8. Assessment of the Flathead Sole Stock in the Gulf of Alaska

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Executive Summary

Changes in the Input Data

1) The fishery catch and length compositions for 2010 and 2011 (through Sept. 24, 2011) were incorporated in the model.
2) The 2009 fishery catch and length compositions were updated.
3) The 2011 GOA groundfish survey biomass estimate and length composition data were added to the model. Survey biomass increased from 225,377 t in 2009 to 235,639 t in 2011. Survey biomass estimates and length compositions were recalculated for all survey years.
4) Age compositions from the 2001 and 2009 groundfish surveys were added to the model.

Changes in the Assessment Model

No changes were made to the structure of the assessment model.

Changes in the Assessment Results

1. Based on the assessment model, the recommended Tier 3a ABC, using an $F_{40\%}$ harvest level of 0.450, is 47,407 t for 2012 and 48,081 t for 2013.
2. The OFL, based on an $F_{35\%}$ harvest level of 0.593, is 59,380 t for 2012 and 60,219 t for 2013.
3. Projected female spawning biomass is estimated at 104,301 t for 2012 and 105,127 t for 2013.
4. Total biomass (age 3+) is estimated at 292,189 t for 2012 and 286,274 t for 2013.

The area apportionments corresponding to the recommended ABCs from the assessment model are:

	Western	Central	West Yakutat	Southeast Outside	Total
Area Apportionment	32.3%	54.5%	9.6%	3.6%	100.0%
2012 ABC (t)	15,300	25,838	4,558	1,711	47,407
2013 ABC (t)	15,518	26,205	4,623	1,735	48,081

A summary of important reference values from the preferred model for this assessment, relative to the 2010 SAFE projections, is as follows:

Quantity	As estimated or specified last year (2010)		As estimated or specified this year (2011)	
	2011	2012	**2012**	**2013**
M (natural mortality)	0.2	0.2	**0.2**	**0.2**
Specified/recommended tier	3a	3a	**3a**	**3a**
Total biomass (Age 3+; t)	325,357	321,355	**292,189**	286,274
Female Spawning Biomass (t)	113,406	115,427	**104,301**	105,127
$B_{100\%}$	111,884	111,884	**103,868**	103,868
$B_{40\%}$	44,754	44,754	**41,547**	41,547
$B_{35\%}$	39,159	39,159	**36,354**	36,354
$F_{OFL} = F_{35\%}$	0.530	0.530	**0.593**	0.593
$max\ F_{ABC} = F_{40\%}$	0.406	0.406	**0.450**	0.450
recommended F_{ABC}	0.406	0.406	**0.450**	0.450
OFL (t)	61,412	63,202	**59,380**	60,219
max ABC (t)	49,133	50,591	**47,407**	48,081
ABC (t)	49,133	50,591	**47,407**	48,081
Status	**As determined last year (2010) for:**		**As determined this year (2011) for:**	
	2009	2010	**2010**	**2011**
Overfishing	no	n/a	**no**	n/a
Overfished	n/a	no	n/a	**no**
Approaching overfished	n/a	no	n/a	**no**

Plan Team Summary Tables

Species	Year	Biomass[1]	OFL[2,3]	ABC[2,3]	TAC[2,3]	Catch[4]
Flathead sole	2010	303,140	59,295	47,422	10,411	3,842
	2011	297,130	61,412	49,133	10,587	2,339
	2012	292,189	59,380	47,407		
	2013	286,274	60,219	48,081		

[1] Age 3+ biomass from the assessment model.
[2] http://www.fakr.noaa.gov/sustainablefisheries/specs10_11/goa_table1.pdf
[3] http://www.fakr.noaa.gov/sustainablefisheries/specs11_12/goa_table1.pdf
[4] As of Sept. 24, 2011.

Stock/ Assemblage	Area	2011 OFL[1]	2011 ABC[1]	2011 TAC[1]	2011 Catch[2]	2012 OFL[3]	2012 ABC[3]	2013 OFL[3]	2013 ABC[3]
Flathead sole	W	--	17,442	2,000	341	--	15,300	--	15,518
	C	--	28,104	5,000	1,998	--	25,838	--	26,205
	WYAK	--	2,064	2,064	0	--	4,558	--	4,623
	SEO	--	1,523	1523	0	--	1,711	--	1,735
	Total	61,412	49,133	10,587	2,339	59,380	47,407	60,219	48,081

[1]http://www.fakr.noaa.gov/sustainablefisheries/specs11_12/goa_table1.pdf
[2]As of Sept. 24, 2011.
[3]Based on the assessment model.

SSC Comments Specific to the Flathead Sole Assessments

SSC request: *The SSC requested that the authors provide a graph allowing comparison of the fit of alternative models, including confidence intervals or SE's, to survey biomass to facilitate model comparison and evaluation of fits.*

Author response: We developed an R function that will allow this comparison among multiple models in the future (see Figure 6.8 in the GOA rex sole chapter for an example application). However, we did not evaluate alternative models in this assessment.

SSC Comments on Assessments in General

SSC request: *The SSC requested that the next round of assessments consider the possible use of ADF&G bottom trawl survey data to expand the spatial and depth coverage.*

Author response: The current assessment model does not accommodate surveys from multiple sources. We are developing a new assessment model that will incorporate surveys from multiple sources as one of its new features. When completed, this new model will allow us to explore the utility of using the ADF&G bottom trawl survey data in future assessments.

Introduction

Flathead sole (*Hippoglossoides elassodon*) are distributed from northern California, off Point Reyes, northward along the west coast of North America and throughout the GOA and the BS, the Kuril Islands, and possibly the Okhotsk Sea (Hart 1973). They occur primarily on mixed mud and sand bottoms (Norcross et al., 1997; McConnaughey and Smith, 2000) in depths < 300 m (Stark and Clausen, 1995). The flathead sole distribution overlaps with the similar-appearing Bering flounder (*Hippoglossoides robustus*) in the northern half of the Bering Sea and the Sea of Okhotsk (Hart, 1973), but not in the Gulf of Alaska.

Adults exhibit a benthic lifestyle and occupy separate winter spawning and summertime feeding distributions on the EBS shelf and in the GOA. From over-winter grounds near the shelf margins, adults begin a migration onto the mid and outer continental shelf in April or May each year for feeding. The spawning period may range from as early as January but is known to occur in March and April, primarily in deeper waters near the margins of the continental shelf. Eggs are large (2.75 to 3.75 mm) and females have egg counts ranging from about 72,000 (20 cm fish) to almost 600,000 (38 cm fish). Eggs hatch in 9 to 20 days depending on incubation temperatures within the range of 2.4 to 9.8°C and have been found in ichthyoplankton sampling on the southern portion of the BS shelf in April and May (Waldron 1981). Larvae absorb the yolk sac in 6 to 17 days, but the extent of their distribution is unknown. Nearshore sampling indicates that newly settled larvae are in the 40 to 50 mm size range (Norcross et al. 1996). Fifty percent of flathead sole females in the GOA are mature at 8.7 years, or at about 33 cm (Stark, 2004). Juveniles less than age 2 have not been found with the adult population and probably remain in shallow nearshore nursery areas.

Fishery

Flathead sole in the Gulf of Alaska are caught in a directed fishery using bottom trawl gear. Typically 25 or fewer shore-based catcher vessels from 58-125’ participate in this fishery, as do 5 catcher-processor vessels (90-130’). Fishing seasons are driven by seasonal halibut PSC apportionments, with approximately 7 months of fishing occurring between January and November. Catches of flathead sole occur only in the Western and Central management areas in the gulf (statistical areas 610 and 620 + 630, respectively). Recruitment to the fishery begins at about age 3.

Historically, catches of flathead sole have exhibited decadal-scale trends (Table 8.1, Fig. 8.1). From a high of ~2000 t in 1980, annual catches declined steadily to a low of ~150 t in 1986 but thereupon increased steadily, reaching a high of ~3100 t in 1996. Catches subsequently declined over the next three years, reaching a low of ~900 t in 1999, followed by an increasing trend through 2010, when the catch reached its highest level ever (3,842 t). As of Sept. 24, the catch in 2011 was 2,310 t. Based on the trend in weekly cumulative catch, the total 2011 catch is projected to be2,891 t—almost one quarter less than in 2010.

Based on observer data, the majority of the flathead sole catch in the Gulf of Alaska is taken in the Shelikof Strait and on the Albatross Bank near Kodiak Island, as well as near Unimak Island (Figure 8.2). The spatial pattern of catches has been reasonably consistent over the past three years. Most of the catch is taken in the first and second quarters of the year (Figure 8.3).

Annual catches of flathead sole have been well below TACs in recent years, although the population appears to be capable of supporting higher exploitation rates (Table 8.2a). Limits on flathead sole catches are driven by within-season closures of the directed fishery due to restrictions on halibut PSC, not by attainment of the TAC (Table 8.2b). Recognizing this, TACs have typically been set much lower than the recommended ABC. Prior to 2003, flathead sole was a Tier 5 species and ABC’s were based on natural mortality rates. Following the development and adoption of an age-structured assessment model in 2003, ABCs for flathead sole in the Gulf of Alaska almost doubled from 2002 to 2003, from ~23,000 to 42,000 t. TACs, however, increased only moderately as a result.

Flathead sole are also caught in the pursuit of other species as bycatch. They are caught in the Pacific cod, bottom pollock and other flatfish fisheries and are caught with these species in the flathead sole-directed fishery. The gross retention rate for flathead sole over all fisheries has been 87% or larger since 2005, and higher than 95% since 2009 (Table 8.2a).

Data

Fishery Data

This assessment used fishery catches from 1984 through Sept. 24, 2011 (Table 8.1, Fig. 8.1), as well as estimates of the proportion of individuals caught by length group and sex for the years 1985-2011 from fishery observer sampling (as of Sept. 24; Tables 8.3a, b). Sample sizes for the size compositions are shown in Table 8.4a. Age composition data from the fishery is not currently used in the assessment model. Limited age data is available from observer sampling for this stock, although some ageing of observer samples has been completed.

Survey Data

Because flathead sole are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries seldom reflects trends in abundance for this species. It is therefore necessary to use fishery-independent survey data to assess the condition of this stock.

This assessment used estimates of total biomass for flathead sole in the Gulf of Alaska from triennial (1984-1999) and biennial (2001-2011) groundfish surveys conducted by the Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering (RACE) division to provide an index of population abundance (Table 8.5, Figure 8.4). Although survey depth coverage has been inconsistent for depth strata > 500 m, the fraction of the flathead sole stock occurring in these depth strata is miniscule (Table 8.6), so we have not attempted to correct the survey estimates of total biomass for missing depth strata. In addition, the 2001 survey estimate did not sample the eastern section of the Gulf. We estimated the average fraction of stock biomass occurring in the unsampled area from the 1993, 1996 and 1999 surveys (~11%) and assigned a corresponding availability factor of 0.9 to the 2001 survey to correct for the missing area (Table 8.5). Since 1984, survey estimates of total biomass have fluctuated about a mean of ~220,000 t with no apparent trend. Estimated total biomass was ~236,000 t in 2011, a 5% increase from the 2009 survey estimate of ~225,000 t (the largest in the time series) but a 16% decrease over the 2007 estimate of ~280,000 t, the largest in the time series.

Size and age compositions (numbers of individuals by size or age group) from the RACE GOA groundfish surveys were also incorporated into the assessment model (Tables 8.7-8). Survey size compositions were available for every survey year, while age compositions were available for all surveys except the most recent (2011). Because age compositions were calculated from age-length data using the corresponding size compositions, size compositions were de-weighted in the model likelihood for years where age composition data was also available to avoid double counting. Survey size composition data was fully weighted in the model likelihood only for years when age composition data was unavailable (2011). Sample sizes for the survey size and age compositions are given in Table 8.4b.

Data on individual growth was incorporated into the assessment using sex-specific age-length transition matrices developed previously (Table 8.9a, b). Previously-developed sex-specific weight-at-age relationships and female maturity schedules (Table 8.10) were also used in this assessment.

To summarize, the following data were incorporated in the assessment:

Source	type	years
Fishery	catch	1984-2011
	size compositions	1985-2011
Survey	biomass	1984-1999 (triennial); 2001-2011 (biennial)
	size compositions	1984-1999 (triennial); 2001-2011 (biennial)
	age compositions	1984-1999 (triennial); 2001-2009 (biennial)

Analytic Approach

Model structure

A number of alternative model configurations have been considered in previous assessments (Stockhausen et al., 2005, 2007, 2009). Due to time constraints, we did not explore any alternative models this year. Rather, we used the model configuration preferred by the GOA Plan Team and SSC from the last full assessment (the "base case" model in Stockhausen et al., 2009) to fit the data, estimate parameters, and calculate Tier 3 biological and management reference points.

The assessment was conducted using a split-sex, age-structured model with parameters evaluated in a maximum likelihood context. The model structure (Appendix A) was developed following Fournier and Archibald's (1982) methods, with many similarities to Methot (1990). We implemented the model using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed for finding the minimum of an objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). It also gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

The current assessment model covers 1984-2011. Age classes included in the model run from age 3 to 20. Age at recruitment was set at 3 years in the model due to the small number of fish caught at younger ages. The oldest age class in the model, age 20, serves as a plus group; the typical maximum age of flathead sole based on otolith age determinations has been estimated at 25 years (Turnock et al., 2003a). Details of the population dynamics and estimation equations, description of variables and likelihood components are presented in Appendix A (Tables A.1, A.2, and A.3). Model parameters that are typically fixed are presented in Table A.4. A total of 81 parameters were estimated in the final model (Table A.5).

Parameters estimated independently

Model parameters related to natural mortality, growth, weight, maturity and survey catchability were fixed in the final model (Table A.4).

Natural mortality

As in the previous assessment (Stockhausen et al., 2009), natural mortality (*M*) was fixed at 0.2 yr^{-1} for both sexes in all age classes. This value was based on a maximum observed age for flathead sole of 22 years (Spencer et al., 1999). Although maximum observed age has increased to 31 years in the Bering

Sea, an analysis of independent estimates of natural mortality for flathead sole is not inconsistent with continued use of this value (Stockhausen, et al. 2010b).

Growth

Individual growth was incorporated in the model using sex-specific age-length transition matrices (Table 8.9). These were identical to those used in the previous assessment (Stockhausen et al., 2009). In terms of the von Bertalanffy growth equation, L_{inf} was estimated at 44.37 cm for females and 37.36 cm for males (Figure 8.6a). The length at age 2 (L_2) was estimated at 10.17 cm for males and 13.25 cm for females. The growth parameter k was estimated at 0.157 for females and 0.204 for males. Length at age t was modeled as:

$$L_t = L_{\text{inf}} + (L_2 - L_{\text{inf}})e^{-k(t-2)}$$

Weight at length

The weight-length relationship used for flathead sole was identical to that used in the previous assessment (Stockhausen et al., 2007): $W = 0.00428\ L^{3.2298}$ for both sexes combined (weight in grams and length in centimeters). Weight-at-age (Table 8.10, Figure 8.6b) was estimated using the mean length-at-age and the weight-length relationship.

Maturity

The maturity schedule for Gulf of Alaska flathead sole was estimated using histological analysis of ovaries collected in January 1999 (Stark, 2004; Table 8.10, Figure 8.6c). A total of 180 samples were analyzed for estimation of age at maturity. Size at 50% mature was estimated to be 33.3 cm with a slope of 0.52 cm^{-1} from a sample of 208 fish. Age at 50% mature was 8.74 years with a slope of 0.773 yr^{-1}. Size at 50% mature was estimated at 32.0 cm for Bering Sea flathead sole (not significantly different from the GOA results), however, age at 50% mature was 9.7 due to slower growth in the Bering sea.

Survey catchability

Based on results from the 2003 assessment (Turnock et al., 2003a), which indicated that estimating survey catchability was problematic, we fixed overall survey catchability (Q in Table A.1) in the model to a value of 1.

Parameters estimated conditionally

A total of 85 parameters were estimated in the model (Table A.5). These consisted primarily of parameters on the recruitment of flathead sole to the population (46 parameters total, including ones determining the initial age composition) and values related to annual fishing mortality (29 parameters total). The separable age-component of fishing mortality was modeled using ascending logistic functions estimated separately for males and females (4 parameters total). The same approach was also used to estimate relative age-specific survey catchability (4 parameters total).

Annual recruitment to the age 3 year class was parameterized in the model using one parameter for the log-scale mean recruitment and 45 parameters for the annual log-scale deviation from the mean. Recruitments were estimated back to 1967 to provide an initial age distribution for the model in its starting year (1984). In an analogous fashion, fully-recruited fishing mortality was parameterized in the model using one parameter for the log-scale mean and 28 parameters for the annual log-scale deviation from the mean.

Parameters in the model were selected based on minimizing an objective function equivalent to a negative log-likelihood function, hence the parameter estimates are maximum likelihood estimates. Components that contribute to the overall negative log likelihood include those related to observed fishery catches, fishery size compositions, survey biomass estimates, survey size compositions, survey age composition, and recruitment deviations (Table A.3). The observed fishery catch was assumed to have a lognormal error structure, as was estimated survey biomass. The recruitment deviation parameters were incorporated directly into the overall likelihood via three components: “early” recruitment, “ordinary” recruitment and “late” recruitment (Table A.3). The “early” recruitment component incorporated deviations from 1967 to 1983, i.e. those that determined the initial model age structure and were thus uninformed by contemporaneous catch data. The “ordinary” recruitment component incorporated deviations from 1984-2008, while the “late” recruitment component incorporated deviations from 2009-2011. "Late" recruitments are weighted separately in the likelihood from "ordinary" recruitments because there is generally little data to constrain recruitment estimates for the final few years in the model. This partitioning does not reflect any assumptions regarding changes in productivity with time: All three components were formulated assuming a lognormal error structure. The size and age compositions were assumed to be drawn from different sex-specific multinomial distributions. If this assumption were strictly correct, then the number of individuals contributing to each composition would be the appropriate corresponding sample size. However, because fish of the same size and age tend to be found together, size and age compositions tend to be overdispersed with respect to actual multinomial distributions. Also, the use of high sample sizes can lead to numerical problems in estimating the model parameters. Previous experience indicates that using a uniform sample size of 200 for compositions with more than 200 individuals provides an adequately simple solution to the problem of assigning sample sizes. Thus, a sample size of 200 was used for all compositions used in the likelihood (all age compositions, as well as all fishery size compositions and survey size compositions from years with no corresponding age compositions).

