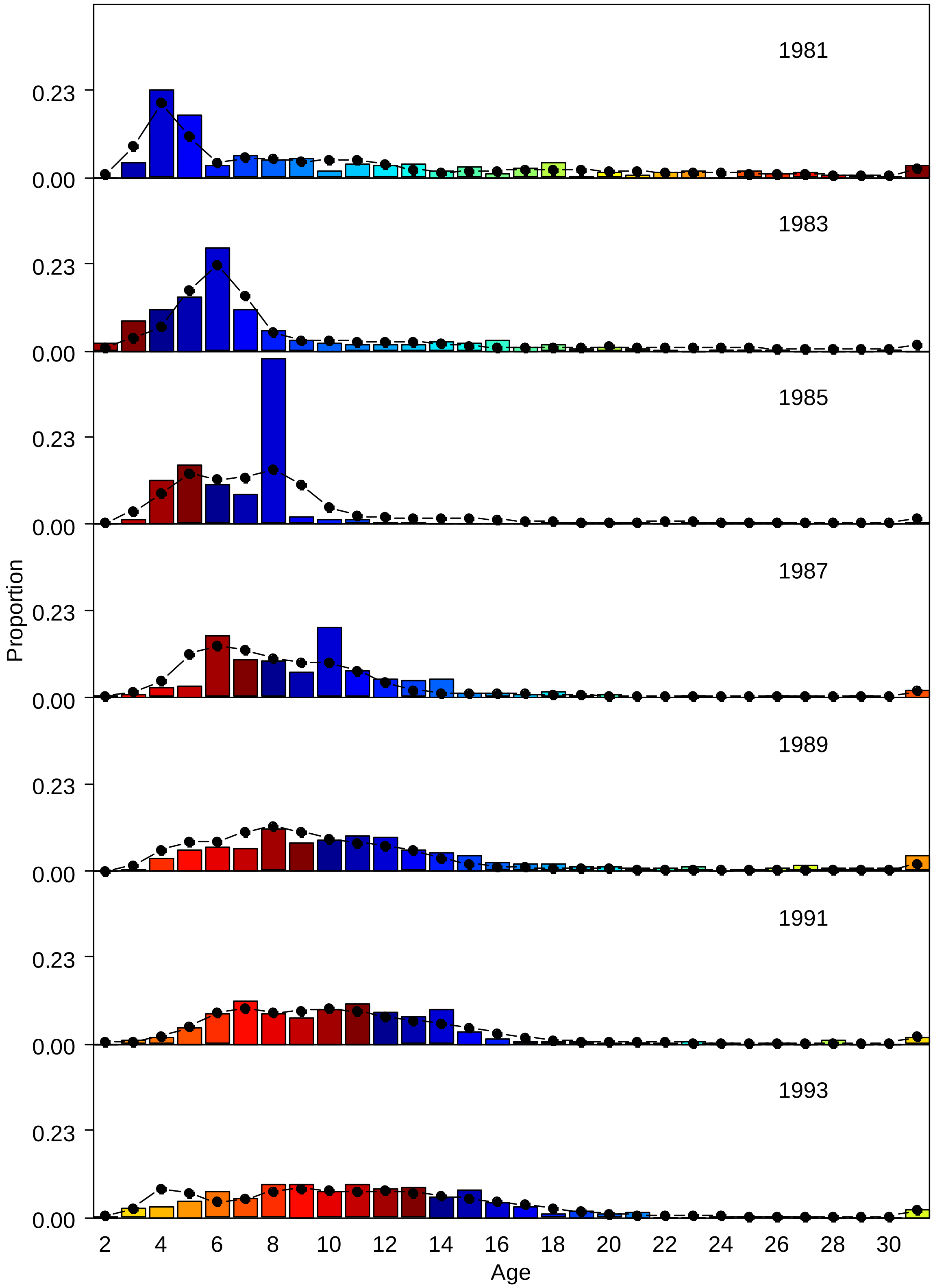

Figure 3.21. Japanese longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

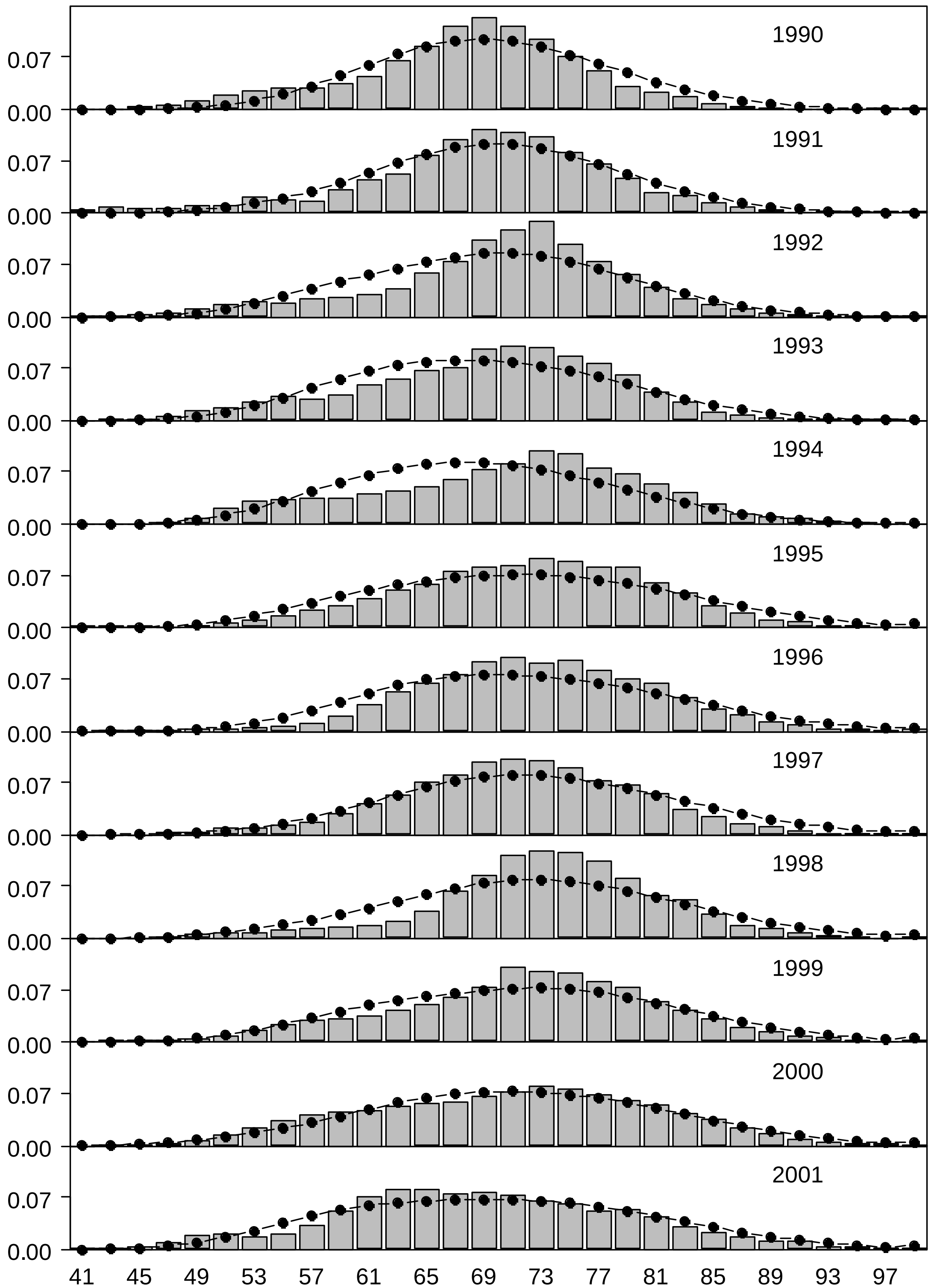

Figure 3.22. Domestic fixed gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

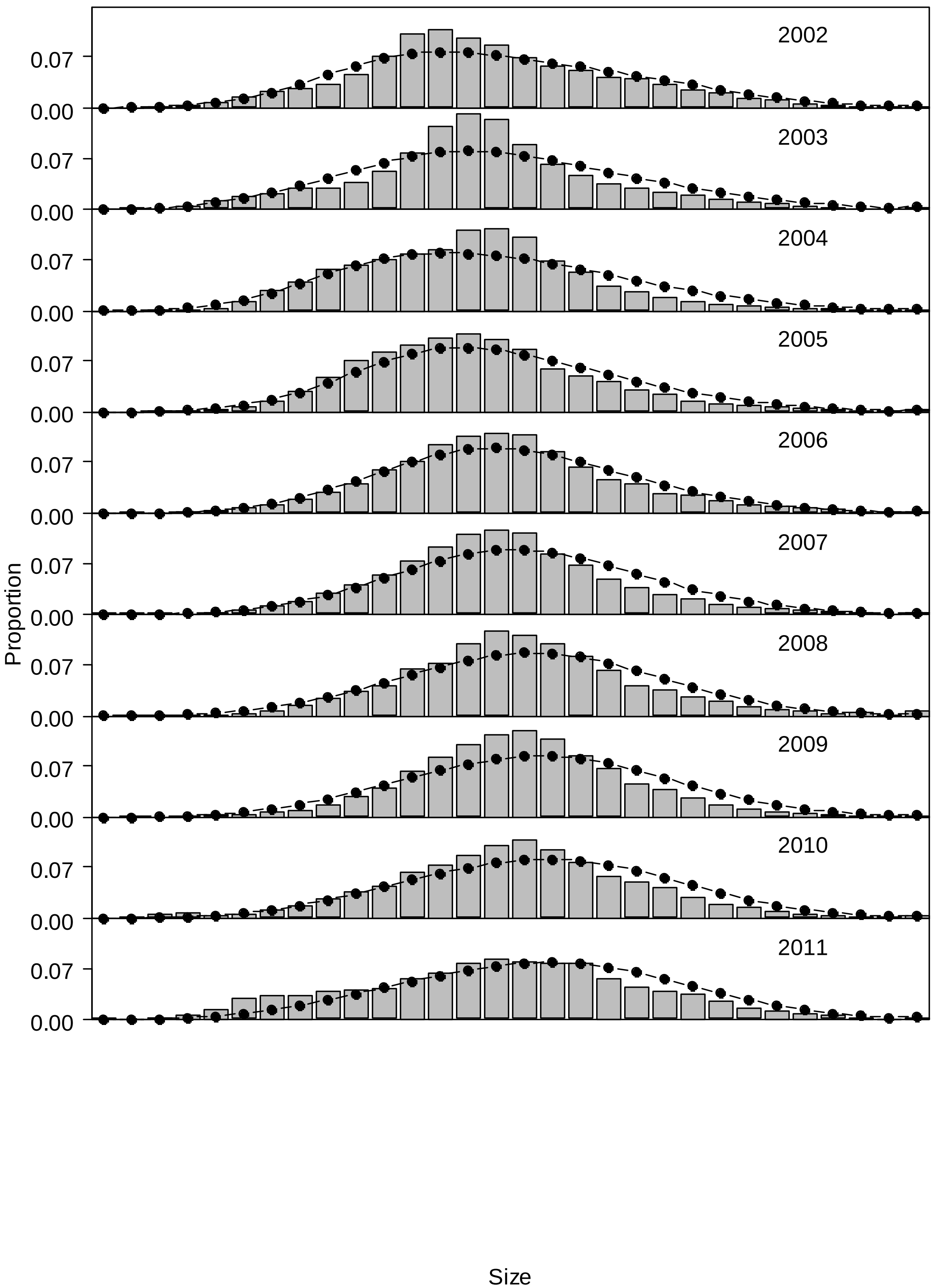

Figure 3.22 (cont.). Domestic fixed gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