Different weights can be assigned to each likelihood component to increase or decrease the relative degree of model fit to the data underlying the respective component; a larger weight induces a closer fit to a given likelihood component. Typically, a relatively large weight (e.g., 30) is applied to the catch component while smaller weights (e.g., 1) are applied to the survey biomass, recruitment, and size and age composition components. This reflects a belief that total catch data are reasonably well known (smaller variance) than the other types of data. For the recruitment components, larger weights applied to a component force the deviations contributing to that component closer to zero (and thus force recruitment closer to the geometric mean over the years that contribute to the component). The weights used in this assessment are given in Table 8.11.

Initial values for the estimable parameters were set as listed in Table 8.12. To test that the resulting model solution was indeed the global, rather than a local, maximum on the likelihood surface, we started the model using several different parameter sets. Most runs converged to the same (maximum) likelihood value and parameter estimates, providing evidence that the original solution was indeed the global maximum. The scores associated with different components of the maximum likelihood (e..g, fishery catch, survey biomass) are given in Table 8.13.

Final parameter estimates

The estimated maximum likelihood parameter values are given in Table 8.14 for all model parameters.

Model evaluation

Model estimates of fishery catch closely matched the observed values (Table 8.15 and Figure 8.7). This, however, is expected because a large weighting factor (30) was placed on the catch biomass component in the likelihood function. The model did not fit observed survey biomass values as closely as it did the catch (Table 8.15 and Figure 8.8), but model estimates of survey biomass fell outside the 95% confidence intervals of the actual surveys for only two out of eleven survey years (1984 and 2001) so the fit was deemed satisfactory.

The model did not fit the fishery size compositions as well, although its performance appeared to be reasonably good in most years (Figures 8.9 and 8.10 for females and males, respectively). Fits to the fishery size compositions were poorest when the observed size composition was dominated by a single size class and thus sharply peaked—for example, females in 1987 or males in 1990 (Figure 8.9). The smoothing inherent in using an age-length transition matrix to convert age classes to size classes in the model precludes close fits to peaked size compositions: the peak will be underestimated and the tails will be overestimated. It also appears, however, that these sharply-peaked size compositions may be associated with lower sample sizes or higher overdispersion (the size composition from 1990 was based on 149 individuals from only 3 different hauls). As with the fishery size compositions, model fits to the survey size compositions were poorest when the observed size compositions were sharply peaked (Figures 8.11 and 8.12). Also, the model consistently overestimates survey composition at small sizes (< 20 cm) for males (Figure 8.12) but not for females (Figure 8.11). This may indicate a shortcoming at small sizes of the current age/size transition matrix used in the model for males (Table 8.9b). However, this currently has little effect on the way the model fits the data because the 2011 survey size composition enters fully-weighted into the likelihood maximization—the remainder are deweighted in favor of the corresponding survey age compositions. Finally, the model also fit the survey age compositions reasonably well (Figures 8.16 and 8.17). Model fits to age and size compositions are quite similar to those obtained in the last full assessment (Stockhausen et al., 2009).

Results

The estimated selectivity curves for the fishery and survey indicate that the fishery generally catches older flathead sole than the survey (Figures 8.15-16). For the fishery, age at 50% selection was 10.4 years for females and 10.1 for males. For the survey, the ages at 50% selection were younger: 5.4 years for females and 4.9 for males. The rates of increase in the selectivity curves at 50% selection were slightly smaller for females vs. males, but quite similar between the fishery and the survey. Examination of the marginal posterior distributions for these parameters indicates that they were well-estimated in the model (Figure 8.16).

The model also estimates other population variables of interest, such as time series of total biomass, spawning biomass, recruitment and fully-selected fishing mortality. In this assessment, total biomass is represented by age 3+ biomass whereas spawning biomass is female spawning biomass. Model quantities such as median recruitment, median fishing mortality, total biomass, spawning biomass and recruitment all seem to be reasonably well-estimated, based on examination of MCMC posterior distributions (Figures 8.17-18). The maximum likelihood estimates of these quantities tends to be very close to the posterior modes, with median recruitment (Fig. 8.17, upper left plot) and the 2010 recruitment (Figure 8.18, lower plot) being exceptions to this. Median recruitment was estimated at 84 million individuals, while the mode was at 79 million. Median fishing mortality was estimated at 0.015 yr^{-1}. Total biomass in 2011 was estimated at 297,000 t, spawning stock biomass at 102,000 t and recruitment at 139 million. Model estimates suggest that age 3+ biomass generally underwent a steady increase from 210,000 t in 1984 to 305,000 t in 2009, followed by a very slight decline in the past two years to 297,000 t (Table 8.16 and Figure 8.19). The estimated age 3+ biomass in this assessment is somewhat (10%) lower than that estimated in previous assessments (Table 8.16, Figure 8.18). Female spawning biomass was estimated to have increased fairly rapidly from 1984 (53,000 t) until 1990 (86,000 t), then to have continued increasing at a much slower rate. The estimated 2011 spawning biomass is the largest in the time series (102,000 t).

Model estimates of annual recruitment (age 3 numbers) ranged from a low of 174 million individuals in 1999 to a high of 362 million in 2008 (Table 8.17 and Figure 8.20). Prior to 2000, recruitment was generally below the long-term average (228 million), while it has generally been higher since 2000. In 2011, recruitment was estimated below the long-term average, but this is expected because of the structure of the recruitment likelihood component. Results from the current assessment are generally similar to those estimated in previous assessments, particularly prior to 2001 (Table 8.17, Figure 8.20). Except in 2008, this year's model estimates for recruitment after 2001 are somewhat smaller than those obtained in 2009 and somewhat less variable than those obtained in 2007.

Marginal posterior distributions based on MCMC integration are shown in Figure 8.21 for $F_{35\%}$ and $F_{40\%}$, $B_{35\%}$ and $B_{40\%}$, and max ABC and OFL for 2012 (based on Tier 3a rules). Based on these distributions, all six quantities appear to be well-estimated in the model. A control rule plot based on the temporal trajectory of estimated fishing mortality and spawning biomass indicates that the GOA flathead sole stock has not been overfished nor has overfishing occurred (Figure 8.22).

Projections and Harvest Alternatives

The reference fishing mortality rate for flathead sole is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1981-2008 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ times the equilibrium number of recruits; this quantity is 49,899 t. The 2011 spawning stock biomass is estimated at 102,000 t. Since reliable estimates of the 2011 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (102,000 t > 41,547 t), the flathead sole reference fishing mortality is defined in Tier 3a.

For this tier, F_{ABC} is constrained to be ≤ $F_{40\%}$, and F_{OFL} is defined to be $F_{35\%}$. The values of these quantities are:

estimated 2011 SSB	=	102,000 t
$B_{40\%}$	=	41,547 t
$F_{40\%}$	=	0.450
F_{ABC} (max)	=	0.450
$B_{35\%}$	=	36,354 t
$F_{35\%}$	=	0.593
F_{OFL}	=	0.593

Because the flathead sole stock has not been overfished in recent years and the stock biomass is relatively high, it is not recommended to adjust F_{ABC} downward from its upper bound; thus, the year 2011 recommended ABC associated with F_{ABC} of 0.450, is 47,407 t. The fishing mortality associated with overfishing (F_{OFL}) is 0.593. The corresponding OFL for 2012 is 59,380 t.

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

For each scenario, the projections begin with the vector of 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2012, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2012 recommended in the assessment to the *max* F_{ABC} for 2012. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2006-2011 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, so scenarios 1 and 2 yield identical results. The 12-year projections of the mean harvest, spawning stock biomass and fishing mortality for the five scenarios are shown in Tables 8.18-20.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the flathead sole 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 its MSY level in 2012, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2024 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the stock is not overfished and is not approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2012 of scenario 6 is 104,301 t, more than 2 times $B_{35\%}$ (36,354 t). Thus the stock is not currently overfished. With regard to whether the stock is approaching an overfished condition, the expected spawning stock size in the year 2024 of scenario 7 (38,140 t) is greater than $B_{35\%}$; thus, the stock is not approaching an overfished condition.

Estimating an ABC and OFL for 2013 is somewhat problematic as these values depend on the catch that will be taken in 2012. The actual catch taken in the GOA flathead sole fishery has been substantially smaller than the TAC for the past several years, but the catch has been rising steadily since 1999 until this year (Figure 8.1). The year end 2011 catch was predicted to be 2,891 t, substantially less than in 2010 (3,842 t; the largest catch in the time series). However, it is not known whether this year's catch is an anomaly to the generally-increasing trend, or not. As such, we assumed that a reasonable estimate of the catch to be taken in 2012 was the same as that taken in 2010. Using these catch values and the estimated population size at the start of 2011 from the model, we projected the stock ahead through 2011-2012 and calculated the ABC and OFL for 2013. The estimated ABC for 2013 is 48,081 t while the estimated OFL is 60,219 t. Total biomass for 2013 is estimated at 286,274 t, while female spawning biomass is estimated at 105,127.

Area allocation of harvests

TAC's for flathead sole in the Gulf of Alaska are divided among four smaller management areas (Western, Central, West Yakutat and Southeast Outside). As previous assessments, the area-specific ABC's for flathead sole in the GOA are divided up over the four management areas by applying the fraction of the most recent survey biomass estimated for each area (relative to the total over all areas) to the 2012 and 2013 ABC's. The area-specific allocations for 2012 and 2013 are:

	Western	Central	West Yakutat	Southeast Outside	Total
Area Apportionment	32.3%	54.5%	9.6%	3.6%	100.0%
2012 ABC (t)	15,300	25,838	4,558	1,711	47,407
2013 ABC (t)	15,518	26,205	4,623	1,735	48,081

Ecosystem Considerations

Ecosystem effects on the stock

Prey availability/abundance trends

Based on results from an ecosystem model for the Gulf of Alaska (Aydin et al., 2007), flathead sole in the Gulf of Alaska occupy an intermediate trophic level as both juvenile and adults (Fig. 8.21). Pandalid shrimp and brittle stars were the most important prey for adult flathead sole in the Gulf of Alaska (64% by weight in sampled stomachs; Yang and Nelson, 2000; Fig. 8.22a), while euphausids and mysids constituted the most important prey items for juvenile flathead sole (Fig. 8.22b).. Other major prey items included polychaetes, mollusks, bivalves and hermit crabs for both juveniles and adults. Commercially important species that were consumed included age-0 Tanner crab (3%) and age-0 walleye pollock (< 0.5% by weight). Little to no information is available to assess trends in abundance for the major benthic prey species of flathead sole.

Predator population trends

Important predators on flathead sole include arrowtooth flounder, walleye pollock, Pacific cod, and other groundfish (Fig. 8.23). Pacific cod and Pacific halibut are the major predators on adults, while arrowtooth flounder, sculpins, walleye pollock and Pacific cod are the major predators on juveniles. The flatfish-directed fishery constitutes the third-largest known source of mortality on flathead sole adults. However, the largest component of mortality on adults is unexplained.

Arrowtooth flounder are currently the most abundant groundfish in the Gulf of Alaska, and have steadily increased in abundance since the early 1970's (Turnock et al., 2003b). The abundance of walleye pollock has declined rather steadily since the early 1990's, but recent evidence suggests the stock may be starting to increase again (Dorn et al., 2004). Pacific cod abundance in the Gulf of Alaska has been declining since 1990 (Thompson et al., 2004). Although the continued increase in abundance of arrowtooth flounder is cause for some concern, the abundance of flathead sole has actually increased in recent years. Predation by arrowtooth may be limiting the potential rate of increase of flathead sole under current conditions, but it does not appear to represent a threat to the stock.

Fishery effects on ecosystem

Catches of flathead sole have been concentrated in several areas in the Gulf of Alaska over the past few years (Figure 8.2). These areas include Shelikof Straight, Portlock Bank and Davidson Bank. The ecosystem effects of this spatial concentration of fishing activity are unknown.

Prohibited species such as halibut, salmon, and crab are also taken to some extent in the flathead sole-directed fishery (Table 8.21). In 2011 thus far, the overall prohibited species catch (PSC) for crab in the directed fishery was exclusively Bairdi tanner crab, with catches sometimes fluctuating by factors of 3-4 between years. The PSC for crab thus far in the 2011 directed fishery was approximately 5,000 Bairdi tanner crab, somewhat less than that caught in 2008-2010. As a fraction of the total Bairdi crab PSC, the fishery accounted for 5.8% in 2011 but less than 3% in 2008-2010—even though the absolute numbers were greater i 2008-2010. The PSC for halibut was almost 92,000 kg halibut—a decrease from the 2010 catch of almost 257,000 kg and similar to the 2009 and 2008 catches (approximately 98,000 and 92,000 kg, respectively). Except for 2011, these catches constituted less than 2.5% of the total halibut PSC. In 2011, the percentage was 5.7%. The PSC for salmon in the directed fishery is mainly Chinook, with 498 individuals caught in 2010 and 118 in 2009. These accounted for 0.9% and 1.5% of the total salmon PSC in those years. In the previous two years (2007-8), no individuals were caught. Preliminary values for 2011 were not available at the time this document was compiled.

Bycatch of non-target species in the flathead sole fishery tends be highly variable between years, at least when expressed as a percentage of the total observed bycatch in the FMP by non-target species group (Table 8.22). In 2011, the flathead sole fishery accounted for more than 5% of the bycatch of six species groups: benthic urochordata (tunicates; 8.5%), eelpouts (9.2%), grenadier (6.4%), unidentified polychaetes (39.2%), sea pens and whips (8.6%), and stichaeidae (pricklebacks; 12.0%). In 2010, the fishery reportedly caught no unidentified polychaetes or grenadier, but again accounted for more than 5% of the bycatch of benthic urochordata (14.1%), eelpouts (11.3%), sea pens and whips (14.0%), and stichaeidae (13.5%), as well as unidentified brittle stars (9.7%), Giant grenadiers (5.1%), greenlings (5.5%), and pandalid shrimp (6.1%). The fishery has had no bycatch of birds and has accounted for less than 5% of bycatch in all shark, skate, and forage fish (capelin, eulachon, sandlance) species groups over the time frame analyzed (2003-2011).

Over the past five years, the flathead sole-directed fishery caught more arrowtooth flounder than any other non-prohibited FMP species, including flathead sole (Table 8.23). Flathead sole was the second most-caught species in the directed fishery. Only small amounts of arrowtooth were retained (typically 10%), while generally more than 90% of flathead sole was retained. Pacific cod was the third most-caught species, with retention rates typically greater than 90%.

Effects of discards and offal production on the ecosystem are unknown for the flathead sole fishery.

Data gaps and research priorities

The AFSC's Age and Growth Program has made substantial progress in processing survey age data for flathead sole in the Gulf of Alaska. While this information has been incorporated in the current stock assessment in the form of survey age compositions, age information also enters the assessment in the form of age-length conversion matrices estimated outside the assessment model. The matrices currently used in the assessment are now several years old. One of our goals for the next assessment is to use the newly-available age data to revise growth schedules for GOA flathead and reassess these age-length conversion matrices. In addition, we anticipate incorporating such estimation directly into the assessment model, rather than performing it outside the model. This approach will also allow us to incorporate ageing error into the model structure.

Although the AFSC's Age and Growth Program has made substantial progress in processing survey age data for flathead sole in the Gulf of Alaska, the amount of fishery age data is almost nonexistent. Additional age data (both survey and fishery) should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

Further modeling research should address the use of length-based approaches to fishery and survey selectivity in the assessment model, as well as alternative forms for the selectivity function. The utility of potential environmental predictors of recruitment (e.g., temperature) should also be investigated. We will also revisit the estimates used for natural mortality in the model.

Summary

Tier	3a	
Reference mortality rates		
M	0.2	
$F_{35\%}$	0.593	
$F_{40\%}$	0.450	
Equilibrium female spawning biomass		
$B_{100\%}$	103,868 t	
$B_{40\%}$	41,547 t	
$B_{35\%}$	36,354 t	
Fishing rates		
F_{OFL}	0.593	
F_{ABC} (maximum permissible)	0.450	
F_{ABC} (recommended)	0.450	
Projected biomass	**2012**	**2013**
Age 3+ biomass (t)	292,189	286,274
Female spawning biomass (t)	104,301	105,127
Harvest limits	**2012**	**2013**
OFL (t)	59,380	60,219
ABC (maximum permissible; t)	47,407	48,081
ABC (recommended; t)	47,407	48,081

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Tables

Table 8.1. Annual catch of flathead sole in the Gulf of Alaska, from 1978 to 2011. The 2011 catch is through Sept. 24, 2011.

year	total catch (t)	Western Gulf	Central Gulf	West Yakutat	Southeast
1978	452				--
1979	165				--
1980	2,068				--
1981	1,070				--
1982	1,368				--
1983	1,080				--
1984	549				--
1985	320				--
1986	147				--
1987	151				--
1988	520				--
1989	747				--
1990	1,447				--
1991	1,717	42	729	1	--
1992	2,034	291	1,735	8	--
1993	2,366	581	2,238	2	--
1994	2,580	499	2,067	14	--
1995	2,181	589	1,563	29	--
1996	3,107	807	2,166	103	--
1997	2,446	449	1,938	59	--
1998	1,742	556	1,156	8	--
1999	900	186	687	16	11
2000	1,547	258	1,274	15	0
2001	1,911	600	1,311	0	0
2002	2,145	421	1,724	0	0
2003	2,425	515	1,910	0	0
2004	2,390	831	1,559	0	0
2005	2,530	611	1,919	0	0
2006	3,134	462	2,671	1	0
2007	3,163	694	2,467	2	0
2008	3,419	288	3,131	0	0
2009	3,658	303	3,355	0	0
2010	3,842	462	3,380	0	0
2011	2,339	341	1,998	0	0

Table 8.2a. Time series of recent reference points (ABC, OFL, TAC), total catch and retention rates for GOA flathead sole. The 2011 catch is through Sept. 24, 2011.

Year	Author ABC (t)	ABC (t)	TAC (t)	OFL (t)	Total Catch (t)	% Retained
1995	--	28,790	9,740	31,557	2,181	
1996	--	52,270	9,740	31,557	3,107	
1997	--	26,110	9,040	34,010	2,446	
1998	--	26,110	9,040	34,010	1,742	
1999	--	26,010	9,040	34,010	900	
2000	--	26,270	9,060	34,210	1,547	
2001	--	26,270	9,060	34,210	1,911	
2002	22,684	22,690	9,280	29,530	2,145	
2003	41,402	41,390	11,150	51,560	2,425	88
2004	51,721	51,270	10,880	64,750	2,390	80
2005	36,247	45,100	10,390	56,500	2,530	87
2006	37,820	37,820	9,077	47,003	3,134	89
2007	39,110	39,110	9,148	48,658	3,163	89
2008	44,735	44,735	11,054	55,787	3,419	90
2009	46,464	46,464	11,181	57,911	3,658	96
2010	47,422	47,422	10,411	59,295	3,842	95
2011	49,133	49,133	10,587	61,412	2,339	97

Table 8.2b. Status of the flathead sole fishery in recent years.

Year	Dates	Status
2005	Jan 20	open
	Aug 19	halibut bycatch status
	Sep 1	open
	Sep 4	halibut bycatch status
2006	Jan 20	open
	Feb 23	halibut bycatch status
	Feb 27	open
	Jun 10	halibut bycatch status
	Jul 1	open
	Sep 1	halibut bycatch status
	Spe 6	open
	Sep 6	halibut bycatch status
	Sep 20	open
	Spe 20	halibut bycatch status
	Sep 25	open
	Sep 25	halibut bycatch status
	Oct 1	open
	Oct 8	halibut bycatch status
2007	Jan 20	open
	Jun 4	halibut bycatch status
	Jul 1	open
	Aug 10	halibut bycatch status
	Sep 1	open
	Sep 1	halibut bycatch status
	Sep 6	open
	Sep 6	halibut bycatch status
	Sep 11	open
	Sep 11	halibut bycatch status
	Sep 21	open
	Sep 23	halibut bycatch status
	Oct 1	open
	Oct. 8	halibut bycatch status
	Oct 10	open
	Oct 15	halibut bycatch status
	Oct 22	open
2008	Jan 20	open
	Jan 23	A80 vessels subject to sideboard limits: halibut bycatch status
	Jan 29	A80 vessels subject to sideboard limits: open
	Mar 10	halibut bycatch status
	Mar 21	open
	May 21	halibut bycatch status
	Jul 1	open
	Aug 7	halibut bycatch status
	Sep 1	open
	Sep 3	halibut bycatch status
	Sep 10	open
	Sep 11	halibut bycatch status
	Oct 1	open
	Nov 6	halibut bycatch status
	Nov 16	open

Year	Dates	Status
2009	Jan 20	open
	Sep 2	halibut bycatch status
	Oct 1	open
2010	Jan 20	open
	Sep 3	halibut bycatch status
	Sep 11	open
2011	Jan 20	open
	Jul 1	halibut bycatch status (RP CPs)
	Aug 1	open (RP CPs)
	Sep 3	halibut bycatch status
	Sep 14	open
	Sep 16	halibut bycatch status
	Sep 20	open

Table 8.3a. Annual fishery length compositions for female flathead sole. The 2011 composition is based on observer reports through Sept. 24. Fishery length compositions are normalized to 1 over both sexes.

	Length cutpoints (cm)																	
year	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0558	0.0657	0.0817	0.1135	0.0837	0.0478	0.0219	0.0060	0.0020	0.0000
1986	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0129	0.0065	0.0774	0.0839	0.0903	0.0645	0.0581	0.0194	0.0129	0.0129	0.0000	0.0000
1987	0.0000	0.0000	0.0000	0.0058	0.0000	0.0058	0.0116	0.0465	0.1047	0.1395	0.2558	0.0698	0.0349	0.0000	0.0000	0.0000	0.0000	0.0000
1988	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0032	0.0053	0.0069	0.0354	0.0994	0.1274	0.1332	0.1142	0.0840	0.0418	0.0143	0.0026
1989	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0256	0.0233	0.0653	0.0956	0.0979	0.0443	0.0140	0.0093	0.0023
1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0201	0.1409	0.0940	0.0940	0.0403	0.0470	0.0000	0.0000	0.0000
1991	0.0000	0.0000	0.0000	0.0000	0.0011	0.0027	0.0106	0.0217	0.0342	0.0422	0.0601	0.0973	0.0927	0.0589	0.0270	0.0084	0.0027	0.0015
1992	0.0000	0.0000	0.0008	0.0011	0.0049	0.0081	0.0111	0.0266	0.0356	0.0465	0.0630	0.0723	0.0603	0.0418	0.0231	0.0242	0.0155	0.0133
1993	0.0011	0.0006	0.0008	0.0011	0.0037	0.0065	0.0034	0.0056	0.0115	0.0213	0.0399	0.0590	0.0581	0.0528	0.0427	0.0371	0.0298	0.0247
1994	0.0000	0.0000	0.0005	0.0029	0.0067	0.0100	0.0257	0.0371	0.0413	0.0689	0.0660	0.0760	0.0698	0.0570	0.0299	0.0247	0.0138	0.0280
1995	0.0000	0.0000	0.0004	0.0004	0.0015	0.0015	0.0062	0.0128	0.0438	0.0601	0.0841	0.0934	0.0790	0.0353	0.0236	0.0120	0.0124	0.0294
1996	0.0000	0.0004	0.0015	0.0030	0.0045	0.0056	0.0054	0.0112	0.0244	0.0337	0.0595	0.0752	0.0802	0.0646	0.0432	0.0277	0.0192	0.0368
1997	0.0005	0.0005	0.0010	0.0017	0.0050	0.0084	0.0109	0.0226	0.0278	0.0533	0.0670	0.0875	0.0794	0.0461	0.0263	0.0174	0.0107	0.0099
1998	0.0000	0.0002	0.0004	0.0004	0.0011	0.0026	0.0046	0.0124	0.0221	0.0322	0.0575	0.0822	0.0877	0.0655	0.0373	0.0254	0.0159	0.0227
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0080	0.0000	0.0240	0.0400	0.0480	0.1040	0.1360	0.0800	0.0560	0.0080	0.0400	0.0160
2000	0.0000	0.0000	0.0007	0.0014	0.0007	0.0036	0.0080	0.0174	0.0282	0.0477	0.0745	0.0788	0.0665	0.0427	0.0398	0.0188	0.0123	0.0072
2001	0.0000	0.0000	0.0000	0.0000	0.0008	0.0025	0.0016	0.0098	0.0263	0.0279	0.0443	0.0541	0.0705	0.0582	0.0533	0.0377	0.0336	0.0410
2002	0.0000	0.0008	0.0023	0.0008	0.0023	0.0039	0.0124	0.0202	0.0419	0.0489	0.0559	0.0761	0.0730	0.0621	0.0466	0.0272	0.0101	0.0163
2003	0.0004	0.0000	0.0004	0.0000	0.0000	0.0028	0.0040	0.0048	0.0132	0.0227	0.0279	0.0450	0.0630	0.0570	0.0514	0.0315	0.0211	0.0191
2004	0.0000	0.0000	0.0000	0.0007	0.0021	0.0057	0.0136	0.0107	0.0264	0.0314	0.0507	0.0600	0.0700	0.0771	0.0707	0.0457	0.0271	0.0300
2005	0.0000	0.0000	0.0000	0.0000	0.0023	0.0087	0.0110	0.0140	0.0308	0.0343	0.0483	0.0797	0.0837	0.0802	0.0500	0.0209	0.0140	0.0116
2006	0.0005	0.0005	0.0016	0.0011	0.0038	0.0055	0.0093	0.0132	0.0241	0.0346	0.0538	0.0757	0.0686	0.0669	0.0461	0.0252	0.0148	0.0115
2007	0.0000	0.0000	0.0000	0.0012	0.0043	0.0031	0.0160	0.0185	0.0314	0.0579	0.0672	0.0702	0.0598	0.0333	0.0333	0.0197	0.0222	0.0327
2008	0.0000	0.0007	0.0042	0.0023	0.0021	0.0105	0.0064	0.0169	0.0301	0.0320	0.0578	0.0915	0.0785	0.0686	0.0316	0.0243	0.0189	0.0219
2009	0.0000	0.0000	0.0003	0.0015	0.0013	0.0057	0.0079	0.0178	0.0187	0.0244	0.0514	0.0728	0.1123	0.0757	0.0679	0.0439	0.0302	0.0335
2010	0.0004	0.0000	0.0000	0.0012	0.0036	0.0065	0.0080	0.0091	0.0159	0.0260	0.0462	0.0674	0.0806	0.0825	0.0460	0.0236	0.0244	0.0256
2011	0.0000	0.0000	0.0000	0.0016	0.0019	0.0011	0.0076	0.0103	0.0114	0.0324	0.0236	0.0664	0.0492	0.0415	0.0222	0.0290	0.0193	0.0304

Table 8.3b. Annual fishery length compositions for male flathead sole. The 2011 composition is based on observer reports through Sept. 24. Fishery length compositions are normalized to 1 over both sexes.

	Length cutpoints (cm)																	
year	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0.0000	0.0000	0.0000	0.0020	0.0020	0.0000	0.0139	0.0677	0.1335	0.1653	0.0916	0.0259	0.0080	0.0020	0.0000	0.0000	0.0000	0.0000
1986	0.0000	0.0000	0.0000	0.0065	0.0000	0.0000	0.0129	0.0645	0.1355	0.1548	0.0645	0.0452	0.0516	0.0258	0.0000	0.0000	0.0000	0.0000
1987	0.0000	0.0000	0.0000	0.0058	0.0000	0.0233	0.0233	0.0640	0.1047	0.0930	0.0116	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1988	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0143	0.0560	0.0957	0.0809	0.0476	0.0233	0.0069	0.0021	0.0011	0.0000	0.0000
1989	0.0000	0.0000	0.0000	0.0000	0.0000	0.0070	0.0210	0.0932	0.0653	0.2051	0.1096	0.0373	0.0396	0.0280	0.0140	0.0023	0.0000	0.0000
1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0336	0.0537	0.2349	0.1678	0.0470	0.0268	0.0000	0.0000	0.0000	0.0000	0.0000
1991	0.0004	0.0004	0.0008	0.0004	0.0072	0.0125	0.0300	0.0391	0.0802	0.1513	0.1365	0.0563	0.0148	0.0061	0.0015	0.0011	0.0004	0.0000
1992	0.0005	0.0038	0.0027	0.0092	0.0144	0.0231	0.0348	0.0598	0.1049	0.1176	0.0989	0.0497	0.0201	0.0084	0.0035	0.0003	0.0000	0.0000
1993	0.0008	0.0011	0.0014	0.0031	0.0067	0.0129	0.0244	0.0385	0.0845	0.1289	0.1457	0.0935	0.0337	0.0183	0.0031	0.0011	0.0003	0.0022
1994	0.0000	0.0000	0.0000	0.0014	0.0076	0.0157	0.0219	0.0323	0.0732	0.1116	0.0893	0.0413	0.0166	0.0043	0.0067	0.0043	0.0010	0.0147
1995	0.0000	0.0000	0.0019	0.0019	0.0050	0.0097	0.0151	0.0480	0.0821	0.1069	0.1031	0.0632	0.0260	0.0163	0.0136	0.0070	0.0027	0.0015
1996	0.0004	0.0006	0.0024	0.0056	0.0065	0.0080	0.0115	0.0292	0.0659	0.1036	0.1094	0.0692	0.0456	0.0277	0.0117	0.0054	0.0004	0.0004
1997	0.0005	0.0007	0.0022	0.0050	0.0067	0.0156	0.0188	0.0419	0.0804	0.1114	0.1029	0.0779	0.0362	0.0126	0.0032	0.0015	0.0005	0.0060
1998	0.0004	0.0000	0.0013	0.0029	0.0040	0.0075	0.0159	0.0390	0.0672	0.1120	0.1149	0.0813	0.0383	0.0159	0.0139	0.0071	0.0042	0.0040
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0160	0.0160	0.0560	0.0880	0.1040	0.0720	0.0320	0.0480	0.0080	0.0000	0.0000	0.0000
2000	0.0000	0.0007	0.0000	0.0036	0.0072	0.0181	0.0296	0.0557	0.0701	0.0940	0.1048	0.0745	0.0419	0.0268	0.0166	0.0043	0.0029	0.0007
2001	0.0000	0.0016	0.0008	0.0033	0.0025	0.0074	0.0107	0.0230	0.0607	0.1066	0.1025	0.0968	0.0648	0.0320	0.0098	0.0074	0.0057	0.0025
2002	0.0000	0.0016	0.0000	0.0031	0.0039	0.0062	0.0148	0.0349	0.0745	0.1017	0.1071	0.0668	0.0404	0.0264	0.0062	0.0078	0.0016	0.0023
2003	0.0000	0.0004	0.0004	0.0024	0.0076	0.0112	0.0239	0.0418	0.0737	0.0961	0.1419	0.1172	0.0697	0.0271	0.0175	0.0032	0.0008	0.0008
2004	0.0000	0.0000	0.0000	0.0014	0.0043	0.0086	0.0286	0.0328	0.0600	0.0785	0.0871	0.0749	0.0500	0.0350	0.0086	0.0071	0.0000	0.0014
2005	0.0000	0.0000	0.0006	0.0006	0.0035	0.0052	0.0163	0.0372	0.0837	0.1041	0.0971	0.0919	0.0401	0.0174	0.0035	0.0023	0.0041	0.0029
2006	0.0000	0.0000	0.0005	0.0027	0.0033	0.0082	0.0148	0.0477	0.0987	0.1240	0.1064	0.0724	0.0384	0.0176	0.0049	0.0016	0.0011	0.0005
2007	0.0000	0.0012	0.0037	0.0074	0.0117	0.0154	0.0259	0.0376	0.0733	0.0998	0.0844	0.0776	0.0462	0.0179	0.0117	0.0074	0.0055	0.0025
2008	0.0004	0.0000	0.0034	0.0025	0.0038	0.0096	0.0204	0.0397	0.0479	0.1103	0.1234	0.0899	0.0279	0.0151	0.0042	0.0015	0.0019	0.0001
2009	0.0000	0.0000	0.0017	0.0027	0.0059	0.0102	0.0200	0.0256	0.0482	0.0787	0.1005	0.0764	0.0357	0.0173	0.0090	0.0017	0.0007	0.0003
2010	0.0000	0.0009	0.0000	0.0018	0.0010	0.0049	0.0139	0.0226	0.0564	0.1054	0.1280	0.1173	0.0446	0.0249	0.0058	0.0047	0.0006	0.0004
2011	0.0000	0.0007	0.0013	0.0009	0.0043	0.0082	0.0186	0.0332	0.0967	0.1637	0.1237	0.1126	0.0475	0.0212	0.0080	0.0050	0.0015	0.0050

Table 8.4a. Sample sizes for the domestic fishery. Fishery age compositions are not currently used in the assessment model.

year	Size compositions				Age compositions			
	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males
1990	3	274	65	84				
1991	48	4301	1213	1418				
1992	77	4958	1650	2034				
1993	55	4801	1425	2140				
1994	56	4089	1175	930				
1995	46	2818	1280	1301				
1996	174	11207	2297	2330				
1997	72	4827	1926	2113				
1998	128	6509	2569	2896				
1999	7	130	70	55				
2000	111	1464	667	796				
2001	80	1446	664	757				
2002	86	1326	645	643				
2003	168	2592	920	1609				
2004	79	1590	816	765				
2005	118	1838	882	947	46	159	77	82
2006	124	1872	835	990				
2007	122	1830	840	985				
2008	100	1628	815	798				
2009	106	1860	986	851	43	180	91	85
2010	172	2852	1423	1427				
2011	79	1282	467	815				

Table 8.4 b. Sample sizes for the groundfish survey.

year	biomass	Size compositions				Age compositions			
	total hauls	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males
1984	929	264	25316	13875	11291				
1987	783	197	27298	15931	11350				
1990	708	286	24322	12939	11255	22	247	138	107
1993	775	364	26124	13592	12294	36	312	179	132
1996	807	417	21416	11086	9975	55	528	285	243
1999	764	389	16052	7941	8023	47	605	316	288
2001	489	245	11877	5962	5899	83	861	458	399
2003	809	434	25885	13279	12479	87	499	249	250
2005	839	413	23499	12501	10907	76	551	296	243
2007	820	411	25539	13563	11860	82	755	410	345
2009	823	454	21010	10304	10360	75	692	366	314
2011	670	379	17627	9290	8286				

Table 8.5. Biomass estimates (t) by NPFMC regulatory area for GOA flathead sole from the NMFS bottom trawl surveys. Note that in 2001 the eastern GOA was not surveyed. This was accounted for in the assessment model by assuming, based on previous surveys, that availability for this year was was 0.9. The maximum depth stratum included in each survey is also noted.