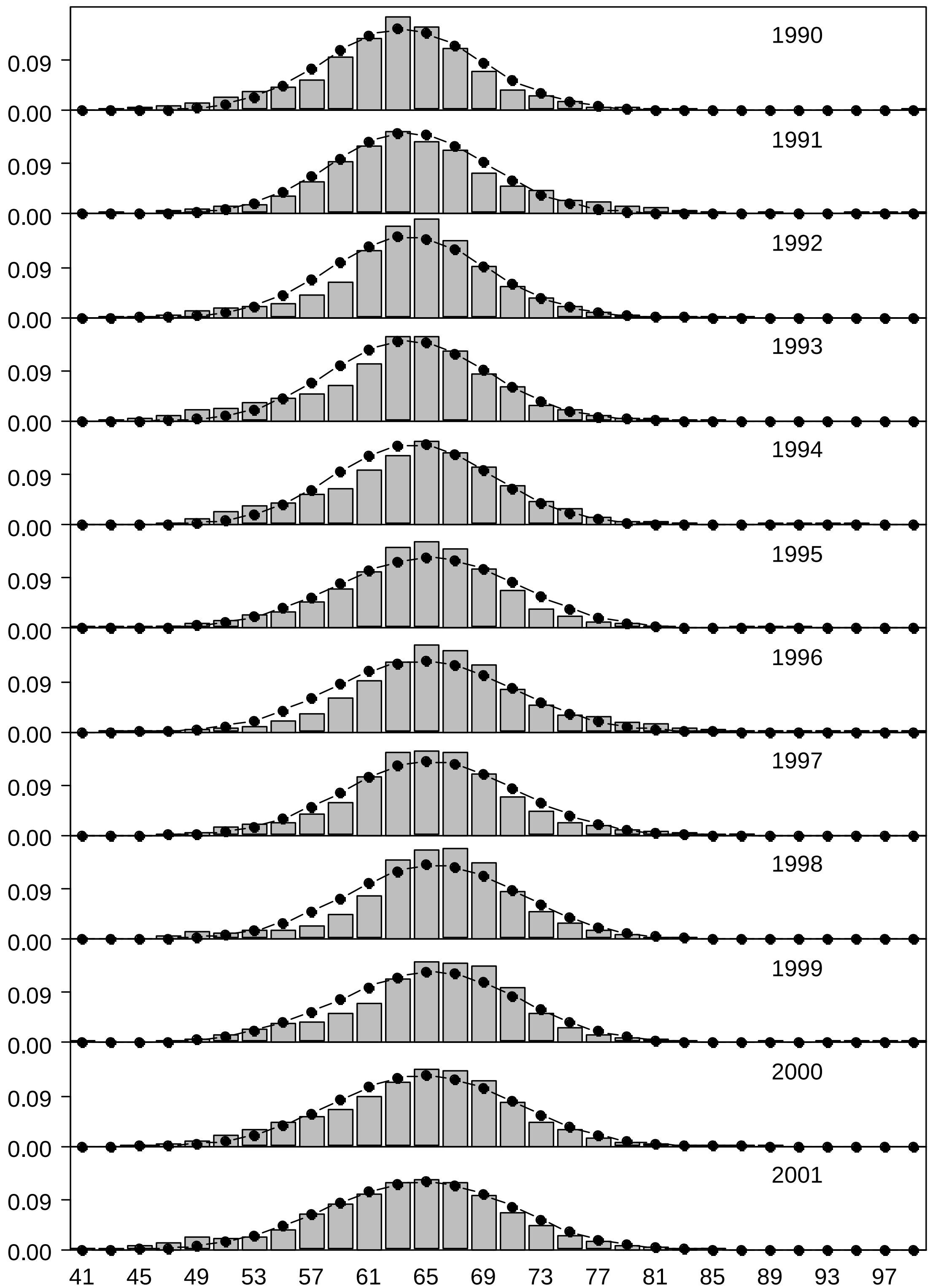

Figure 3.23. Domestic fixed gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

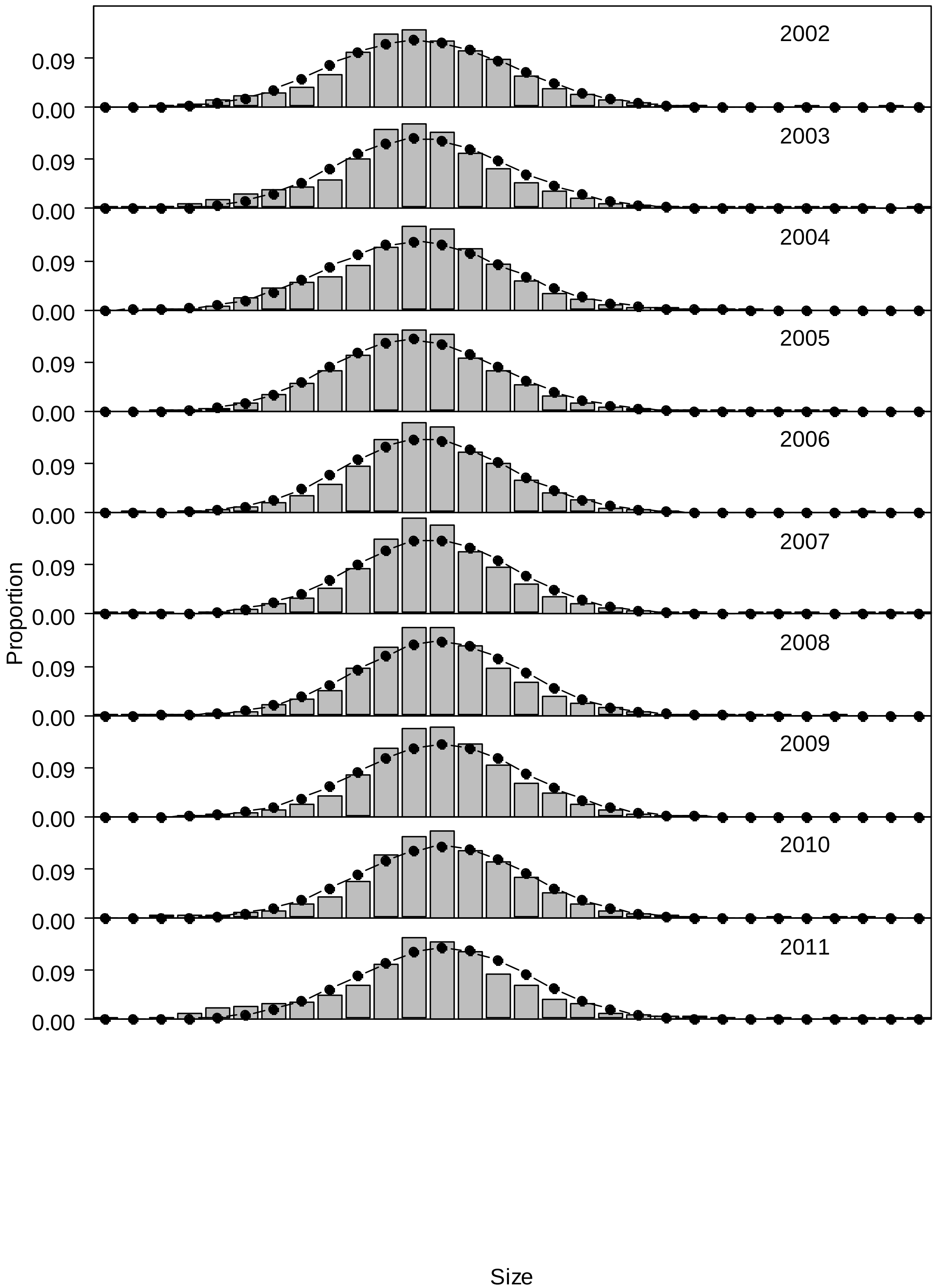

Figure 3.23 (cont.). Domestic fixed gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