Year	Western Gulf	Central Gulf	West Yakutat	Southeast	Total	Std. Dev	Max Depth (m)
1984	45,100	158,539	45,694	9	249,341	30,355	1000
1987	33,603	113,483	30,455	5	177,546	18,956	1000
1990	58,740	161,257	23,019	40	243,055	28,877	500
1993	57,871	113,976	16,720	124	188,690	24,486	500
1996	66,732	122,730	12,751	3,308	205,521	18,430	500
1999	49,636	139,356	15,115	3,482	207,590	24,404	1000
2001	68,164	85,430	0	0	153,594	18,300	500
2003	67,055	170,852	17,154	2,234	257,294	19,913	700
2005	59,458	142,043	11,400	312	213,213	16,944	1000
2007	78,361	176,529	21,430	3,970	280,290	23,778	1000
2009	80,115	128,910	9,458	6,894	225,377	25,041	1000
2011	76,049	128,428	22,656	8,506	235,639	22,329	700

Table 8.6. Biomass estimates (t) by depth stratum for GOA flathead sole from the NMFS bottom trawl surveys. Note that in 2001 the eastern GOA was not surveyed.

year	Depth range (m)				
	1-100	101-200	201-300	301-500	>500
1984	118,974	121,791	8,571	5	0
1987	91,482	75,475	10,553	36	0
1990	157,014	76,306	9,713	22	--
1993	113,072	65,143	10,278	198	--
1996	119,657	78,545	7,270	50	--
1999	145,347	58,641	3,581	14	8
2001	93,433	56,133	4,006	22	--
2003	146,018	101,421	9,855	0	0
2005	114,895	92,869	5,297	151	0
2007	139,806	130,661	9,823	0	0
2009	138,824	80,395	6,157	0	0
2011	149,836	73,718	12,086	0	0

Table 8.7. Survey size compositions for flathead sole. Numbers are in 1000's of individuals.

a) Females.

year	Length bin cutpoints (cm) 14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1984	567	3,098	3,337	7,306	14,170	20,489	29,800	45,645	63,475	76,302	69,592	48,288	28,087	17,406	10,172
1987	883	2,085	2,838	4,499	6,056	12,189	17,593	25,161	36,188	50,279	54,302	45,327	26,573	14,468	8,169
1990	1,269	3,347	6,036	6,002	9,283	15,446	19,887	24,583	37,464	46,874	55,347	60,532	52,045	30,967	12,912
1993	2,584	5,010	7,744	12,730	13,216	15,423	20,372	21,820	25,208	31,170	41,270	43,396	36,634	23,356	11,688
1996	3,360	6,318	10,043	14,294	16,104	19,497	21,345	25,059	29,741	34,375	37,894	40,168	33,867	23,395	12,837
1999	2,895	2,940	5,795	8,718	10,041	16,134	18,845	21,287	25,158	28,741	31,886	35,669	31,739	27,829	17,274
2001	2,777	4,699	5,728	8,070	9,822	7,348	9,242	12,441	17,973	20,460	29,033	26,925	24,106	18,520	11,972
2003	3,066	6,647	10,771	15,271	20,514	25,006	23,932	24,520	28,685	35,373	46,891	47,205	42,591	35,524	21,997
2005	4,988	7,391	10,305	14,894	20,011	22,229	27,086	30,483	33,432	38,116	37,285	35,590	34,358	24,141	14,563
2007	2,429	6,105	10,258	20,784	19,669	18,962	23,767	25,095	35,366	40,489	50,426	51,280	44,436	33,157	20,019
2009	4,488	3,880	7,286	10,748	14,502	16,873	24,109	28,080	35,058	28,175	38,788	43,340	39,670	24,950	13,921
2011	4,073	5,359	7,286	10,426	14,248	23,161	27,878	27,508	33,530	41,161	43,376	40,572	33,238	24,696	15,377

b) Males.

year	Length bin cutpoints (cm) 14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1984	958	2,651	3,872	10,794	19,758	34,522	54,303	81,720	76,269	40,785	19,368	10,317	5,446	1,990	541
1987	1,257	2,623	3,876	5,448	6,445	15,112	26,507	48,973	53,591	33,389	14,119	7,290	3,550	1,731	480
1990	1,061	4,055	5,883	8,099	11,657	19,990	29,710	45,839	65,958	73,288	42,626	12,664	3,977	850	386
1993	2,205	5,315	9,757	12,897	16,987	23,213	29,095	39,372	50,735	54,631	36,488	12,636	5,513	2,599	343
1996	4,039	6,250	9,608	14,129	18,421	22,021	27,807	37,472	49,772	52,356	41,352	17,459	5,026	1,607	464
1999	2,484	4,313	7,246	11,893	17,227	21,067	30,364	42,405	59,243	60,992	49,672	24,469	7,967	1,647	1,492
2001	2,519	5,015	7,128	8,810	10,981	13,831	17,031	27,453	37,617	39,651	36,558	19,205	6,125	2,013	432
2003	4,634	6,574	11,065	17,329	24,994	31,230	36,233	41,029	54,997	57,972	53,126	33,017	14,061	4,857	990
2005	4,727	7,283	12,201	15,830	23,301	33,863	45,026	49,439	52,297	49,895	37,689	24,343	9,653	2,244	543
2007	4,193	6,756	13,904	23,942	25,572	25,987	33,841	43,613	53,834	57,061	48,581	34,411	14,458	5,925	1,711
2009	3,558	4,350	8,914	16,447	23,573	31,578	41,192	46,564	52,118	56,359	47,310	28,938	11,366	3,234	745
2011	3,572	3,931	7,738	14,131	26,323	34,825	41,670	46,065	55,727	55,017	43,498	24,163	9,663	3,714	1,518

Table 8.8. Survey age compositions for flathead sole. Numbers are in 1000's of individuals.

a) Females.

year	Age bins 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1984	2,554	5,732	6,984	36,300	74,155	104,300	74,810	47,661	24,199	24,848	4,627	2,992	0	0	0	0	0	0
1990	5,347	5,317	22,314	39,700	22,879	41,042	42,977	12,137	29,626	31,845	39,978	45,470	16,957	16,633	3,215	9,072	0	1,850
1993	12,043	23,746	18,705	18,484	22,728	23,396	24,017	49,392	25,997	22,142	19,556	17,817	4,674	10,333	10,345	5,432	758	9,712
1996	14,353	40,180	36,747	26,716	45,246	32,697	20,360	22,297	24,929	16,811	17,244	14,740	6,557	12,507	2,794	4,049	803	1,423
1999	6,932	13,068	23,768	20,784	21,354	37,554	32,344	30,160	22,069	19,428	20,935	9,843	11,778	7,231	6,379	7,171	1,791	4,052
2001	11,791	19,800	14,024	15,168	28,225	28,937	16,633	21,531	19,368	7,060	11,883	6,196	4,593	4,184	4,939	2,684	1,522	5,470
2003	27,825	39,592	50,233	52,481	13,806	37,912	43,306	50,772	16,791	14,290	10,785	24,386	3,205	2,332	382	4,405	4,587	3,712
2005	21,097	46,779	48,192	56,383	33,181	23,400	32,891	24,245	16,342	14,216	9,983	10,575	9,960	4,152	5,346	2,470	1,387	7,602
2007	19,430	40,782	39,391	31,794	27,647	56,539	51,838	24,195	28,469	23,276	12,987	28,467	12,684	6,019	12,587	4,513	1,923	8,673
2009	13,273	36,231	29,081	50,468	37,877	21,776	22,589	34,692	30,904	16,305	18,961	8,881	4,319	6,387	5,712	2,045	882	3,118

b) Males.

year	Age bins 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1984	0	10,403	29,061	41,741	48,344	96,634	61,205	16,899	21,343	9,159	1,421	4,745	2,773	0	0	0	0	0
1990	7,392	11,683	29,810	33,483	28,696	36,881	38,549	35,774	13,969	12,160	26,810	24,797	17,194	4,452	0	3,360	0	716
1993	8,357	31,800	26,579	38,034	21,547	48,187	19,371	15,327	30,706	12,449	14,387	13,195	6,993	5,117	1,902	0	68	7,770
1996	16,381	37,078	30,360	23,837	44,421	34,830	34,399	31,534	16,454	9,247	6,710	6,140	6,892	3,200	2,905	232	1,202	345
1999	9,794	16,733	31,988	29,956	21,892	61,304	44,990	33,109	26,041	22,030	10,088	13,624	4,753	1,572	7,129	3,766	1,975	1,340
2001	11,844	27,780	18,472	26,731	36,430	23,497	15,761	16,711	11,266	13,890	8,441	8,339	2,636	2,857	2,444	1,522	1,689	3,273
2003	32,103	53,090	64,911	68,289	28,709	16,977	39,693	21,243	18,447	5,498	10,919	3,074	3,654	1,189	3,116	3,308	4,701	4,686
2005	29,361	48,735	39,610	56,586	60,672	38,238	22,515	14,721	15,575	3,836	14,354	10,745	1,379	6,296	1,724	2,006	2,560	336
2007	22,275	40,202	42,624	50,947	38,778	53,202	51,104	11,552	9,996	12,399	8,488	20,030	5,047	8,022	7,170	4,121	0	6,497
2009	17,074	53,552	42,754	64,591	46,282	26,472	26,736	26,812	8,453	20,983	10,507	8,842	6,307	3,325	1,617	3,289	174	6,332

Table 8.9a. Age-length transition matrices for female flathead sole. Values at a row/column combination correspond to the fraction of individuals at the age indicated by the row that fall into the length group indicated by the column.

	length cutpts (cm)																
age	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**
3	0.154	0.396	0.348	0.094	0.008	0	0	0	0	0	0	0	0	0	0	0	0
4	0.004	0.038	0.175	0.348	0.302	0.113	0.018	0.001	0	0	0	0	0	0	0	0	0
5	0	0.002	0.018	0.09	0.235	0.321	0.229	0.086	0.017	0.002	0	0	0	0	0	0	0
6	0	0	0.002	0.013	0.063	0.174	0.281	0.265	0.146	0.047	0.009	0.001	0	0	0	0	0
7	0	0	0	0.002	0.013	0.056	0.15	0.251	0.263	0.173	0.071	0.018	0.003	0	0	0	0
8	0	0	0	0	0.003	0.016	0.061	0.148	0.237	0.251	0.175	0.08	0.024	0.005	0.001	0	0
9	0	0	0	0	0.001	0.005	0.023	0.074	0.159	0.235	0.236	0.162	0.075	0.024	0.005	0.001	0
10	0	0	0	0	0	0.002	0.009	0.035	0.095	0.179	0.236	0.217	0.139	0.063	0.02	0.004	0.001
11	0	0	0	0	0	0.001	0.004	0.017	0.055	0.125	0.202	0.233	0.19	0.111	0.046	0.013	0.003
12	0	0	0	0	0	0	0.002	0.009	0.032	0.085	0.161	0.221	0.218	0.155	0.079	0.029	0.008
13	0	0	0	0	0	0	0.001	0.005	0.019	0.057	0.125	0.196	0.225	0.188	0.114	0.05	0.016
14	0	0	0	0	0	0	0	0.003	0.012	0.04	0.096	0.169	0.219	0.208	0.144	0.073	0.027
15	0	0	0	0	0	0	0	0.002	0.008	0.028	0.074	0.144	0.206	0.217	0.169	0.096	0.04
16	0	0	0	0	0	0	0	0.001	0.005	0.02	0.058	0.122	0.191	0.22	0.187	0.117	0.054
17	0	0	0	0	0	0	0	0.001	0.004	0.015	0.046	0.104	0.175	0.218	0.2	0.136	0.068
18	0	0	0	0	0	0	0	0	0.003	0.011	0.037	0.09	0.161	0.213	0.209	0.151	0.081
19	0	0	0	0	0	0	0	0	0.002	0.009	0.03	0.078	0.148	0.207	0.215	0.164	0.093
20	0	0	0	0	0	0	0	0	0.001	0.007	0.025	0.069	0.137	0.201	0.218	0.175	0.103

Table 8.9b. Age-length transition matrices for male flathead sole. Values at a row/column combination correspond to the fraction of individuals at the age indicated by the row that fall into the length group indicated by the column.

	length cutpts (cm)																
age	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**
3	0.706	0.265	0.029	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.038	0.205	0.405	0.279	0.067	0.005	0	0	0	0	0	0	0	0	0	0	0
5	0.001	0.015	0.095	0.274	0.353	0.204	0.052	0.006	0	0	0	0	0	0	0	0	0
6	0	0.001	0.011	0.067	0.205	0.323	0.26	0.108	0.023	0.002	0	0	0	0	0	0	0
7	0	0	0.001	0.013	0.066	0.188	0.298	0.263	0.13	0.036	0.005	0	0	0	0	0	0
8	0	0	0	0.003	0.019	0.081	0.199	0.288	0.245	0.122	0.036	0.006	0.001	0	0	0	0
9	0	0	0	0.001	0.006	0.033	0.112	0.227	0.281	0.212	0.097	0.027	0.005	0	0	0	0
10	0	0	0	0	0.002	0.014	0.06	0.158	0.257	0.261	0.165	0.065	0.016	0.002	0	0	0
11	0	0	0	0	0.001	0.007	0.033	0.106	0.213	0.271	0.217	0.11	0.035	0.007	0.001	0	0
12	0	0	0	0	0	0.003	0.019	0.071	0.17	0.258	0.248	0.153	0.06	0.015	0.002	0	0
13	0	0	0	0	0	0.002	0.012	0.049	0.135	0.236	0.263	0.188	0.086	0.025	0.005	0.001	0
14	0	0	0	0	0	0.001	0.007	0.035	0.108	0.212	0.267	0.214	0.11	0.036	0.008	0.001	0
15	0	0	0	0	0	0.001	0.005	0.026	0.088	0.191	0.264	0.234	0.132	0.047	0.011	0.002	0
16	0	0	0	0	0	0	0.003	0.019	0.072	0.172	0.259	0.248	0.151	0.058	0.014	0.002	0
17	0	0	0	0	0	0	0.002	0.015	0.061	0.156	0.253	0.258	0.167	0.068	0.017	0.003	0
18	0	0	0	0	0	0	0.002	0.012	0.052	0.143	0.246	0.266	0.18	0.076	0.02	0.003	0
19	0	0	0	0	0	0	0.001	0.009	0.045	0.132	0.241	0.272	0.191	0.083	0.022	0.004	0
20	0	0	0	0	0	0	0.001	0.008	0.039	0.122	0.235	0.278	0.201	0.089	0.024	0.004	0

Table 8.10. Age-specific schedules for flathead sole in the Gulf of Alaska. Maturity ogive is based on Stark (2004).

	Length (cm)		Weight (kg)		Maturity
Age	Males	Females	Males	Females	ogive
3	15.2	17.8	0.03	0.05	0.0117
4	19.3	21.6	0.06	0.09	0.0251
5	22.6	24.9	0.10	0.14	0.0527
6	25.3	27.8	0.15	0.20	0.1076
7	27.6	30.2	0.20	0.26	0.2072
8	29.4	32.2	0.24	0.32	0.3615
9	30.8	34.0	0.28	0.38	0.5508
10	32.0	35.5	0.32	0.44	0.7265
11	33.0	36.8	0.35	0.49	0.8520
12	33.8	37.9	0.37	0.54	0.9257
13	34.5	38.8	0.40	0.58	0.9643
14	35.0	39.6	0.42	0.62	0.9832
15	35.4	40.3	0.43	0.66	0.9922
16	35.8	40.9	0.45	0.69	0.9964
17	36.1	41.4	0.46	0.72	0.9983
18	36.3	41.8	0.47	0.74	0.9992
19	36.5	42.2	0.48	0.76	0.9996
20	36.7	42.5	0.48	0.83	0.9998

Table 8.11. Likelihood multiplier settings.

Fishery		Survey			Recruitment		
catch	length compositions	biomass	length compositions	age compositions	early	ordinary	late
30	1	1	1	1	1	1	1

Table 8.12. Initial parameter values.

Recruitment										
$\overline{\ln R_0}$	17									
τ_t						1967-2011:	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000									
Fishing mortality										
$\overline{\ln F}$	0									
ε_t			1984-2011:	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000									
Fishery Selectivity										
	females	**males**								
slope	0.4	0.4								
A_{50}	5	5								
scale par.	--	--								
Survey Selectivity										
	females	**males**								
slope	0.8	0.4								
A_{50}	4	4								
scale par.	--	--								

Table 8.13. Log-likelihood components for the assessment model.

likelihood component	Base model
ordinary recruitment	-16.95
"late" recruitment	-0.11
"early" recruitment	-13.40
fishery catch	-0.02
fishery size composition	-600.32
survey biomass	-14.28
survey size composition	-27.77
survey age composition	-176.80

Table 8.14. Final parameter estimates.

Recruitment										
$\overline{\ln R_0}$	18.24449									
τ_t						1967-2011:	-1.7027	-0.8710	-0.9444	-1.0158
	-1.0749	-1.1220	-1.1564	-1.1778	-0.4903	-0.8957	-0.0161	0.4192	0.9251	0.7041
	0.1579	0.2212	0.1807	0.1912	0.2059	0.0519	0.1357	0.3594	0.0905	0.1971
	0.2515	0.4367	0.2083	0.3709	0.1787	0.2896	0.3149	0.0675	0.0392	0.4505
	0.5796	0.6423	0.3292	0.3761	0.4638	0.6889	0.3681	0.7684	0.1948	-0.2016
	-0.1898									
Fishing mortality										
$\overline{\ln F}$	-4.177899									
ε_t			1984-2011:	-0.2605	-0.9900	-1.9391	-2.0771	-0.9868	-0.6984	-0.0804
	0.0742	0.2344	0.3850	0.4731	0.3067	0.6473	0.4136	0.0764	-0.5787	-0.0705
	0.1199	0.2269	0.3440	0.3341	0.3831	0.5884	0.5916	0.6474	0.6867	0.7198
	0.4292									
Fishery Selectivity										
	females	**males**								
slope	0.8110	0.9033								
A_{50}	10.42	10.12								
scale par.	--	--								
Survey Selectivity										
	females	**males**								
slope	0.7660	0.8697								
A_{50}	5.29	4.89								
scale par.	--	--								

Table 8.15. Estimated catch and survey biomass from the assessment model. Estimate uncertainty (standard deviation) based on model hessian.

year	catch (t)			survey biomass (t)		
	estimated	std dev	observed	estimated	std dev	observed
1984	557	71	549	167,440	9,914	249,341
1985	331	42	320	180,910	9,958	
1986	157	20	147	190,710	9,897	
1987	162	21	151	197,680	9,769	177,546
1988	539	69	520	202,540	9,590	
1989	769	98	747	205,510	9,375	
1990	1,476	189	1,447	207,560	9,144	243,055
1991	1,746	224	1,717	208,580	8,903	
1992	2,054	263	2,034	209,460	8,664	
1993	2,378	305	2,366	210,260	8,438	188,690
1994	2,580	330	2,580	211,550	8,245	
1995	2,179	278	2,181	213,100	8,077	
1996	3,059	390	3,107	215,220	7,925	205,521
1997	2,419	308	2,446	216,120	7,782	
1998	1,740	221	1,742	217,080	7,640	
1999	919	117	900	218,030	7,503	207,590
2000	1,554	198	1,547	219,160	7,375	
2001	1,902	241	1,911	197,550	6,547	170,745
2002	2,128	270	2,145	220,770	7,232	
2003	2,393	304	2,425	223,820	7,290	257,294
2004	2,364	300	2,390	228,490	7,504	
2005	2,477	313	2,530	233,850	7,878	213,221
2006	3,039	384	3,134	238,960	8,390	
2007	3,076	389	3,163	243,190	9,026	280,290
2008	3,319	420	3,419	248,060	9,844	
2009	3,538	447	3,658	252,770	10,886	225,377
2010	3,734	473	3,842	256,310	12,172	
2011	2,847	361	2,339	257,190	13,666	235,639

Table 8.16a. Age 3+ population biomass estimated in this year's model, compared with estimates from previous assessments. Estimate uncertainty (standard deviation) based on model hessian.

year	Age 3+ Biomass (1000's t)							
	2011 Assessment		2009 Assessment		2007 Assessment		2005 Assessment	
	mean	std dev	mean	std dev	mean	std dev	mean	std dev
1984	210	11	222	11	244	13	248	13
1985	221	11	233	11	254	13	256	13
1986	229	11	241	11	262	13	263	13
1987	234	11	247	11	266	12	266	12
1988	240	10	253	11	271	12	270	12
1989	243	10	256	11	274	12	271	12
1990	245	10	258	11	275	12	271	11
1991	247	10	259	11	276	11	271	11
1992	249	10	262	10	280	11	274	11
1993	251	10	264	10	281	11	273	11
1994	253	9	266	10	282	11	272	11
1995	255	9	267	10	283	11	272	11
1996	256	9	269	10	284	11	272	11
1997	257	9	269	10	283	11	269	11
1998	257	9	267	10	279	11	265	11
1999	256	9	263	10	274	11	258	11
2000	258	9	263	10	275	11	259	11
2001	262	9	266	10	279	12	262	12
2002	268	10	273	11	288	13	269	14
2003	273	10	281	12	297	14	280	16
2004	278	11	291	13	302	16	286	18
2005	282	11	302	15	308	18	292	20
2006	290	12	314	17	320	21		
2007	294	14	325	19	322	24		
2008	302	15	330	22				
2009	305	17	330	24				
2010	303	18						
2011	297	20						

Table 8.16b. Female spawning biomass estimated in this year's model, compared with estimates from previous assessments. Estimate uncertainty (standard deviation) based on model hessian.

year	Female Spawning Stock Biomass (1000's t)							
	2011 Assessment		2009 Assessment		2007 Assessment		2005 Assessment	
	mean	std dev	mean	std dev	mean	std dev	mean	std dev
1984	49	3	53	4	61	4	65	4
1985	59	4	63	4	73	4	76	4
1986	68	4	73	4	83	5	85	5
1987	76	4	80	4	90	5	91	5
1988	81	4	85	4	94	5	95	5
1989	84	4	88	4	96	5	97	5
1990	86	4	90	4	97	5	97	5
1991	86	4	91	4	97	5	97	4
1992	86	4	91	4	97	4	97	4
1993	86	4	91	4	97	4	96	4
1994	86	4	91	4	97	4	95	4
1995	86	4	91	4	97	4	95	4
1996	87	4	92	4	98	4	95	4
1997	87	3	92	4	98	4	95	4
1998	88	3	93	4	99	4	95	4
1999	89	3	94	4	99	4	95	4
2000	90	3	95	4	100	4	95	4
2001	91	3	95	4	100	4	94	4
2002	91	3	95	4	99	4	93	4
2003	91	3	94	4	98	4	92	4
2004	91	3	93	4	97	4	91	4
2005	92	3	93	4	98	4	91	5
2006	93	4	95	4	100	5		
2007	95	4	98	5	103	5		
2008	97	4	102	5				
2009	99	4	106	6				
2010	101	5						
2011	102	5						

Table 8.17. Age 3 recruitment values as estimated in this year's model, compared with estimates from previous assessments. Estimate uncertainty (standard deviation) based on model hessian.

Year	2011 Assessment		2009 Assessment		2007 Assessment		2005 Assessment	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1984	203	29	215	31	165	36	163	35
1985	206	27	216	29	247	43	241	42
1986	177	24	185	26	239	39	233	38
1987	192	25	199	27	180	32	175	32
1988	240	29	255	31	269	39	259	38
1989	184	25	196	27	211	34	201	33
1990	204	25	212	27	224	34	212	33
1991	216	26	220	29	238	36	222	34
1992	260	27	281	31	326	42	305	40
1993	207	24	211	26	188	33	175	31
1994	243	26	252	30	215	38	200	36
1995	201	23	215	27	272	42	253	39
1996	224	24	223	28	228	38	211	36
1997	230	25	211	28	212	39	193	36
1998	179	22	169	25	154	34	140	31
1999	174	22	162	24	133	32	121	29
2000	263	28	247	32	351	54	320	52
2001	299	31	332	38	349	57	327	57
2002	319	34	368	44	366	69	359	73
2003	233	29	286	41	337	75	352	86
2004	244	33	340	53	167	80	192	96
2005	267	37	323	57	302	114	242	105
2006	334	49	365	78	447	174		
2007	242	45	311	90	148	113		
2008	362	69	214	122				
2009	204	64	174	98				
2010	137	86						
2011	139	77						

Table 8.18. Projected catch (t) for the seven projection scenarios.

	Catch (t)						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2011	2,891	2,891	2,891	2,891	2,891	2,891	2,891
2012	47,407	47,407	25,718	3,508	0	59,380	47,407
2013	36,167	36,167	22,773	3,566	0	41,437	36,167
2014	29,073	29,073	20,507	3,611	0	31,370	36,568
2015	24,241	24,241	18,598	3,621	0	25,204	28,127
2016	20,522	20,522	16,801	3,576	0	20,508	22,430
2017	17,570	17,570	15,093	3,477	0	15,707	16,855
2018	15,154	15,154	13,700	3,356	0	14,215	14,601
2019	14,394	14,394	12,832	3,255	0	14,462	14,578
2020	14,649	14,649	12,450	3,191	0	15,351	15,366
2021	15,114	15,114	12,355	3,161	0	16,107	16,092
2022	15,459	15,459	12,374	3,149	0	16,497	16,481
2023	15,646	15,646	12,419	3,147	0	16,620	16,609
2024	15,721	15,721	12,456	3,146	0	16,623	16,617

Table 8.19. Female spawning biomass (t) for the seven projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 41,547 t and 36,354 t, respectively.

	Female spawning biomass (t)						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2011	102,433	102,433	102,433	102,433	102,433	102,433	102,433
2012	104,301	104,301	104,301	104,301	104,301	104,301	104,301
2013	82,277	82,277	93,589	105,304	107,165	76,100	82,277
2014	67,620	67,620	84,618	105,193	108,749	59,471	67,620
2015	56,943	56,943	76,434	103,581	108,651	48,568	53,132
2016	48,816	48,816	68,962	100,798	107,189	40,910	43,404
2017	43,214	43,214	62,879	97,798	105,301	36,234	37,401
2018	40,306	40,306	58,790	95,379	103,765	35,098	35,500
2019	39,805	39,805	56,645	93,837	102,886	35,735	35,851
2020	40,392	40,392	55,819	92,952	102,472	36,828	36,839
2021	41,105	41,105	55,666	92,533	102,402	37,639	37,622
2022	41,596	41,596	55,755	92,363	102,502	38,029	38,010
2023	41,853	41,853	55,894	92,341	102,705	38,142	38,131
2024	41,966	41,966	56,005	92,299	102,826	38,146	38,140

Table 8.20. Fishing mortality for the seven projection scenarios.

	Fishing mortality						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2011	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2012	0.45	0.45	0.23	0.03	0.00	0.59	0.45
2013	0.45	0.45	0.23	0.03	0.00	0.59	0.45
2014	0.45	0.45	0.23	0.03	0.00	0.59	0.59
2015	0.45	0.45	0.23	0.03	0.00	0.59	0.59
2016	0.45	0.45	0.23	0.03	0.00	0.58	0.59
2017	0.45	0.45	0.23	0.03	0.00	0.51	0.53
2018	0.43	0.43	0.23	0.03	0.00	0.50	0.50
2019	0.43	0.43	0.23	0.03	0.00	0.51	0.51
2020	0.43	0.43	0.23	0.03	0.00	0.52	0.52
2021	0.43	0.43	0.23	0.03	0.00	0.53	0.53
2022	0.44	0.44	0.23	0.03	0.00	0.54	0.54
2023	0.44	0.44	0.23	0.03	0.00	0.54	0.54
2024	0.44	0.44	0.23	0.03	0.00	0.54	0.54

Table 8.21. Prohibited species catches (PSC) in the flathead sole target fishery.

a) Crab PSC.

year	PSC in target fishery (#)					fraction of total PSC				
	King Crab			Tanner Crab		King Crab			Tanner Crab	
	Blue	Golden	Red	Bairdi	Opilio	Blue	Golden	Red	Bairdi	Opilio
2003	0	533	0	17,330	174	0.0%	64.6%	0.0%	11.7%	11.9%
2004	0	0	0	7,275	0	0.0%	0.0%	0.0%	10.1%	0.0%
2005	0	0	0	32,471	0	0.0%	0.0%	0.0%	13.9%	0.0%
2006	0	0	0	25,884	0	0.0%	0.0%	0.0%	6.3%	0.0%
2007	0	0	0	254	0	0.0%	0.0%	0.0%	0.1%	0.0%
2008	0	0	0	7,077	272	0.0%	0.0%	0.0%	1.9%	13.6%
2009	0	0	0	7,688	0	0.0%	0.0%	0.0%	3.0%	0.0%
2010	0	0	0	6,498	0	0.0%	0.0%	0.0%	2.5%	0.0%
2011	0	0	0	5,220	0	0.0%	0.0%	0.0%	5.8%	0.0%

b) Halibut PSC.

Year	directed fishery halibut PSC (kg)	% total halibut PSC
2003	203,807	3.7%
2004	101,755	1.7%
2005	52,798	1.1%
2006	36,528	0.6%
2007	27,029	0.6%
2008	91,959	1.5%
2009	97,728	2.1%
2010	256,572	5.7%
2011	91,931	2.1%

c) Salmon PSC. (Salmon PSC for 2011 was unavailable at time of document preparation.)

Year	Chinook		Non-Chinook	
	PSC (#)	fraction of total	PSC (#)	fraction of total
2003	612	3.9%	19	0.2%
2004	1,389	7.8%	90	1.6%
2005	16	0.1%	0	0.0%
2006	56	0.3%	0	0.0%
2007	0	0.0%	0	0.0%
2008	0	0.0%	0	0.0%
2009	118	1.5%	0	0.0%
2010	498	0.9%	0	0.0%

Table 8.22. Catch of nontarget species in the flathead sole target fishery, expressed as the fraction of species catch by all fisheries in the FMP.

Nontarget Species	Year								
Group	2011	2010	2009	2008	2007	2006	2005	2004	2003
Benthic urochordata	8.5%	14.1%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%
Birds	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bivalves	3.0%	4.2%	2.5%	2.0%	1.7%	2.8%	6.4%	5.6%	4.2%
Brittle star unidentified	2.4%	9.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Capelin	0.0%	0.0%	0.0%	0.0%	--	0.0%	0.0%	0.0%	0.0%
Corals Bryozoans	0.0%	6.9%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	1.8%
Dark Rockfish	0.0%	0.0%	9.3%	0.0%	--	--	--	--	--
Eelpouts	9.2%	11.3%	0.0%	6.0%	7.1%	4.9%	6.9%	6.3%	9.3%
Eulachon	1.8%	3.9%	2.6%	2.1%	0.0%	1.2%	2.9%	0.4%	1.4%
Giant Grenadier	0.0%	5.1%	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Greenlings	2.4%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%
Grenadier	6.4%	0.0%	0.0%	0.0%	0.0%	1.3%	5.8%	3.3%	4.5%
Gunnels	--	--	--	2.8%	--	100.0%	--	--	0.0%
Hermit crab unidentified	2.7%	3.6%	0.0%	1.8%	0.0%	0.0%	0.1%	0.6%	4.4%
Invertebrate unidentified	2.6%	0.0%	4.8%	2.1%	0.0%	1.6%	0.0%	2.6%	2.4%
Lanternfishes (myctophidae)	--	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Large Sculpins	1.0%	2.0%	1.6%	0.6%	0.8%	1.0%	2.7%	3.0%	1.9%
Misc crabs	2.1%	4.2%	3.1%	0.0%	0.0%	0.0%	0.0%	3.6%	0.9%
Misc crustaceans	0.0%	0.0%	0.0%	--	--	--	0.0%	0.0%	0.0%
Misc deep fish	--	--	--	0.0%	--	--	--	--	--
Misc fish	1.1%	2.5%	1.5%	0.9%	0.7%	0.5%	2.0%	1.7%	2.3%
Misc inverts (worms etc)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	--	--
Octopus	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%
Other osmerids	2.6%	0.0%	0.0%	0.6%	0.0%	2.7%	0.0%	0.0%	3.1%
Other Sculpins	2.1%	4.7%	2.3%	0.9%	0.9%	2.0%	4.2%	0.4%	3.3%
Pacific Sand lance	0.0%	--	0.0%	0.0%	--	0.0%	0.0%	0.0%	0.0%
Pandalid shrimp	2.1%	6.1%	2.9%	1.6%	0.9%	2.2%	3.7%	0.5%	4.8%
Polychaete unidentified	39.2%	0.0%	0.0%	0.0%	0.0%	--	51.1%	--	0.0%
Scypho jellies	0.0%	2.3%	3.1%	0.0%	0.0%	1.0%	0.0%	1.0%	0.8%
Sea anemone unidentified	2.2%	3.2%	2.2%	0.0%	0.0%	2.0%	0.0%	1.6%	3.8%
Sea pens whips	8.6%	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.2%	0.0%
Sea star	1.3%	3.1%	2.1%	1.0%	1.3%	0.8%	2.9%	2.5%	2.8%
Shark, Other	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	4.3%	3.9%	1.2%
Shark, Pacific sleeper	0.0%	1.6%	0.2%	0.0%	1.6%	1.0%	1.1%	0.8%	2.8%
Shark, salmon	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%
Shark, spiny dogfish	0.1%	2.0%	0.1%	0.0%	0.0%	0.1%	0.7%	0.0%	4.1%
Skate, Alaska	0.7%	0.1%	--	--	--	--	--	--	--
Skate, Aleutian	0.2%	--	--	--	--	--	--	--	--
Skate, Big	1.8%	4.1%	2.6%	1.9%	0.7%	2.6%	2.5%	1.3%	--
Skate, Longnose	1.8%	4.0%	2.0%	1.4%	1.2%	1.3%	1.3%	1.8%	1.1%
Skate, Other	1.7%	4.2%	2.2%	1.5%	1.8%	1.9%	4.2%	2.9%	4.4%
Skate, Whiteblotched	0.0%	--	--	--	--	--	--	--	--
Snails	2.0%	4.0%	2.8%	1.4%	0.8%	1.4%	4.3%	0.9%	4.7%
Sponge unidentified	2.1%	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	4.9%
Squid	0.1%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%	2.7%
Stichaeidae	12.0%	13.5%	6.8%	0.6%	0.0%	8.3%	20.8%	7.5%	19.0%
Surf smelt	--	--	--	0.0%	--	--	0.0%	0.0%	--
urchins dollars cucumbers	2.0%	3.9%	0.0%	0.0%	0.0%	0.0%	4.0%	0.9%	2.9%

Table 8.23. Catch of non-prohibited species in the flathead sole target fishery. The species accounting for the two largest totals are highlighted.

Species	2011 total (t)	2011 % retained	2010 total (t)	2010 % retained	2009 total (t)	2009 % retained	2008 total (t)	2008 % retained	2007 total (t)	2007 % retained
all sculpins, sharks, squid, octopus	6	78%	22	20%	9	57%	14	74%	35	0%
arrowtooth flounder	779	7%	2650	6%	1337	10%	801	21%	723	10%
Atka mackerel	18	99%	10	98%	17	99%	3	98%	36	71%
big skate	39	94%	112	92%	53	96%	66	84%	23	99%
Dover sole and turbot	1	100%	45	48%	18	8%	4	98%	1	0%
flathead sole	367	97%	1242	96%	696	98%	572	92%	423	90%
longnose skate	12	95%	30	97%	24	66%	11	81%	13	19%
northern rockfish	1	89%	6	53%	1	89%	0	100%	2	0%
other rockfish complex	0	--	2	4%	0	--	2	53%	0	99%
pacific cod	108	94%	297	81%	279	97%	125	84%	131	90%
pelagic shelf rockfish	1	82%	9	72%	4	94%	2	100%	2	0%
pollock	57	94%	319	46%	135	81%	45	97%	27	99%
POP	2	6%	74	7%	2	5%	2	2%	11	13%
rex sole	77	86%	397	96%	184	94%	86	98%	110	98%
rougheye	2	16%	15	94%	3	44%	0	42%	0	100%
sablefish	8	98%	13	98%	19	77%	1	61%	4	100%
shallow water flatfish	56	97%	122	98%	95	98%	41	98%	26	95%
shortraker	2	97%	1	78%	3	98%	0	--	0	--
thornyhead	5	100%	13	76%	8	100%	0	100%	7	100%
unidentified skate	9	52%	19	13%	13	49%	5	28%	20	64%

Figures

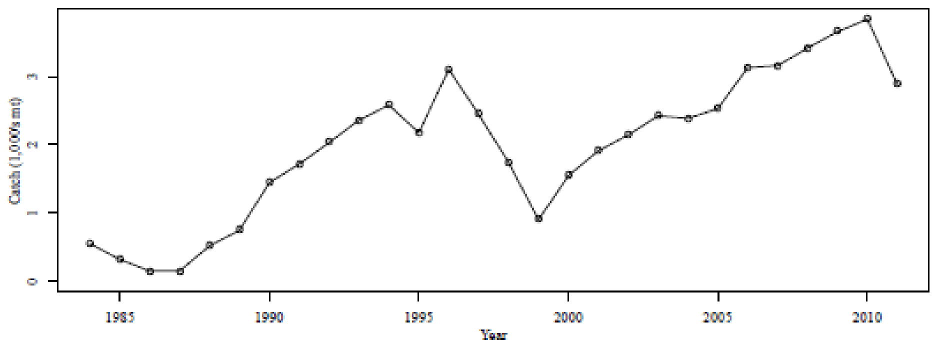


Figure 8.1. Fishery catches for GOA flathead sole, 1984-2011 (as of Sept. 24, 2011).