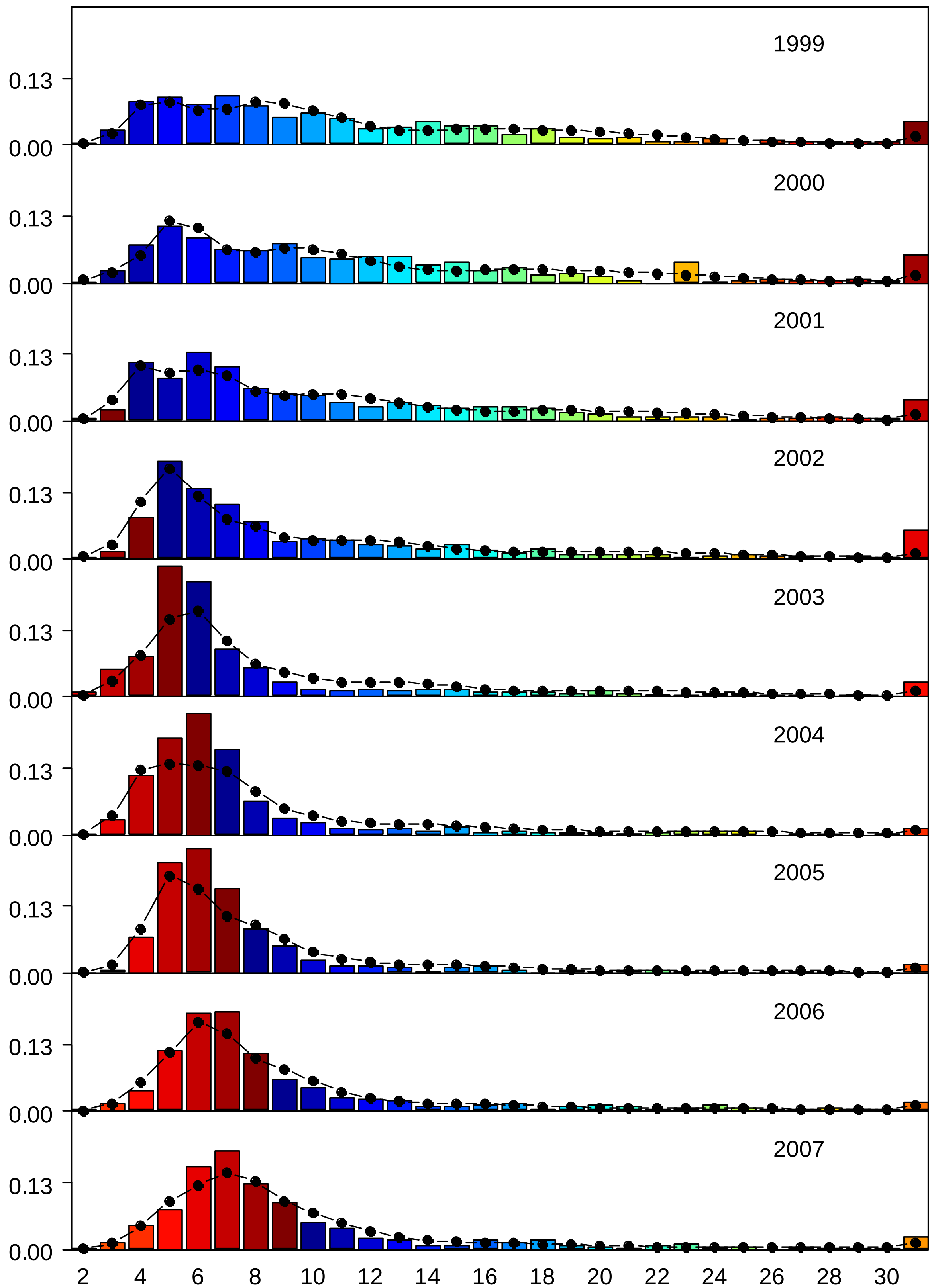

Figure 3.24. Domestic fishery age compositions. Bars are observed frequencies and lines are predicted frequencies.

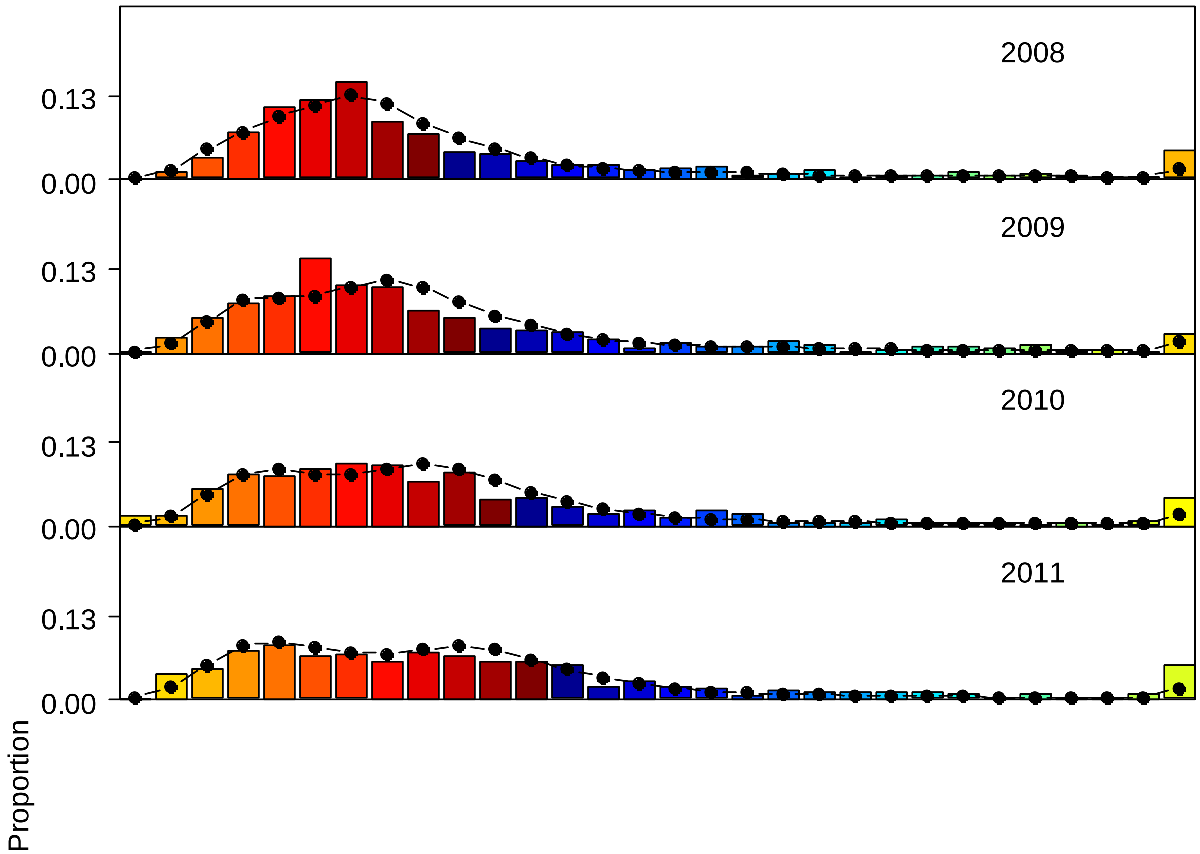

Figure 3.24 (cont.). Domestic fishery age compositions. Bars are observed frequencies and lines are predicted frequencies.

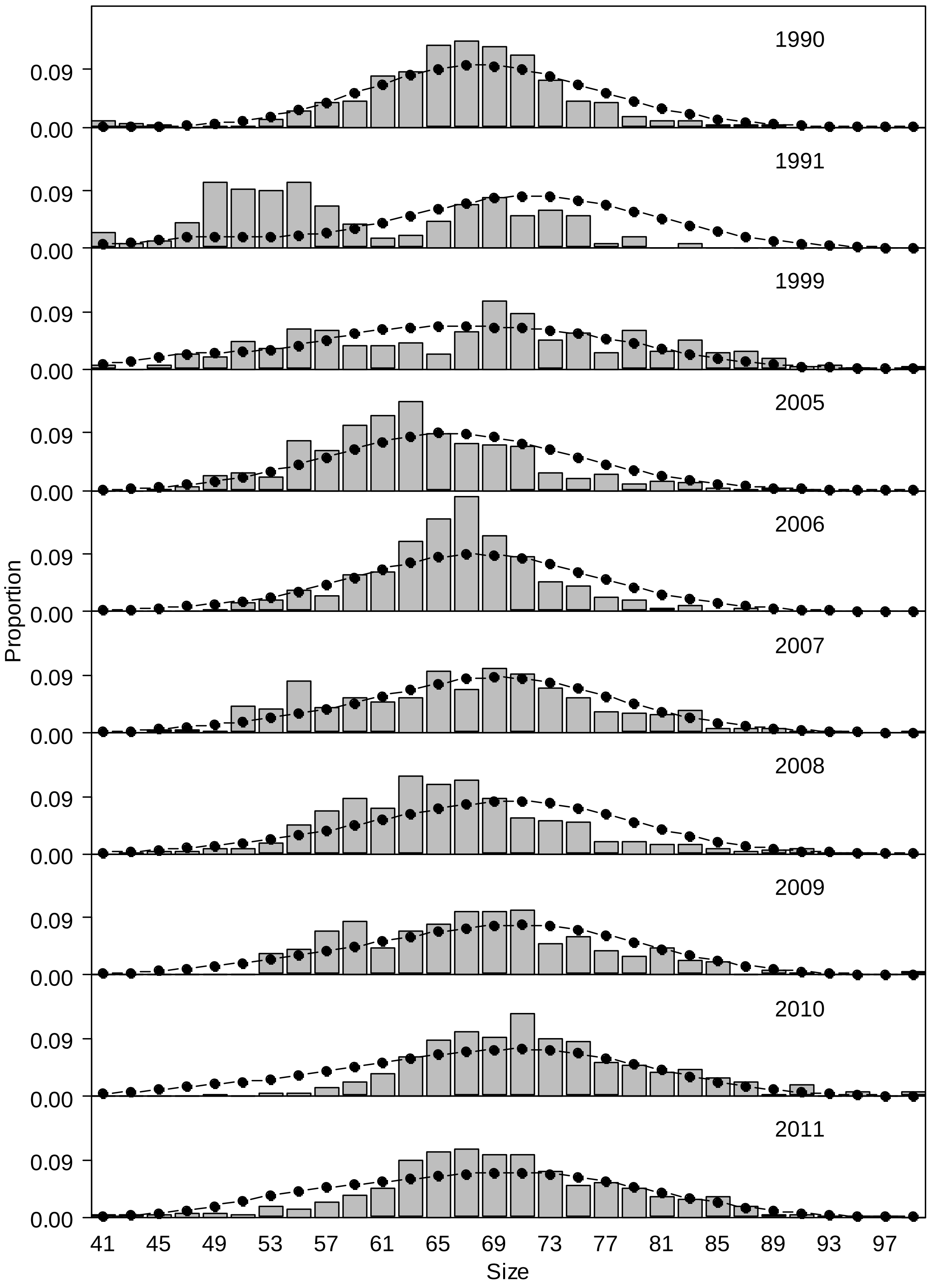

Figure 3.25a. Domestic trawl gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