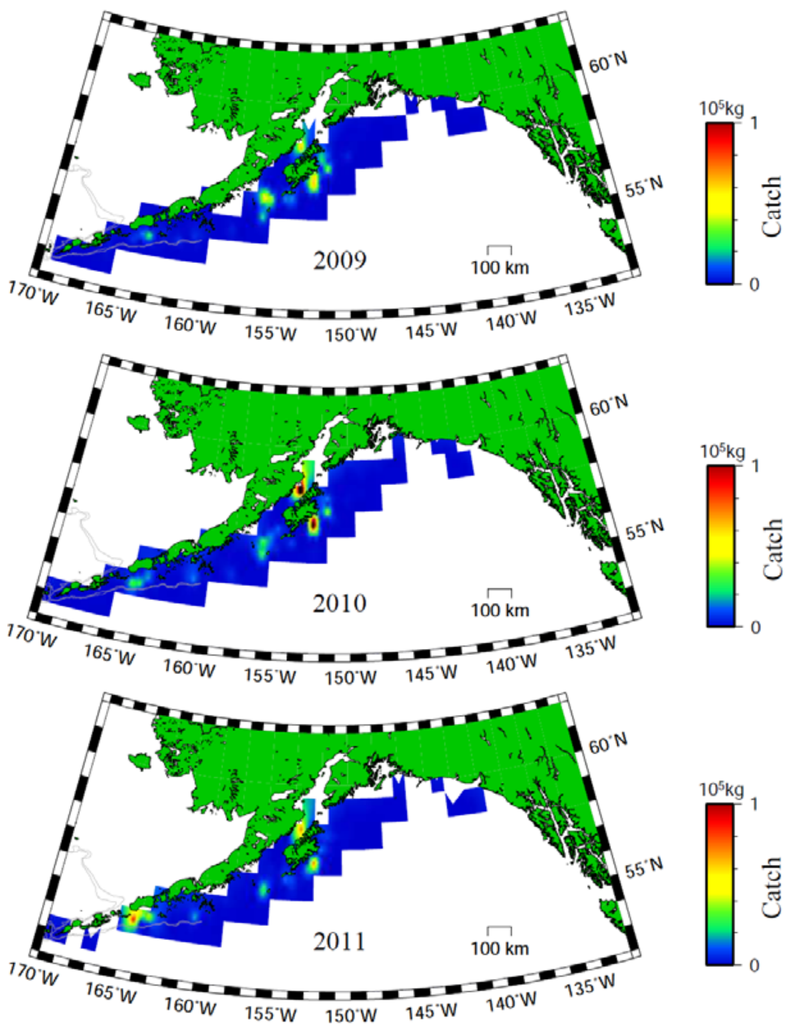


Figure 8.2. Spatial patterns of fishery catches for GOA flathead sole, 2009-2011.

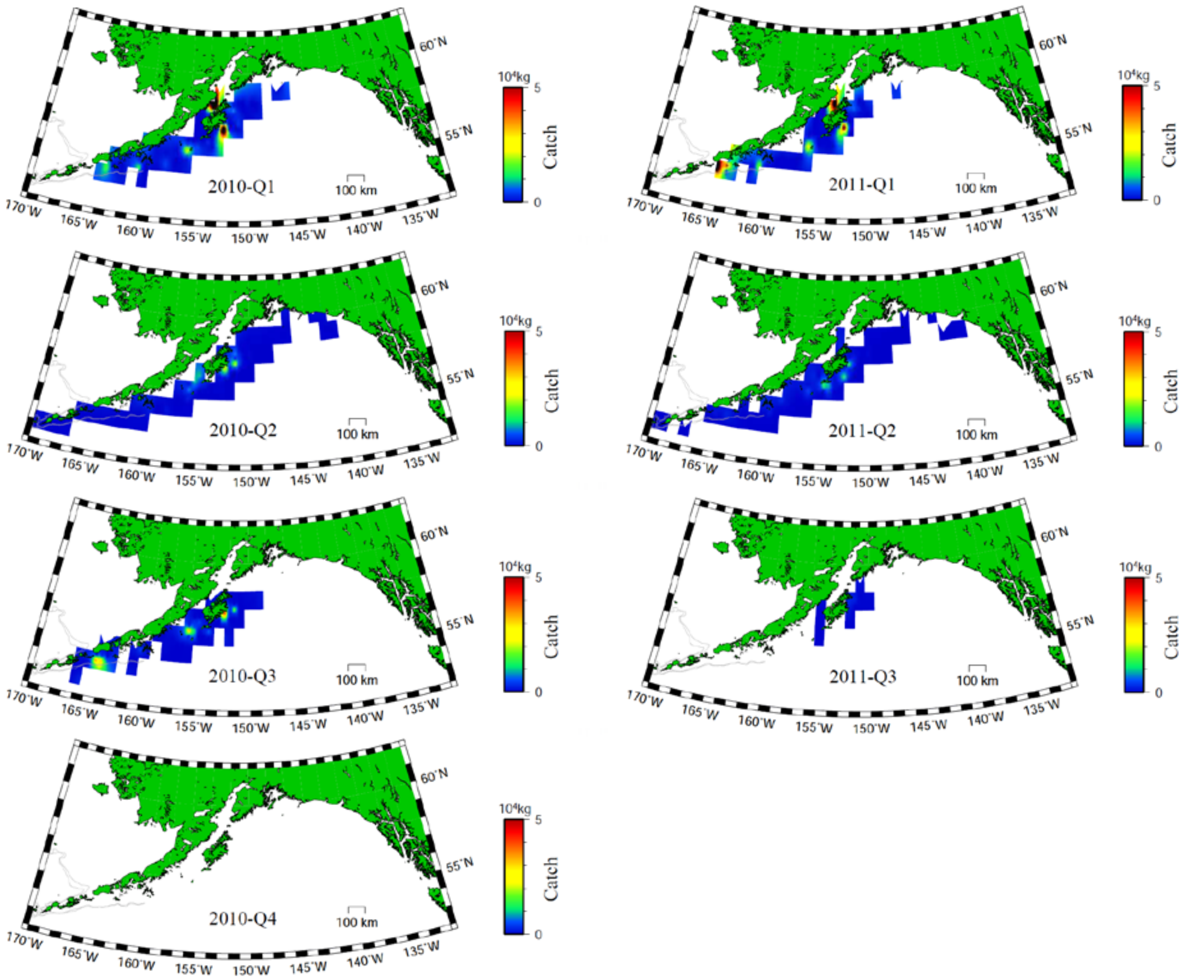


Figure 8.3. Spatial patterns of fishery catches for GOA flathead sole by quarter for 2010- 2011 (through Sept. 24).

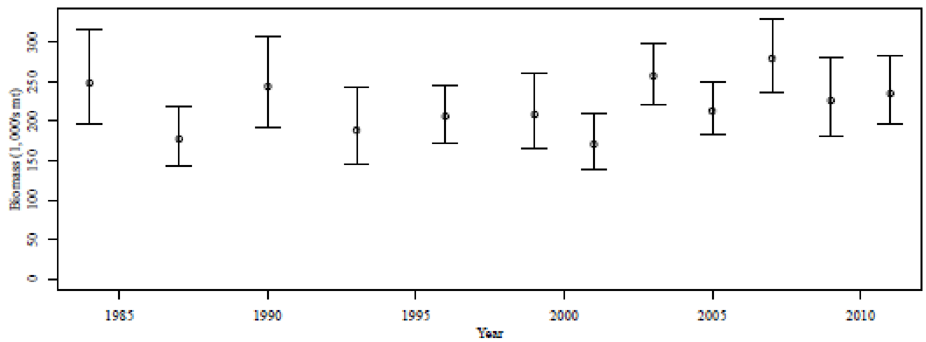


Figure 8.4. GOA survey biomass for flathead sole. Error bars represent 95% lognormal confidence intervals. The GOA survey did not include the eastern gulf in 2001. The value shown here for 2001 has been corrected to account for this (see text).

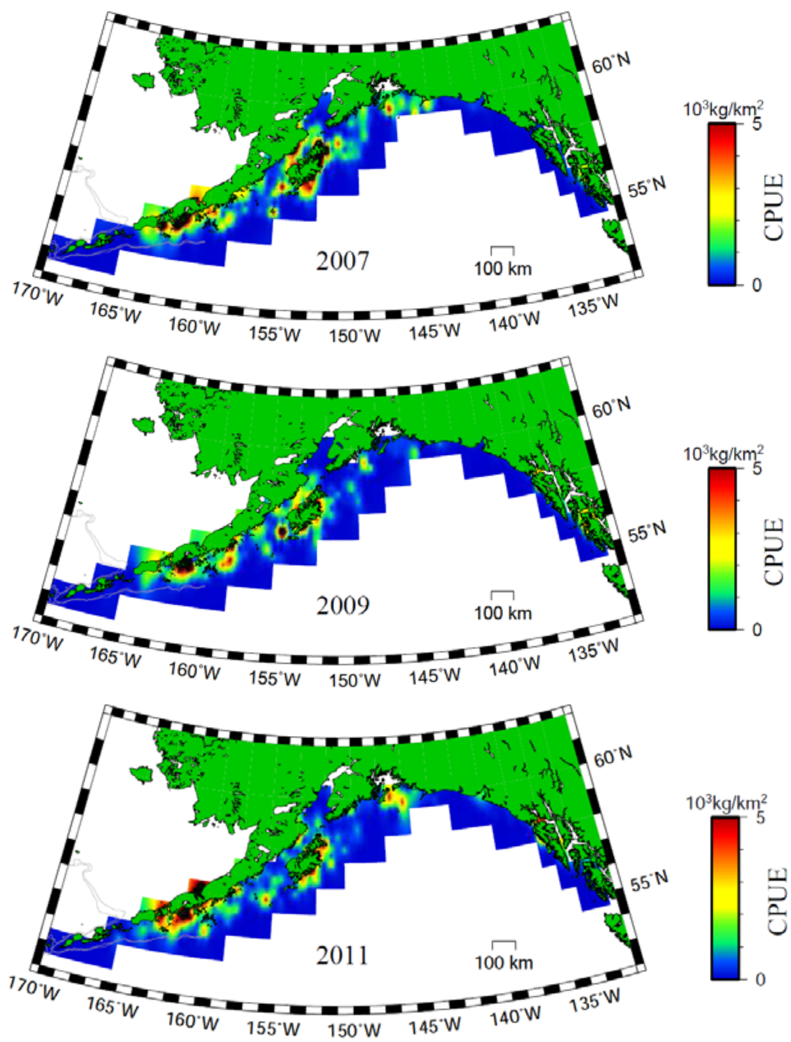
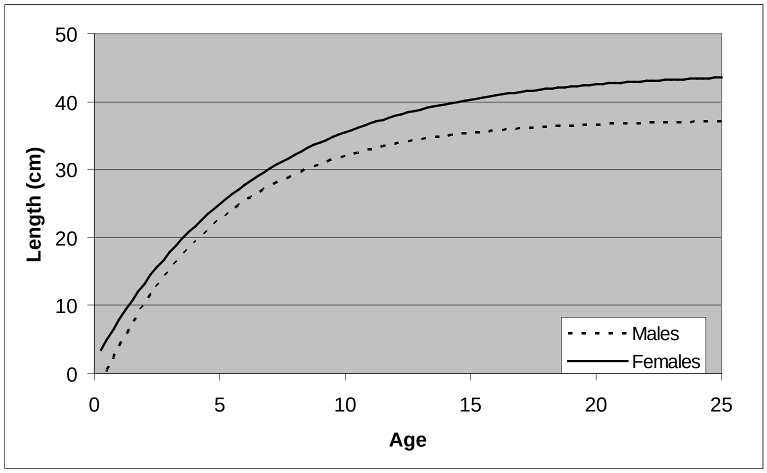
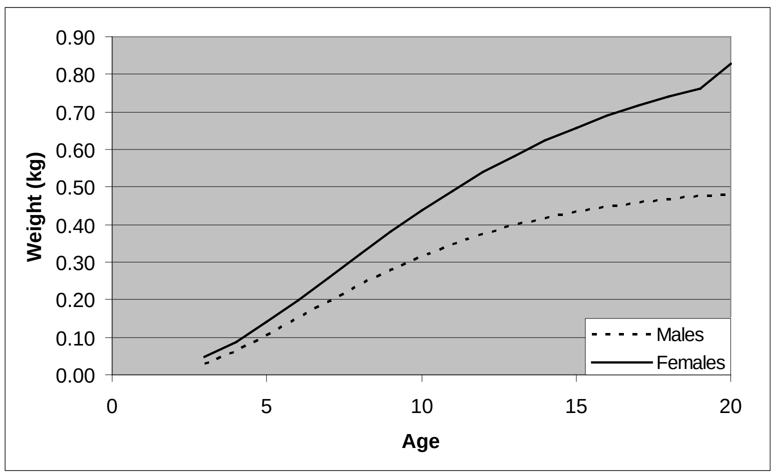


Figure 8.5. Spatial patterns of CPUE for flathead sole in the GOA groundfish surveys for 2007, 2009 and 2011.

a) Length-at-age.



b) Weight –at-age.



c) Maturity-at-age (females).

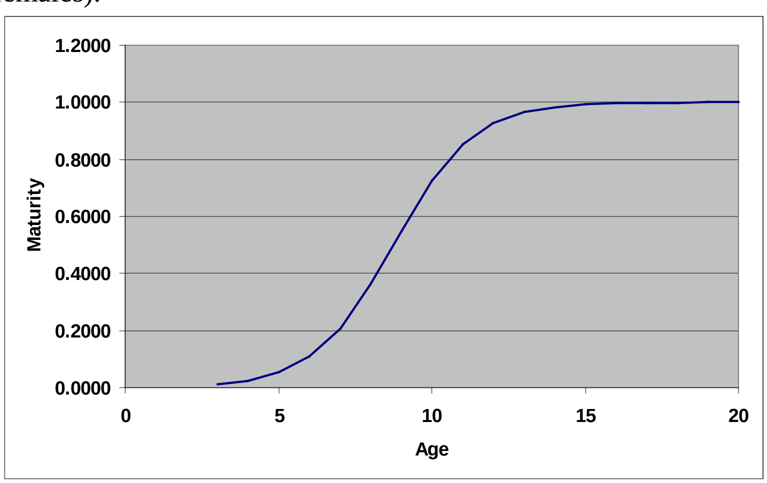


Figure 8.6. Age-specific schedules for GOA flathead sole: females solid line, males dotted line.

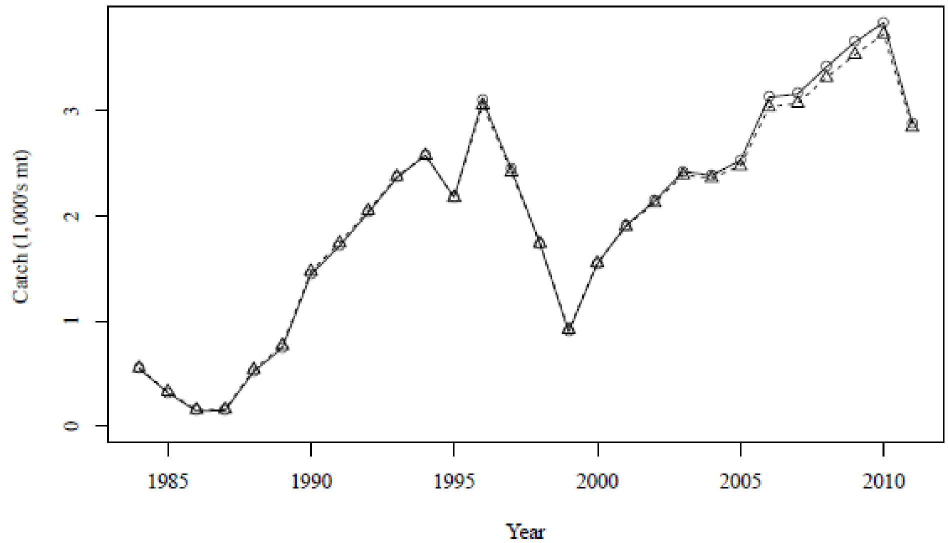


Figure 8.7. Estimated and observed annual catches for GOA flathead sole for the assessment model. Estimated catch = solid line, observed catch = dotted line with circles.