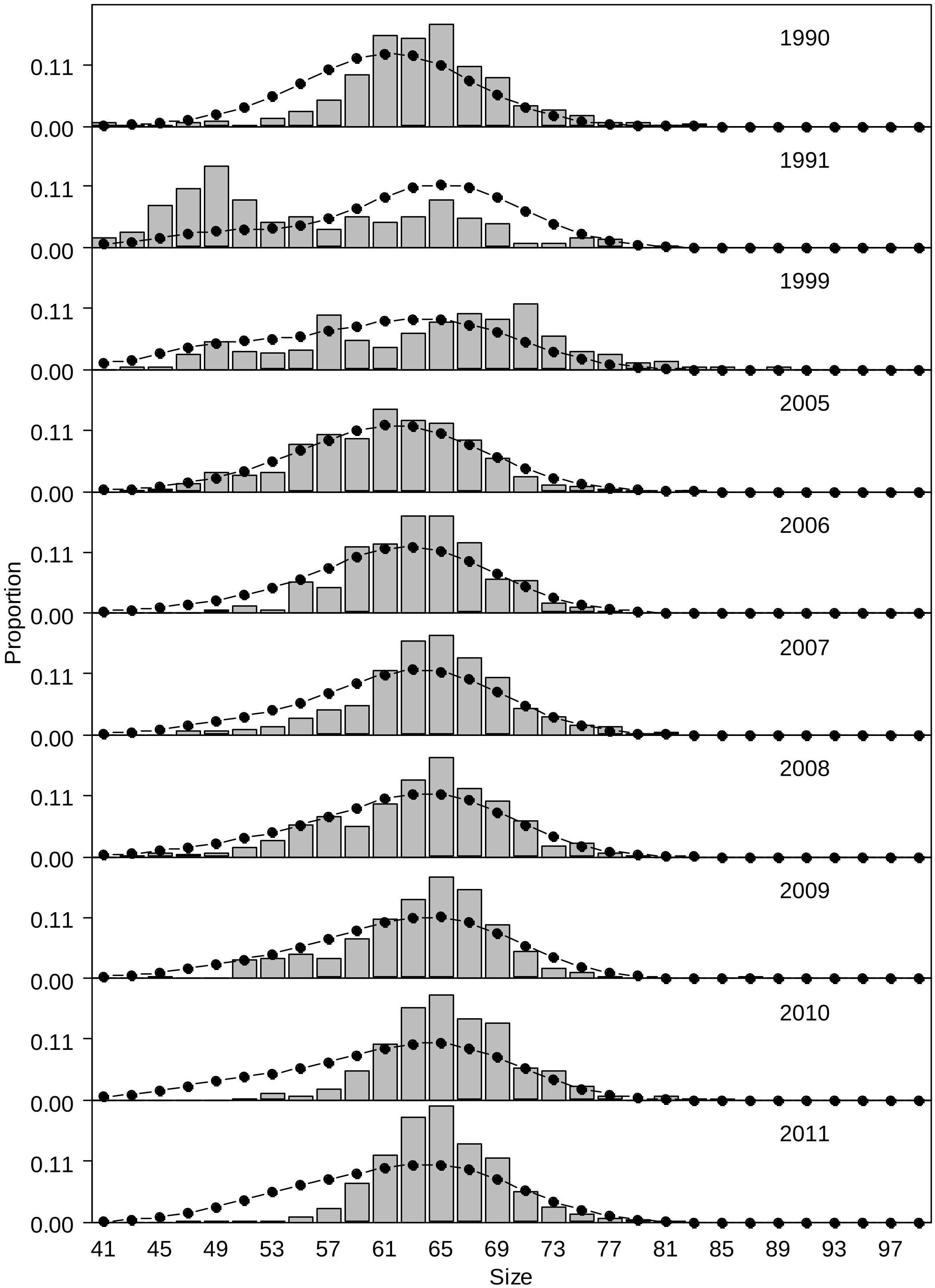

Figure 3.25b. Domestic trawl gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

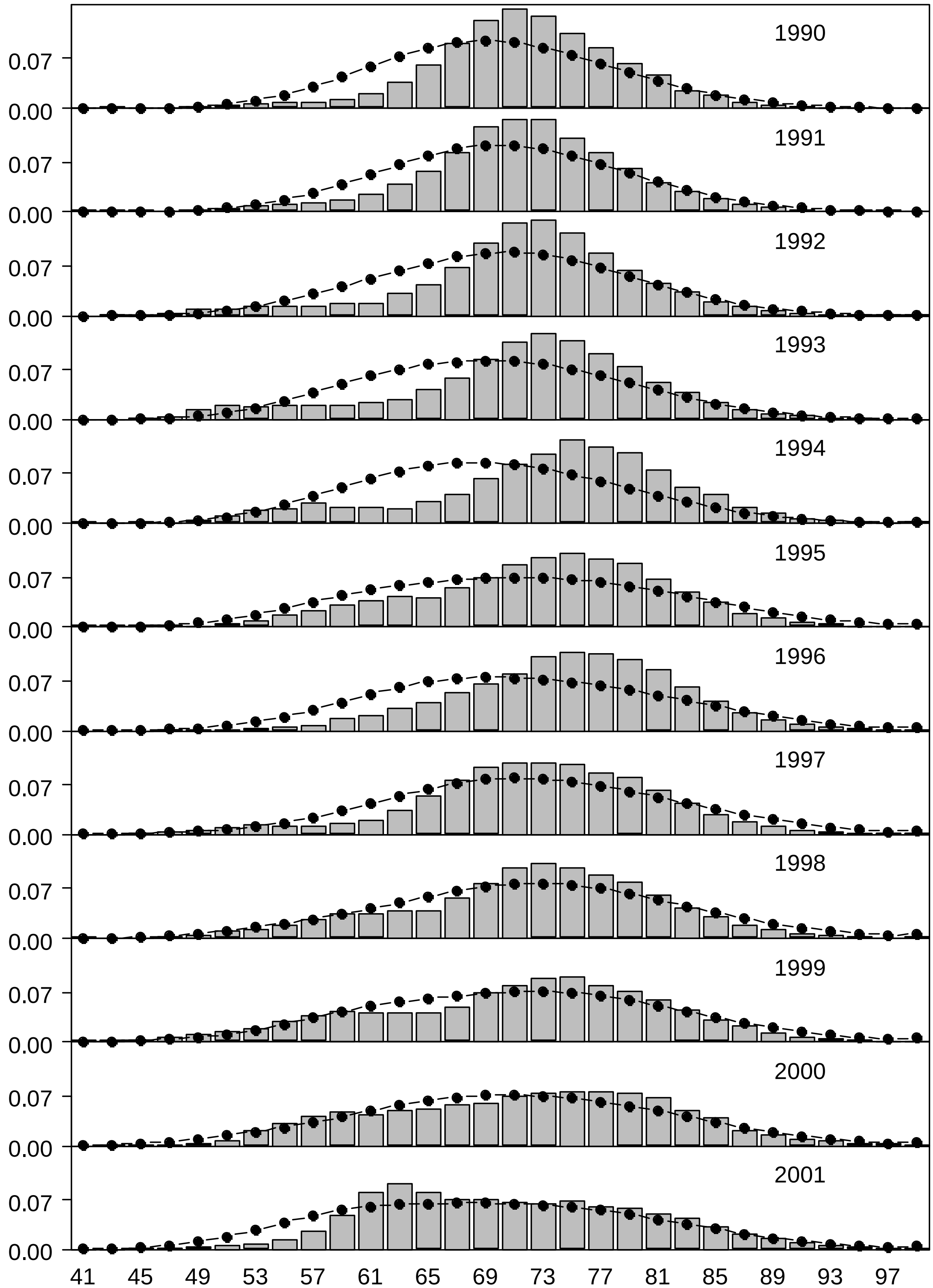

Figure 3.26. Domestic longline survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

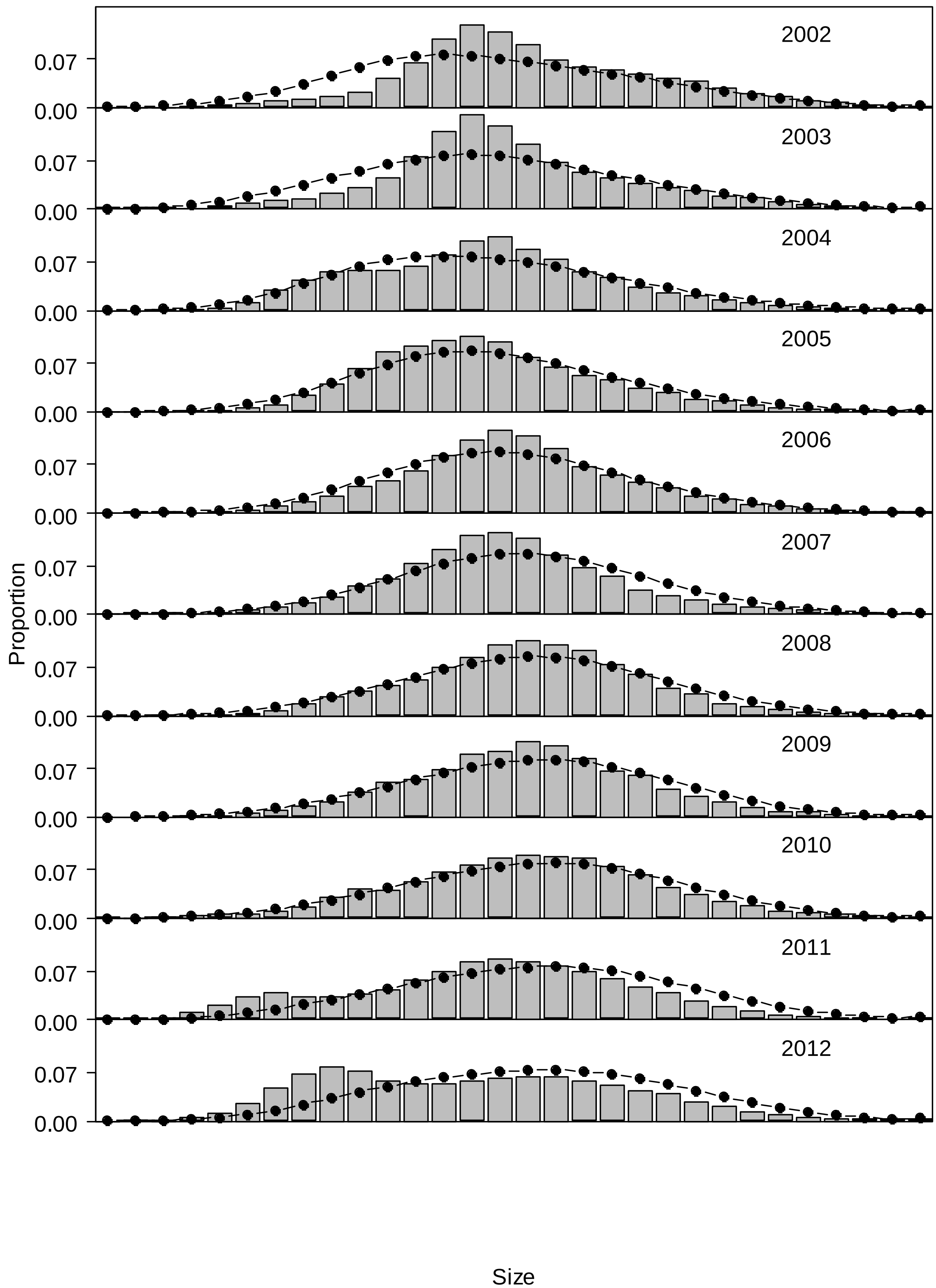

Figure 3.26 (cont.). Domestic longline survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

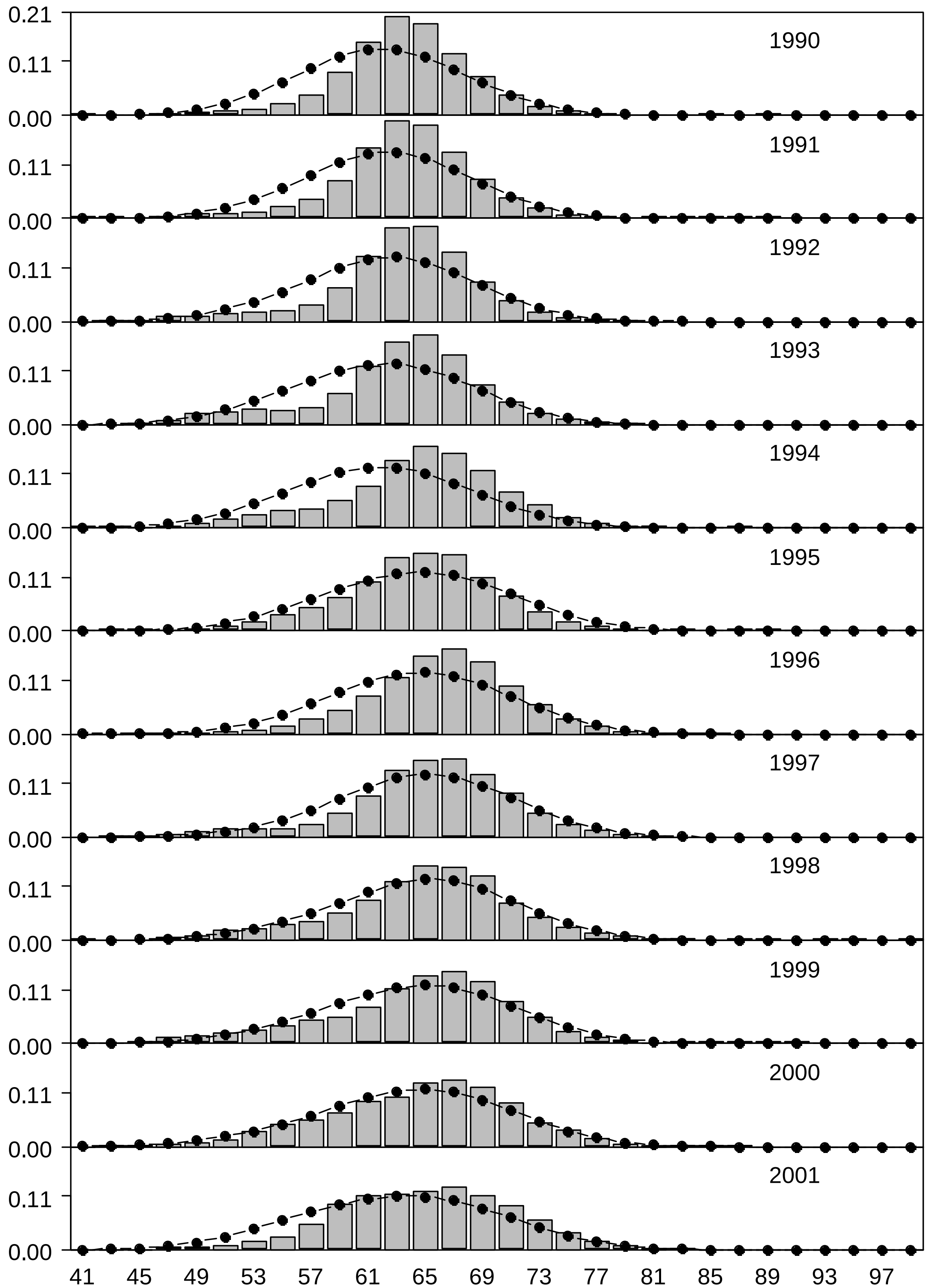

Figure 3.27. Domestic longline survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

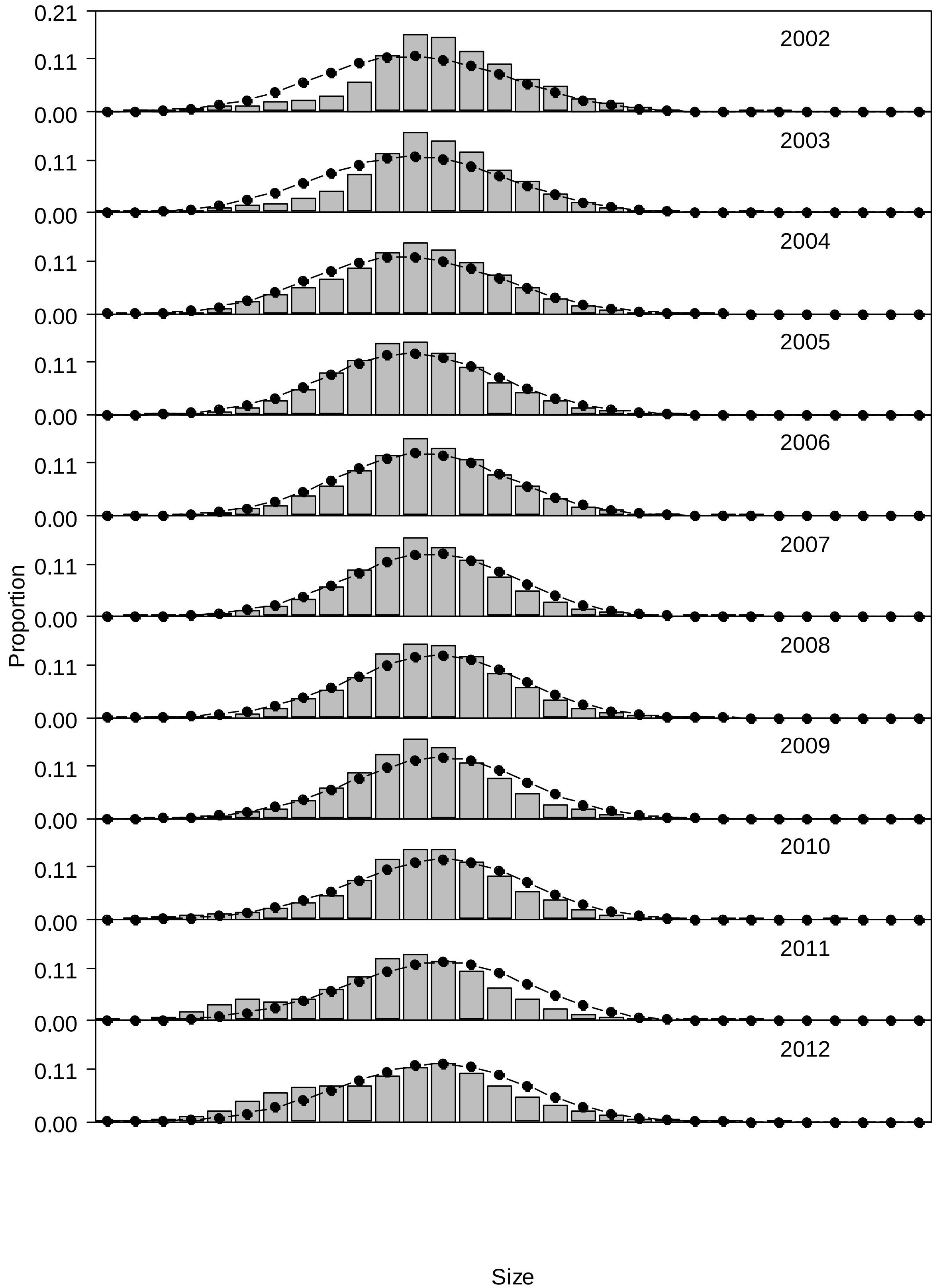

Figure 3.27.(cont.). Domestic longline survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

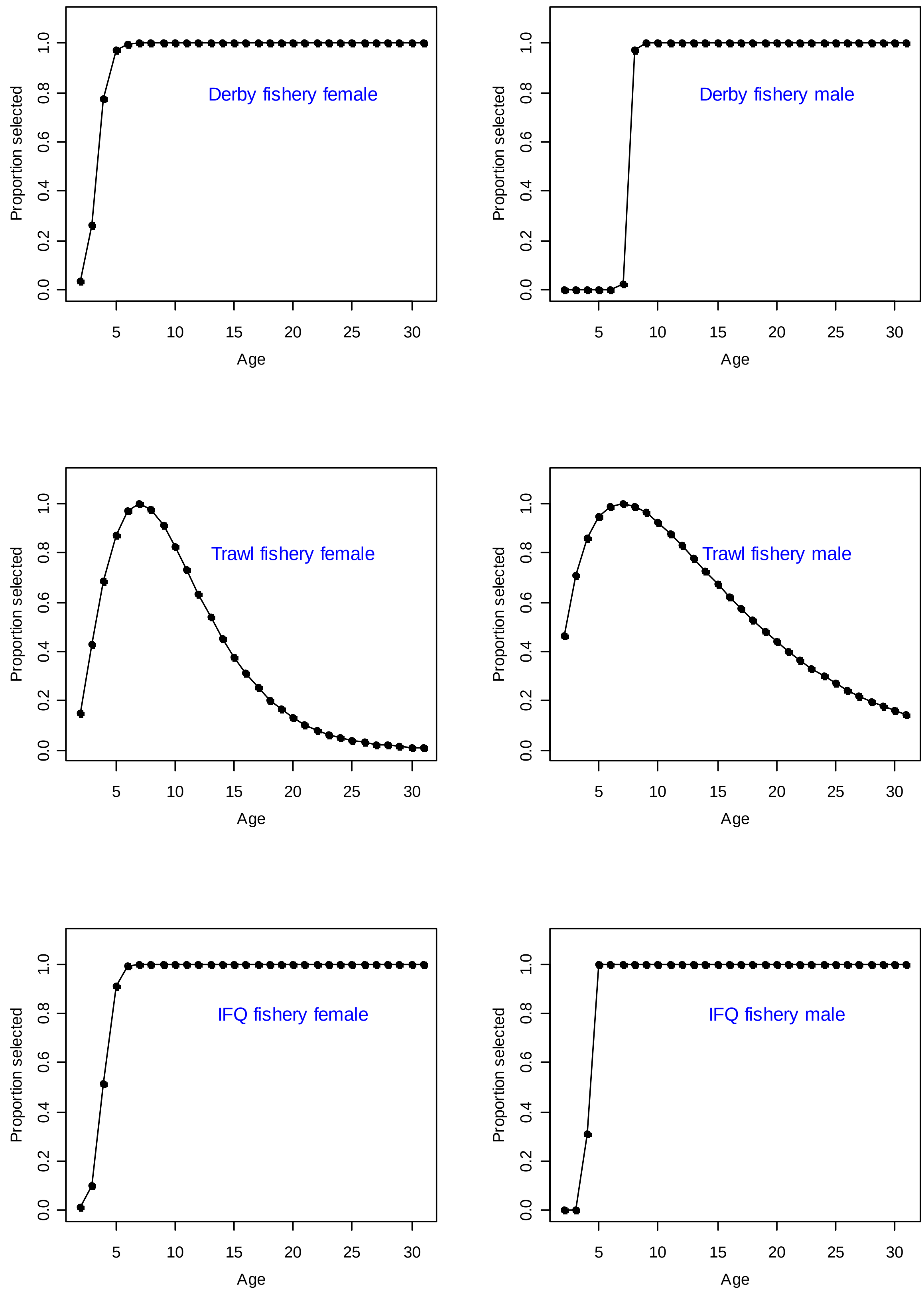

Figure 3.28. Sablefish selectivities for fisheries.