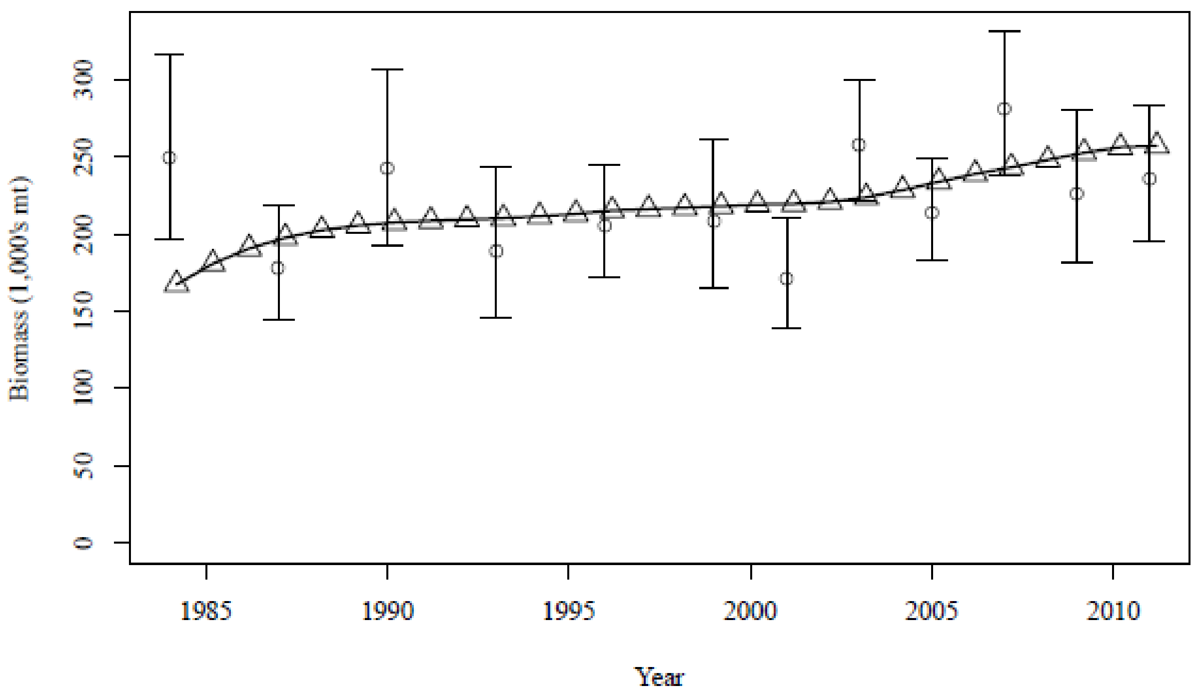


Fig. 8.8. Estimated and observed survey biomass for GOA flathead sole for the assessment model. Estimated survey biomass = triangles, observed survey biomass = circles (error bars are approximate lognormal 95% confidence intervals).

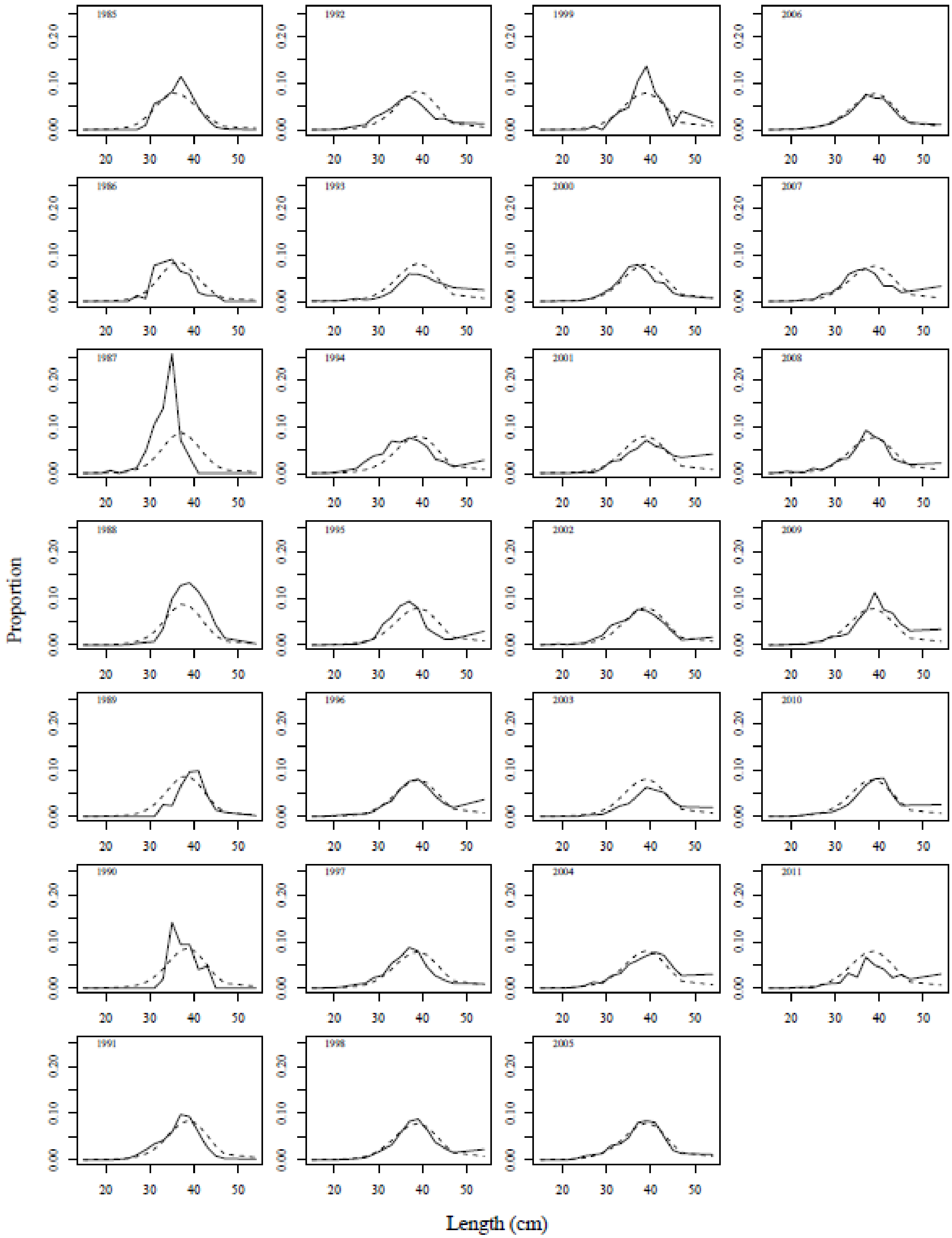


Figure 8.9. Fits to female GOA flathead sole fishery size composition data for the assessment model. Dashed lines represent the model estimates, solid lines represent the data.

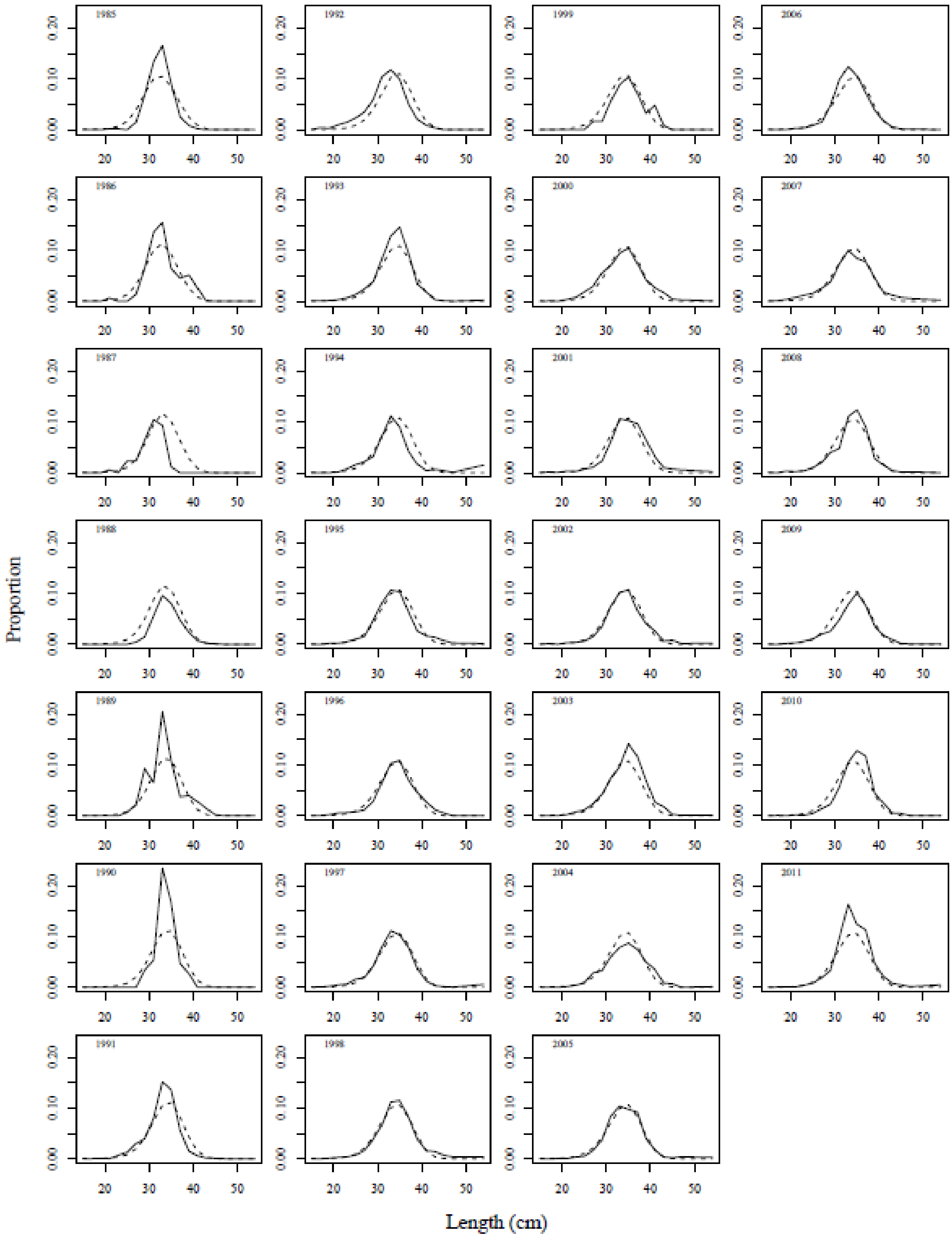


Figure 8.10. Fits to male GOA flathead sole fishery size composition data for the assessment model. Dashed lines represent the model estimates, solid lines represent the data.

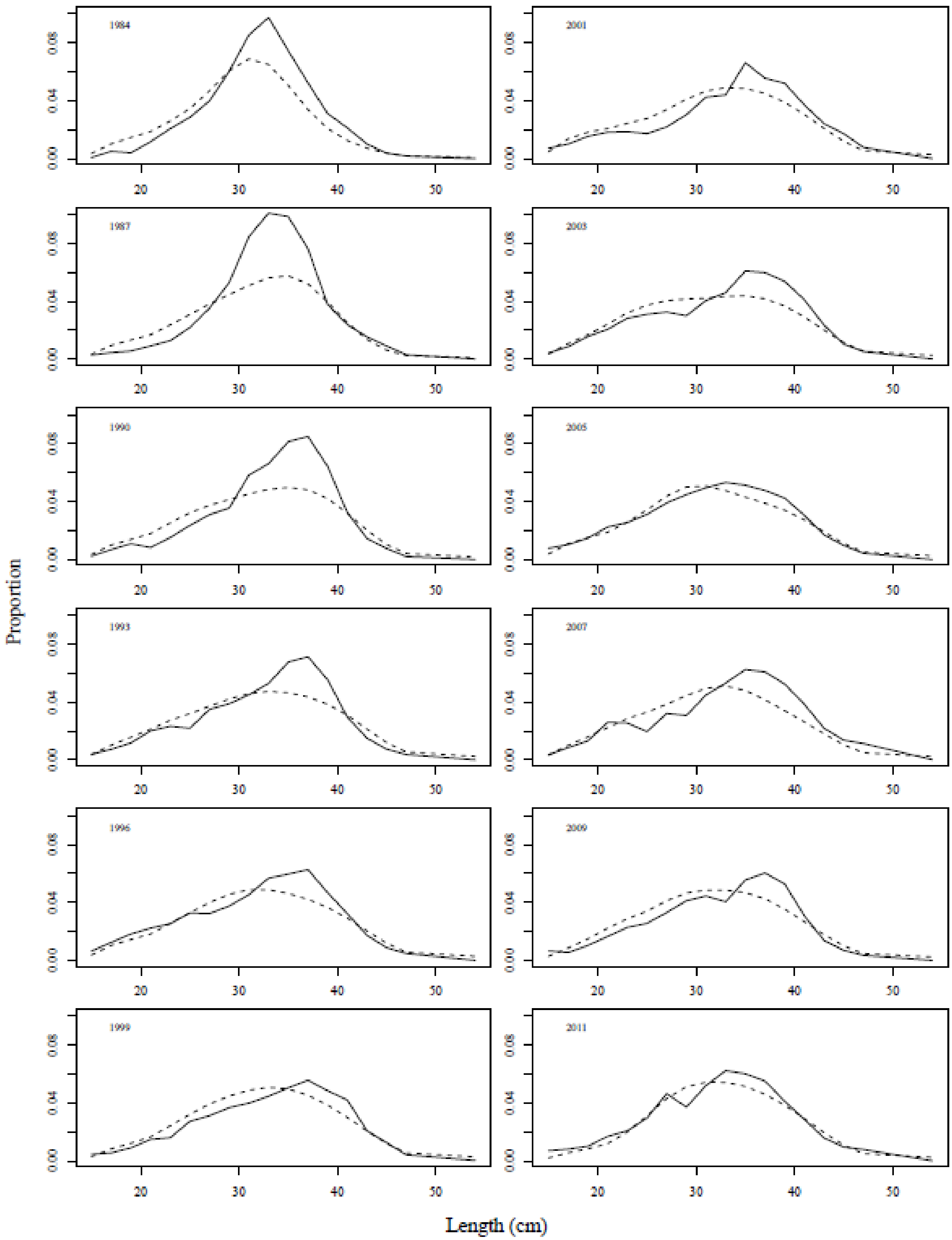


Figure 8.11. Model fits to the female GOA flathead sole survey size composition data. Dashed lines represent the model estimates, solid lines represent the data.

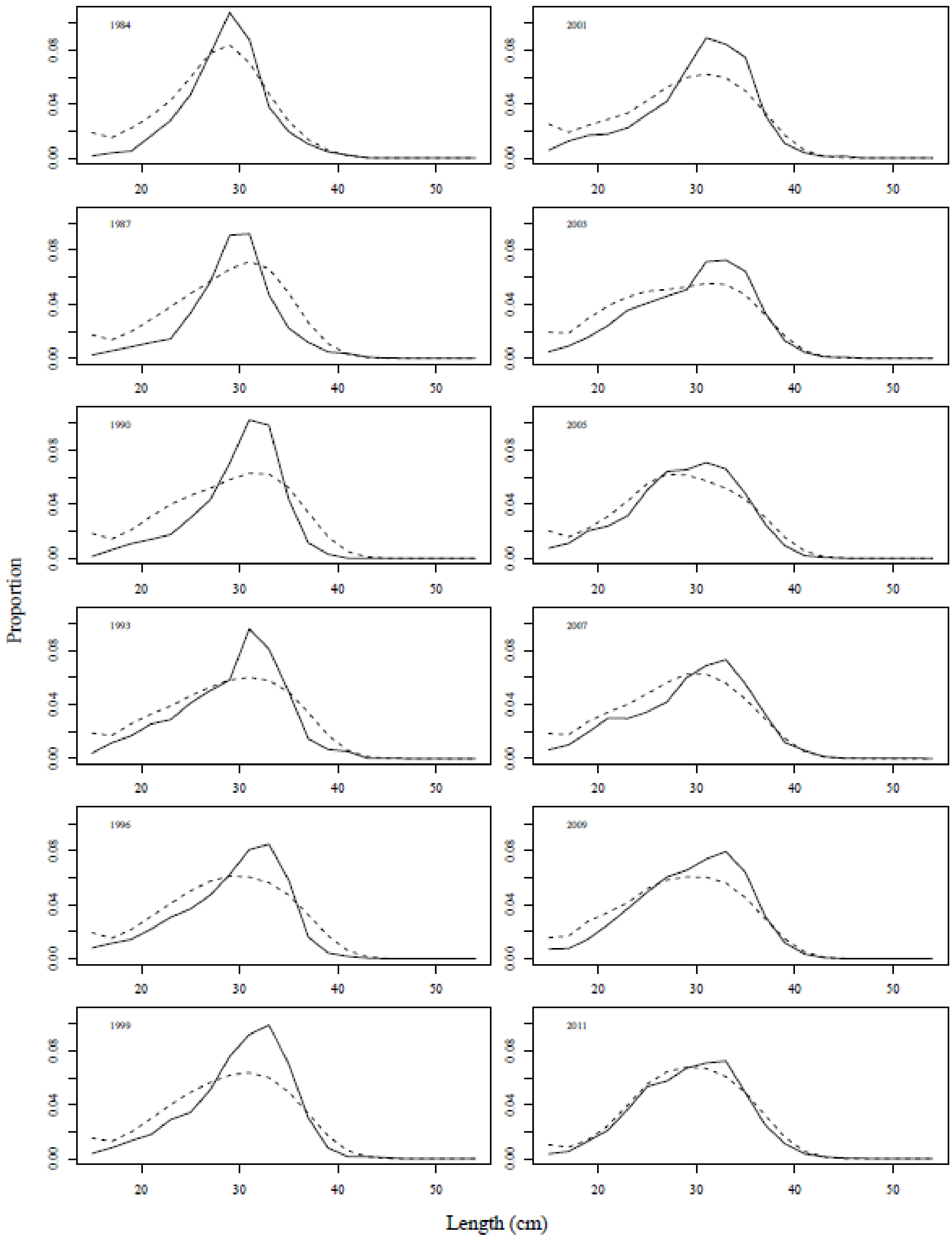


Figure 8.12. Model fits to the male GOA flathead sole survey size composition data. Dashed lines represent the model estimates, solid lines represent the data.