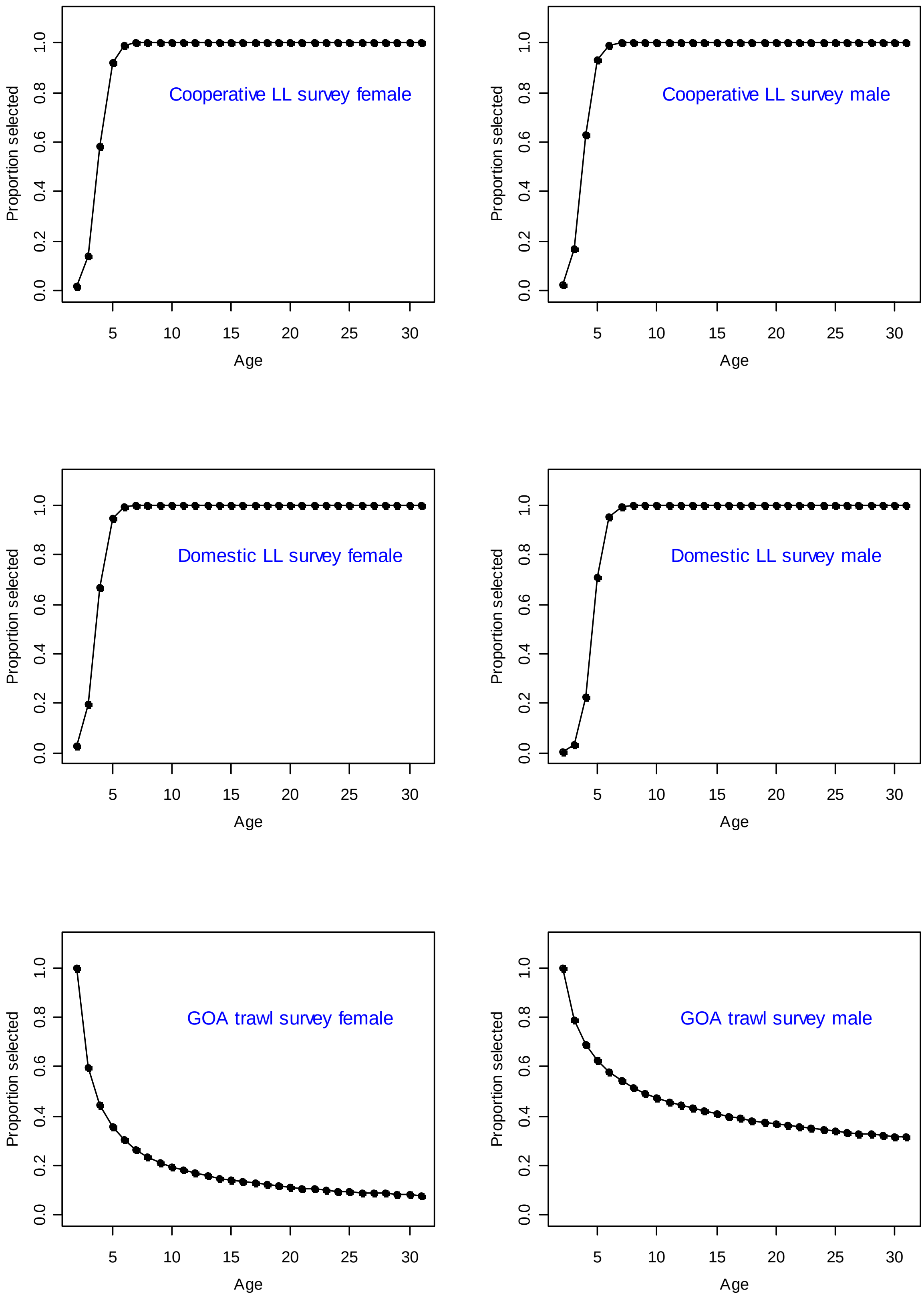

Figure 3.28 (cont.). Sablefish selectivities for surveys.

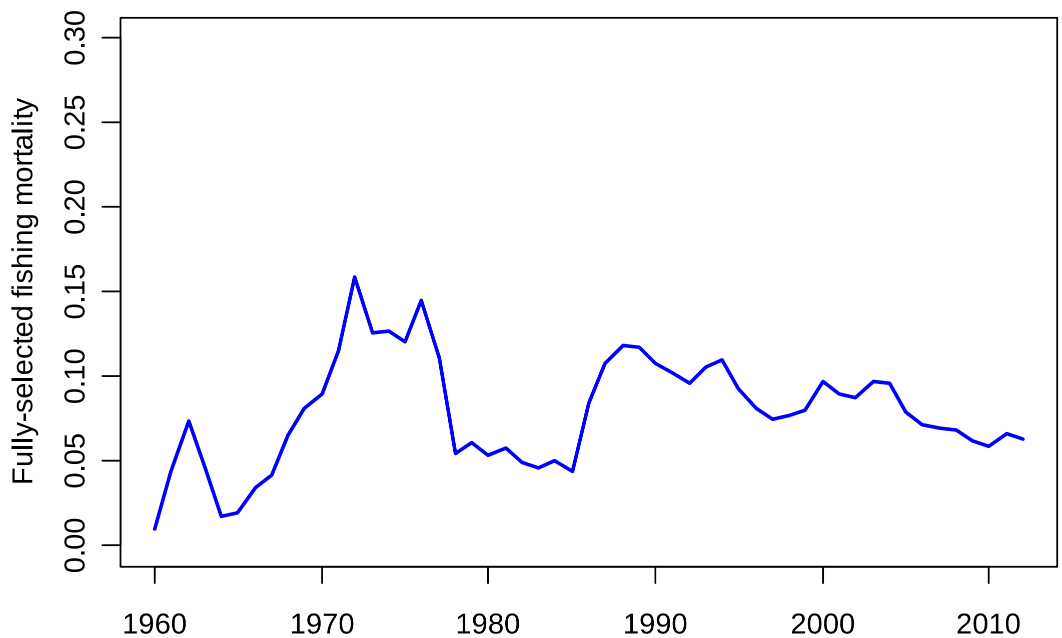

Figure 3.29. Time series of combined fully-selected fishing mortality for fixed and trawl gear for sablefish.

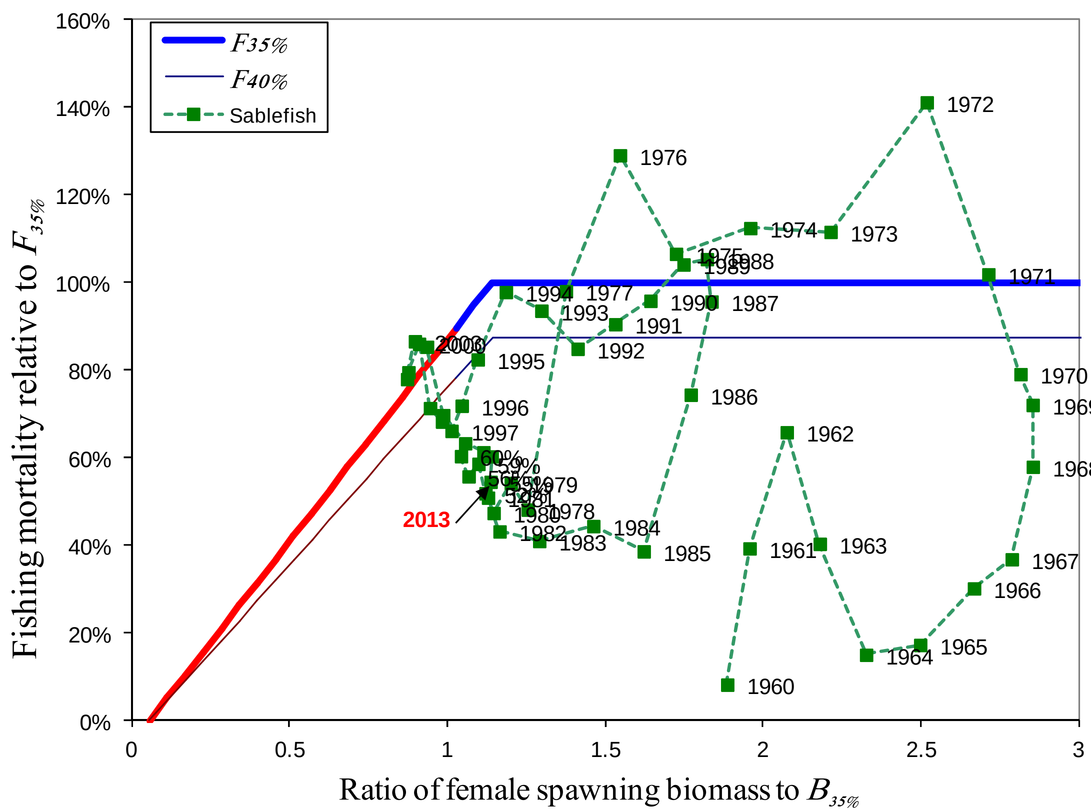

Figure 3.30. Phase-plane diagram of time series of sablefish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

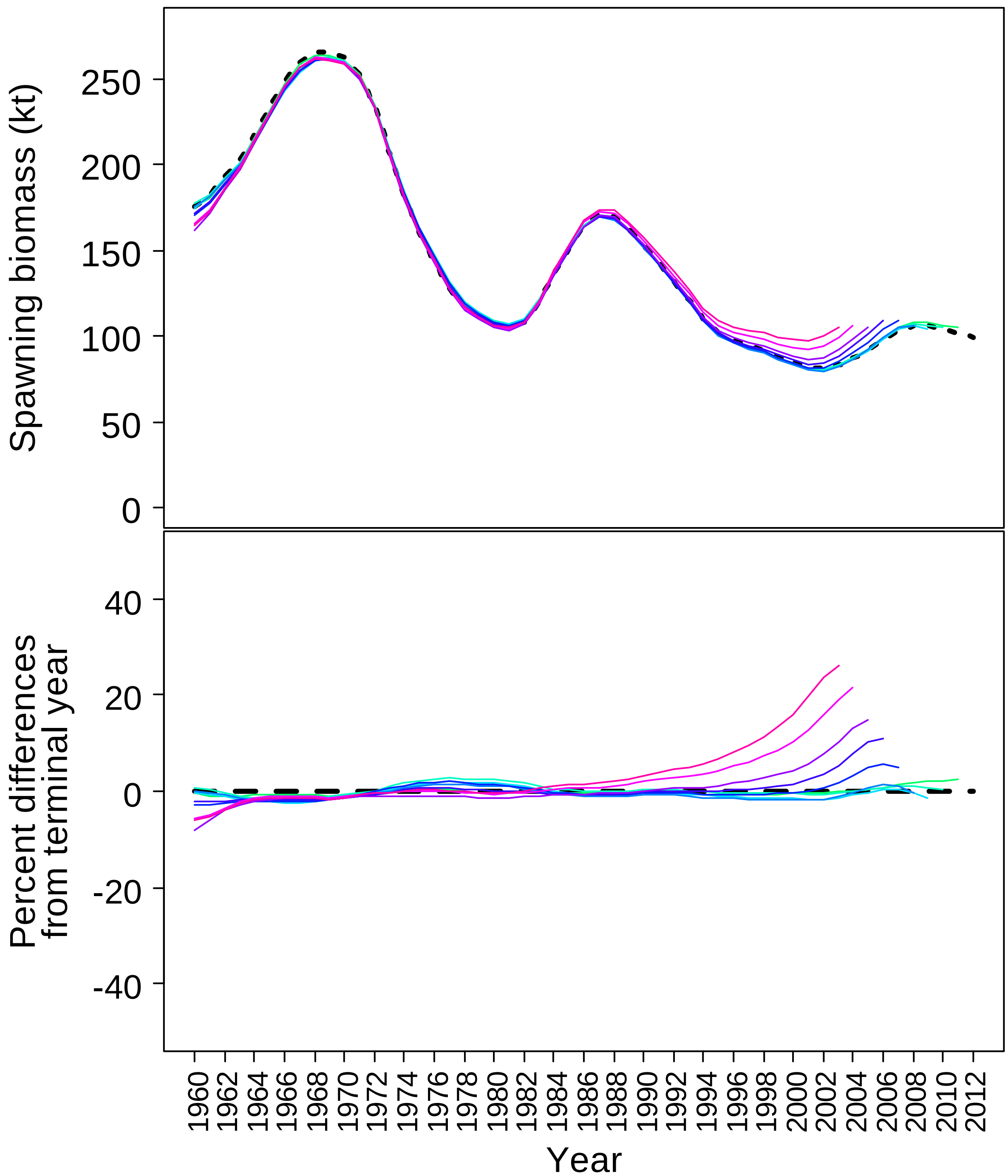

Figure 3.31. Retrospective trends for spawning biomass (top) and percent difference from terminal year (bottom) from 2002-2012.

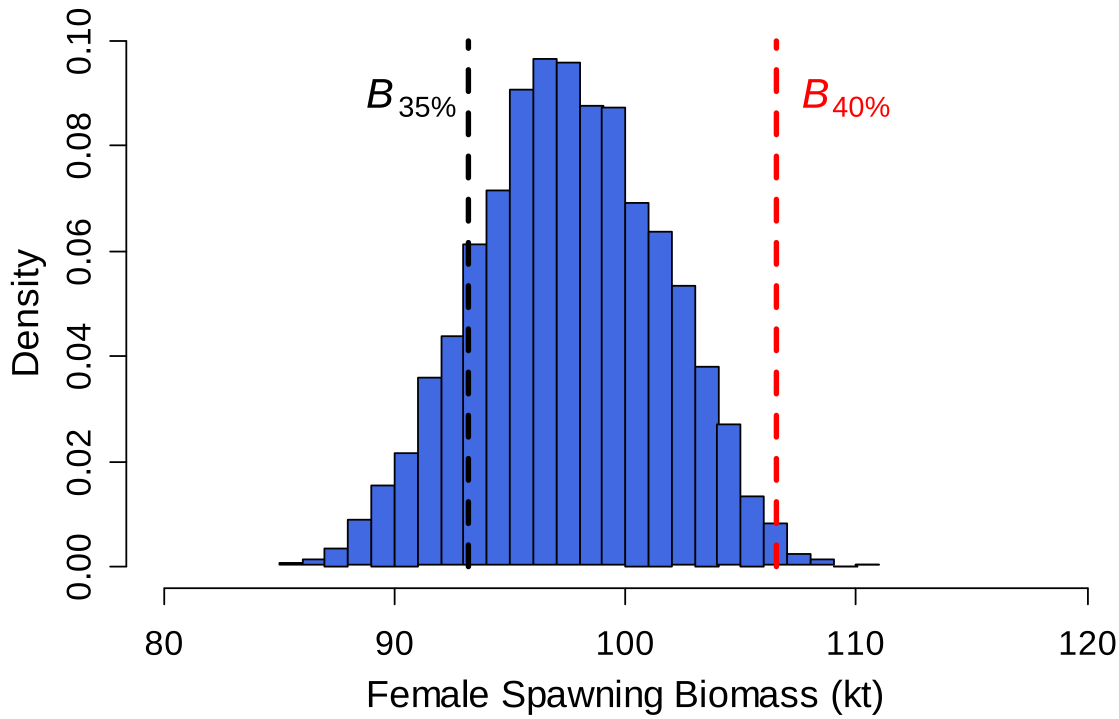

Figure 3.32. Posterior probability distribution for projected spawning biomass (thousands t) in 2013.

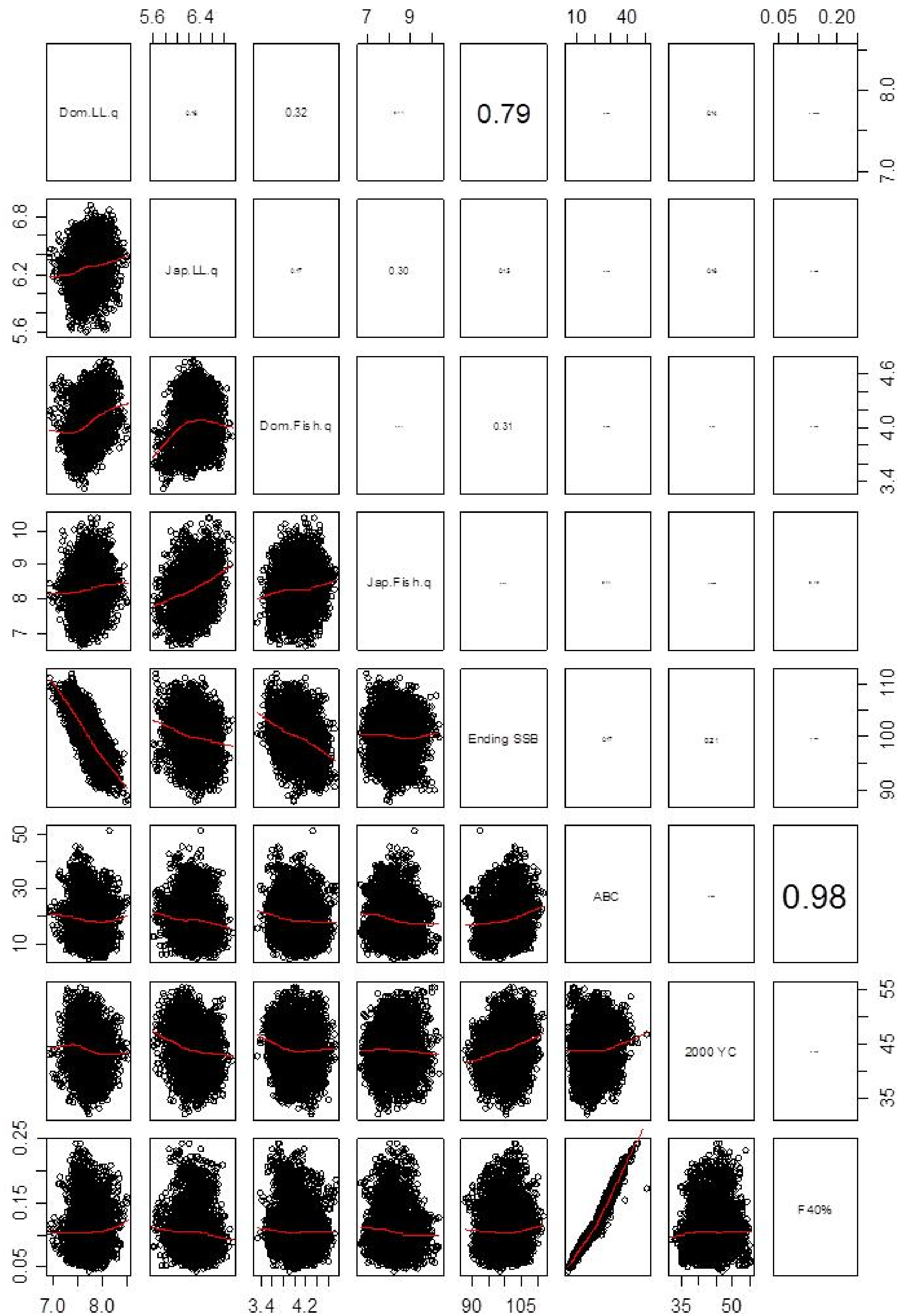

Figure 3.33. Pairwise scatterplots of key parameter MCMC runs. Red curve is loess smooth. Numbers in upper right hand panel are correlation coefficients between parameters.

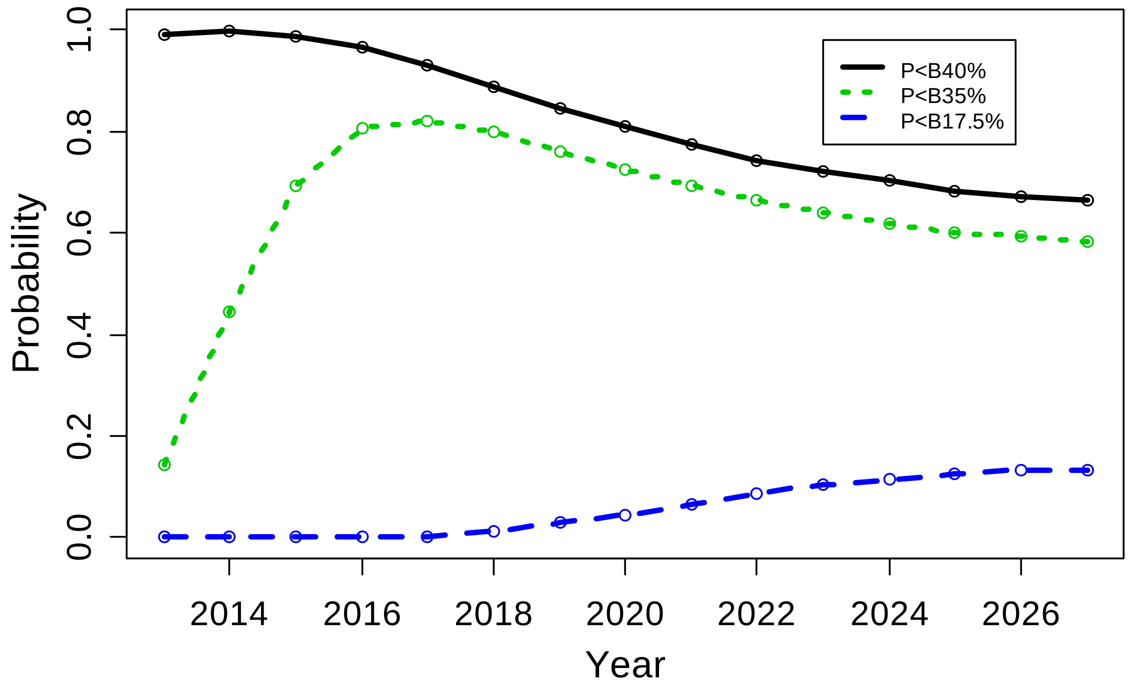

Figure 3.34. Probability that projected spawning biomass (from MCMC) will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

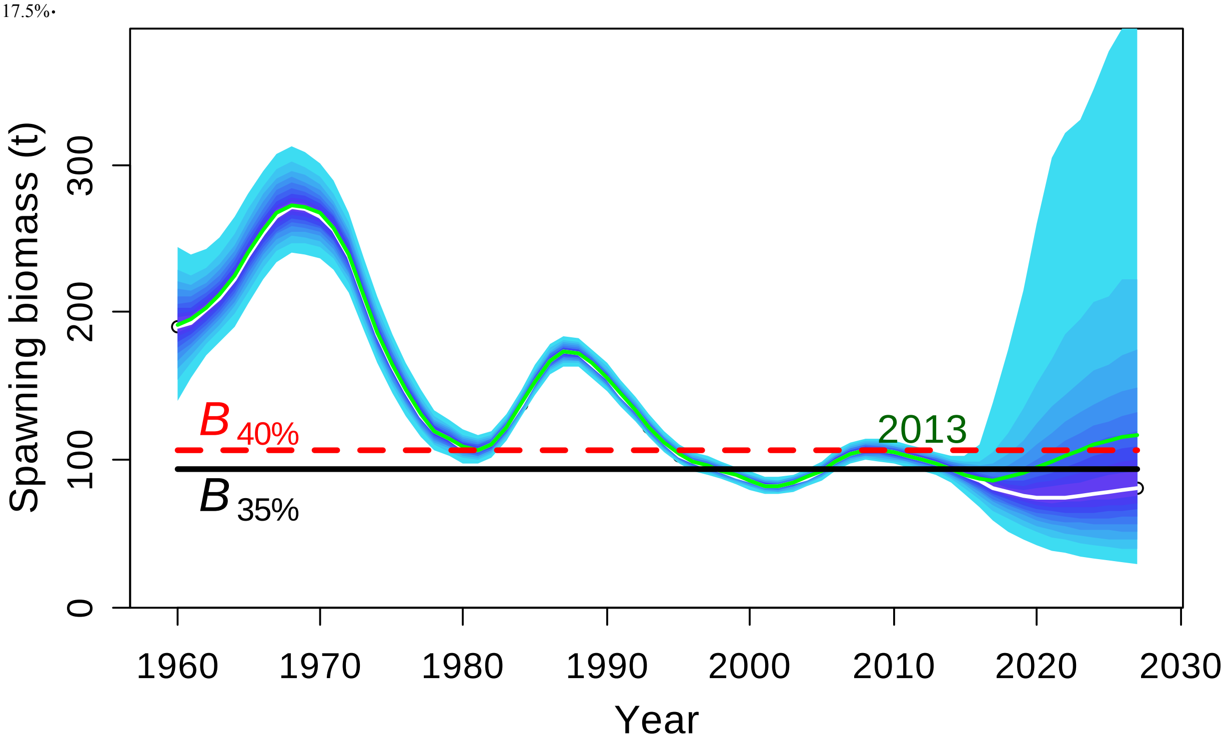

Figure 3.35. Estimates of female spawning biomass (thousands t) and their uncertainty. White line is the median and green line is the mean, shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 20,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval. Harvest policy is the same as the projections in Scenario 2 (Author's F).

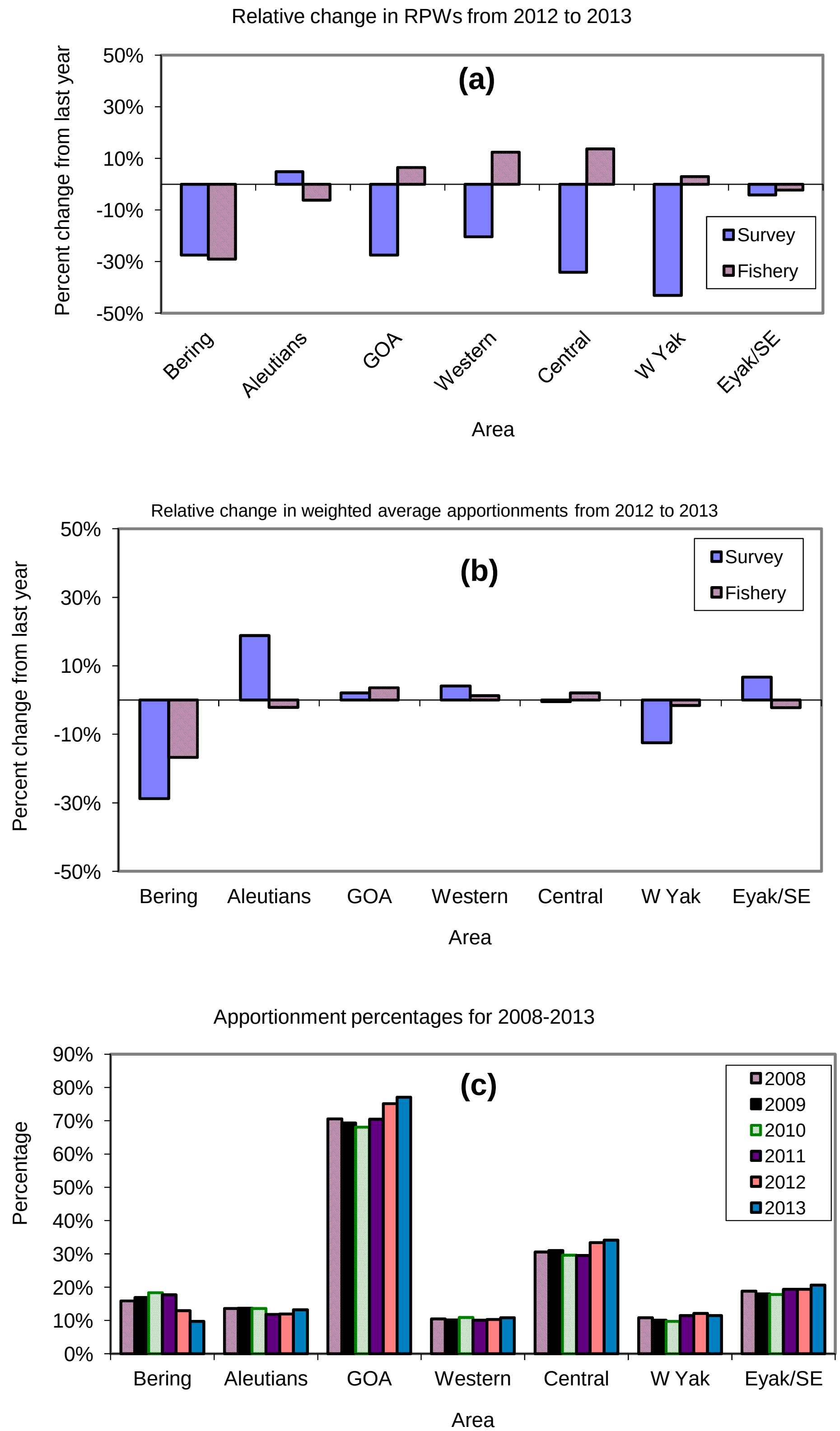

Figure 3.36. (a) The percentage change of each Relative Population Weight (RPW) index by area from 2012 apportionment to the 2013 apportionment. (b) The percentage change of the weighted average of apportionment by area. (c) The apportionment percentages by area of ABCs for 2008-2013.

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
2012	5	5	0	0	0	0	5	5

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 but increased in 2012. Discussions with vessels encountered on the survey this year indicates an increasing level of "hired" skippers who are unaware of the survey schedule. Publicizing the survey schedule to skippers who aren't quota share holders should be improved. 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 was 2.2% of the 2011 recommended ABC of 16,040. Removals in 2011 were lower (312 t) and represent a relatively low risk to the sablefish stock. In 2011, we conducted a model run where these removals were accounted for in the stock assessment model, and it resulted 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.

Literature Cited

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Tribuzio, C.A., S. Gaichas, J. Gasper, H. Gilroy, T. Kong, O. Ormseth, J. Cahalan, J. DiCosimo, M. Furuness, H. Shen, and 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	**Assessment of the sablefish stock in Alaska (Hanselman et al. 2010)**	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		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
2011		9		273	39		312

* 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.