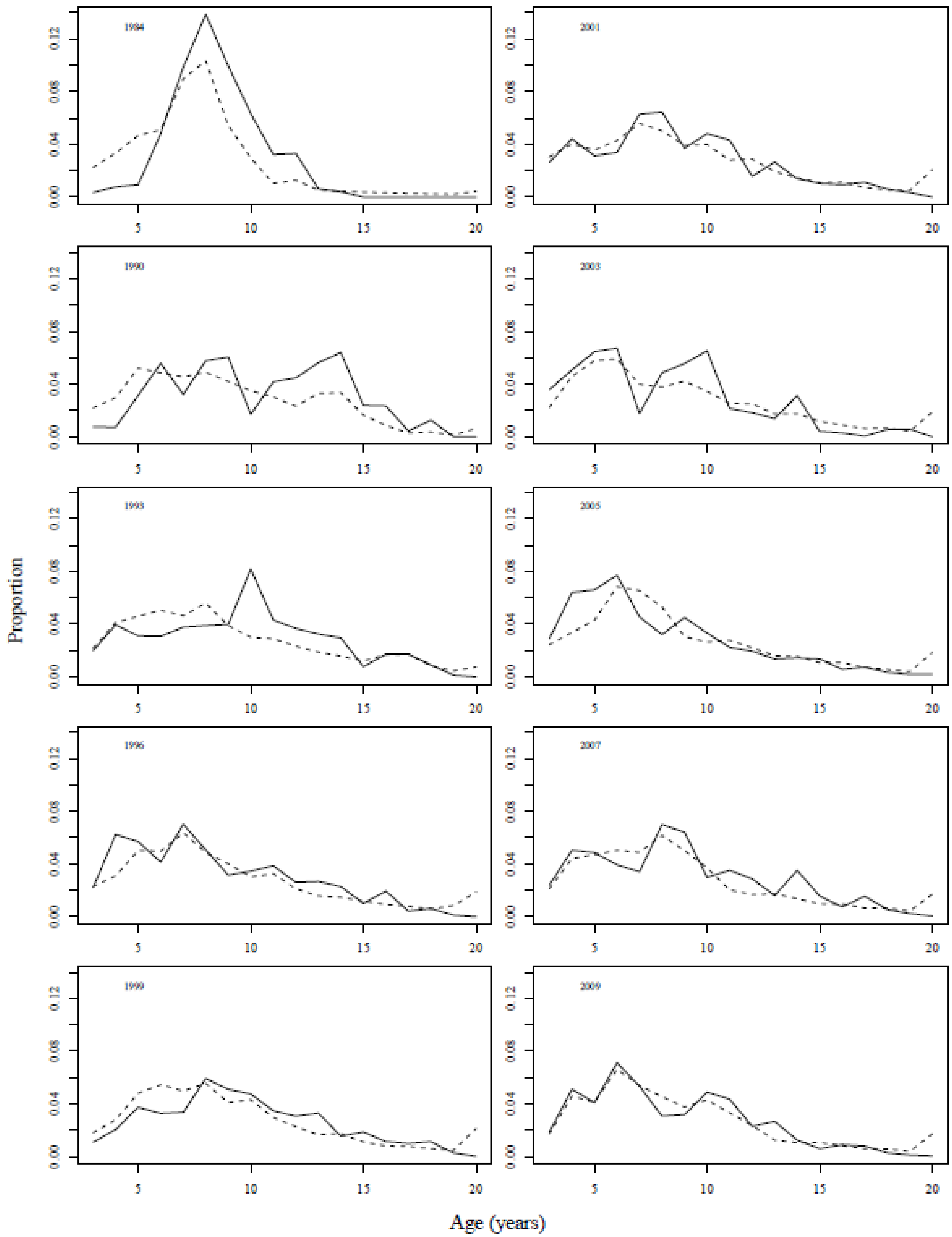


Figure 8.13. Model fits to the female survey GOA flathead sole age composition data. Dashed lines represent the model estimates, solid lines represent the data.

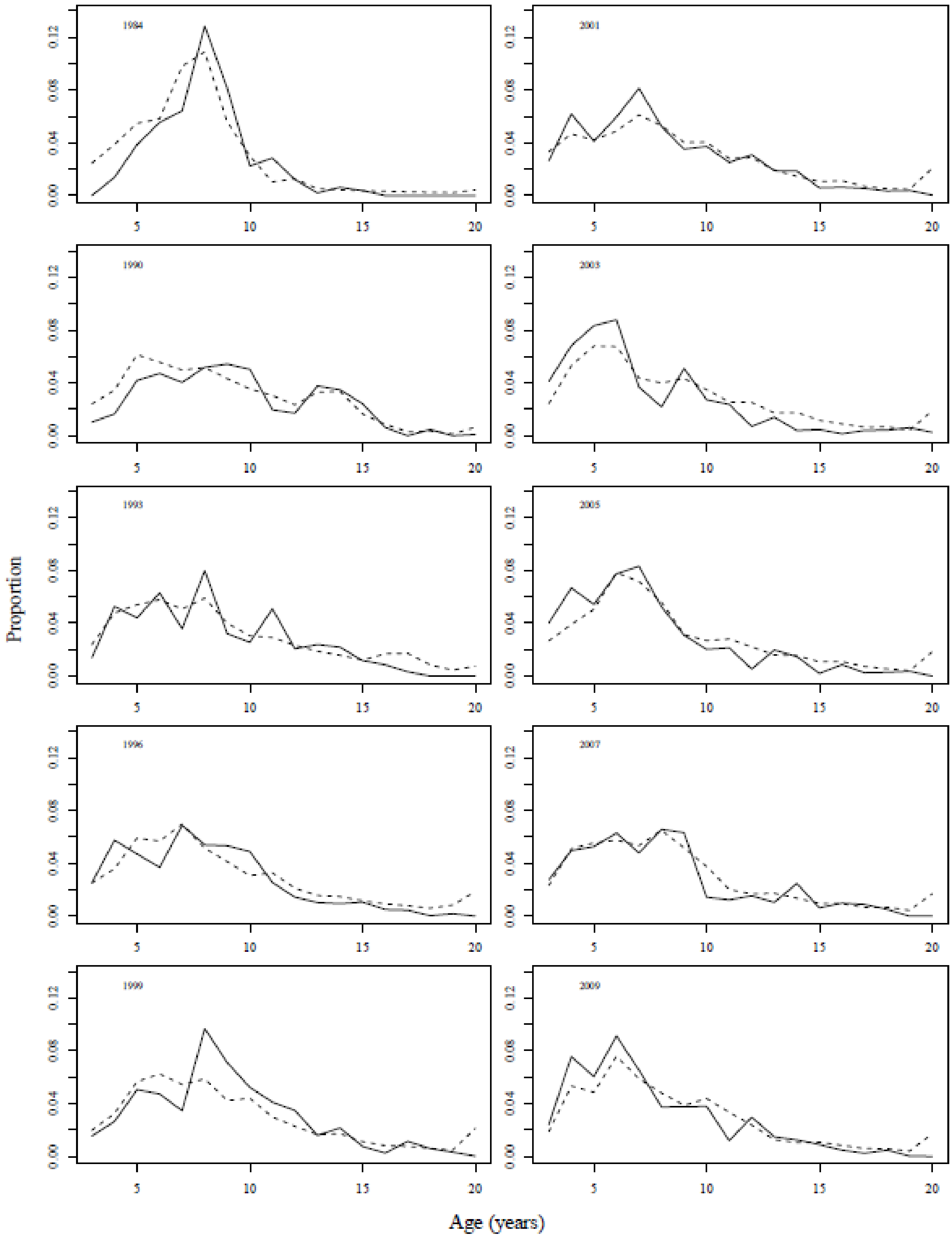


Figure 8.14. Model fits to the male survey GOA flathead sole age composition data. Dashed lines represent the model estimates, solid lines represent the data.

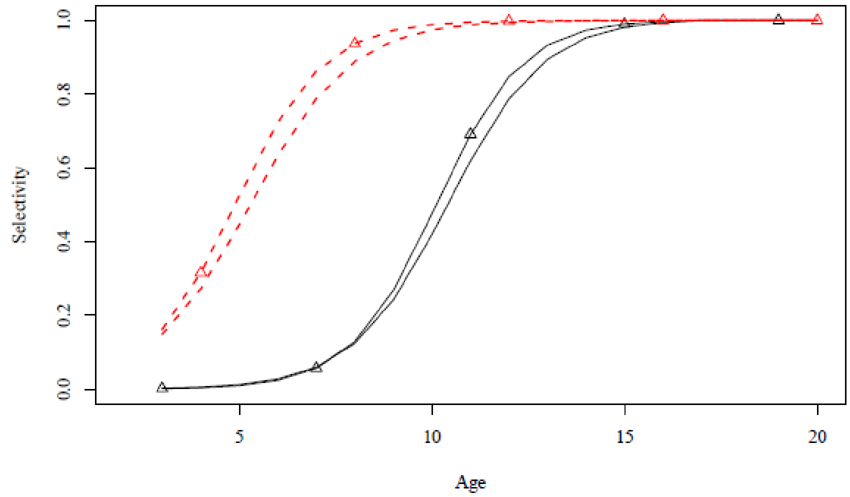


Figure 8.15. Estimated survey and fishery selectivities. Survey selectivities are plotted in red with a dotted line, fishery selectivities are plotted in black with asolid line. Male selectivity functions are plotted with a triangle symbol, female selectivity functions are plotted without a symbol.

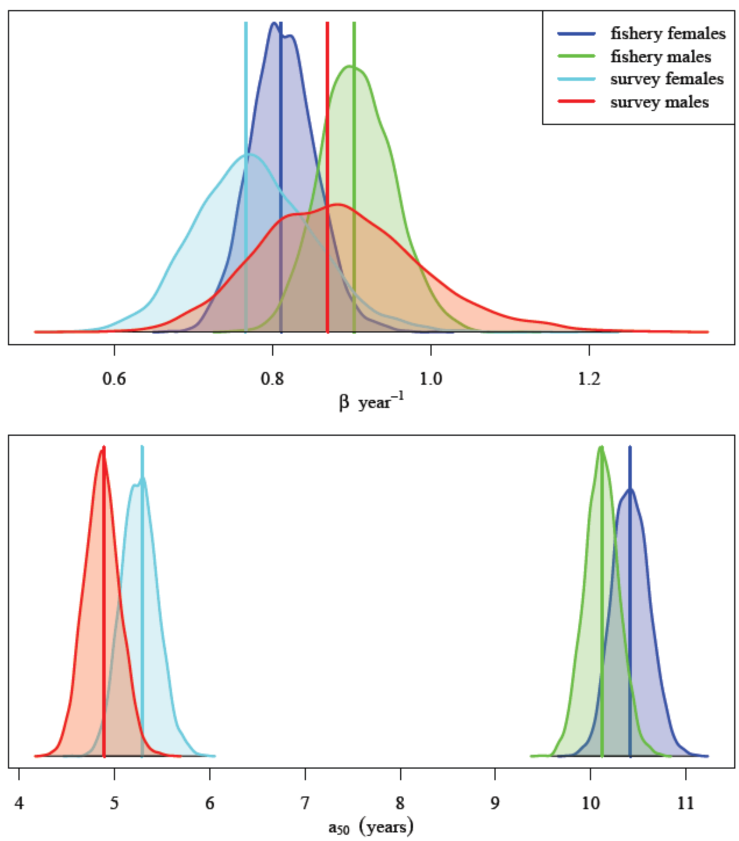


Figure 8.16. Marginal posterior distributions based on MCMC integration for parameters related to fishery and survey age selectivity functions. "a_{50}" denotes the parameter for the age at which the logistic selectivity function is 50%. "β" is related to the slope of the selectivity function at age = a_{50}. The maximum likelihood estimate for each parameter is indicated by the appropriately-colored vertical line.

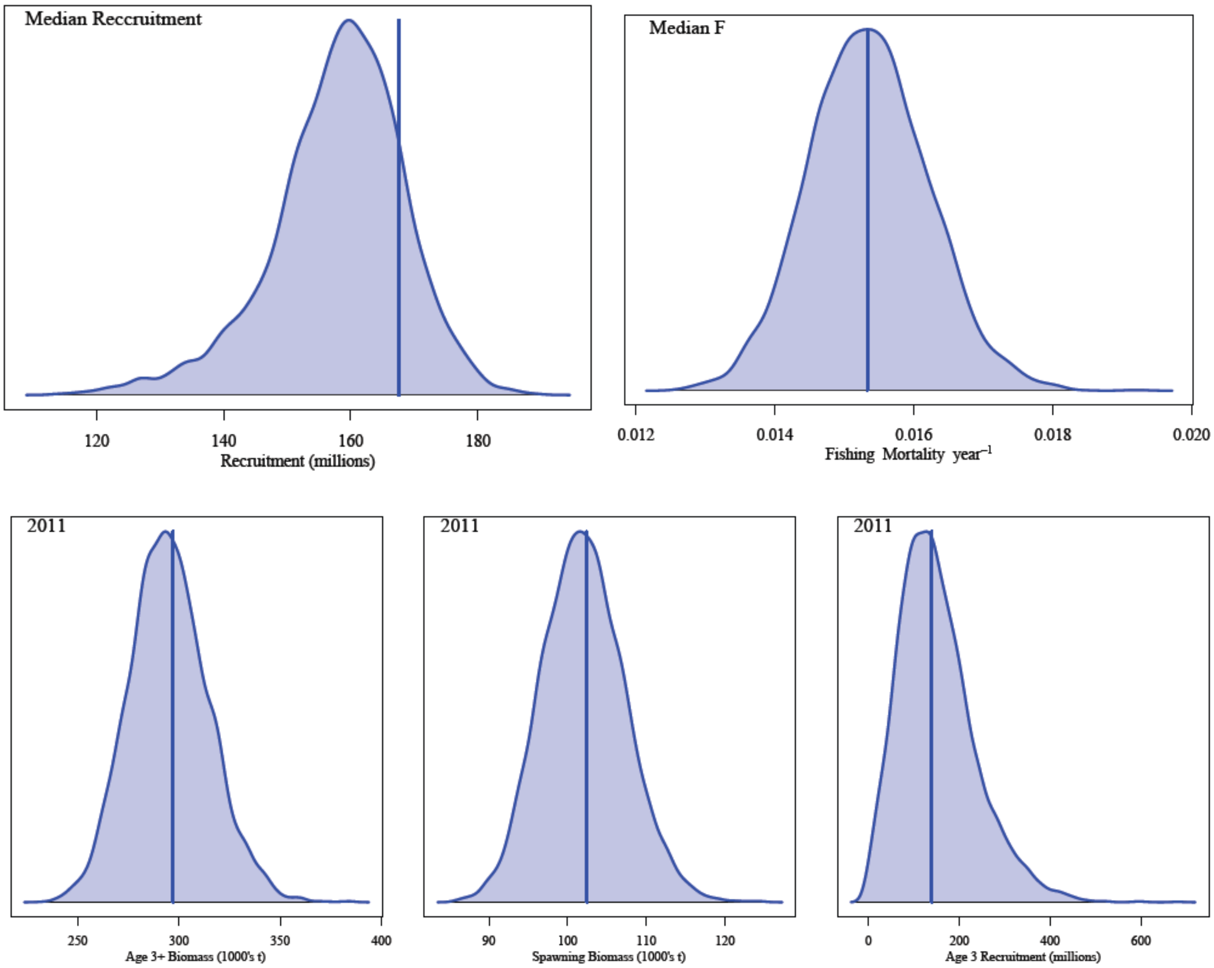


Figure 8.17. Marginal posterior distributions based on MCMC integration for: median recruitment (upper left), median fishing mortality (upper right), total (age 3+) biomass in 2011 (lower left), spawning biomass in 2011 (lower middle), and recruitment in 2011 (lower right). The maximum likelihood estimate for each quantity is indicated by the vertical line.

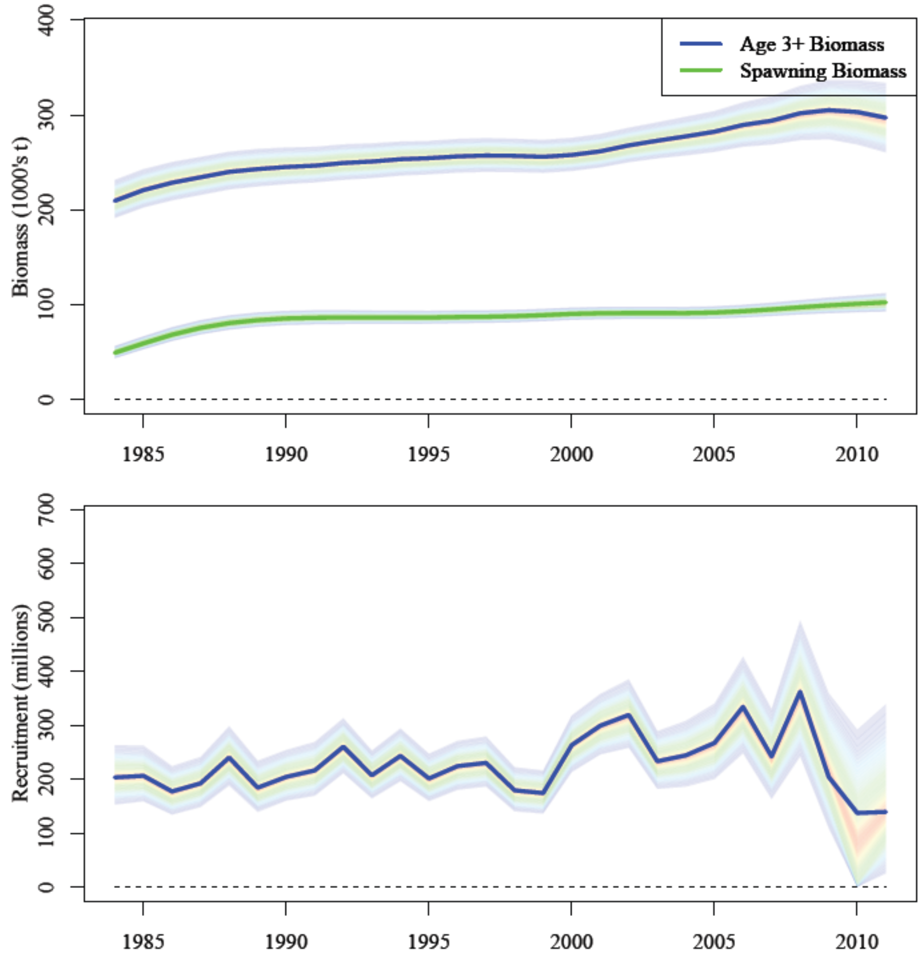


Figure 8.18. Time series plots of estimated total (age 3+) biomass and spawning biomass (upper graph) and recruitment (lower graph). 95% credibility intervals based on marginal posterior distributions from MCMC integration for parameters related to fishery (top row) and survey (bottom row) age selectivity functions. The solid lines indicate time series of maximum likelihood estimates.

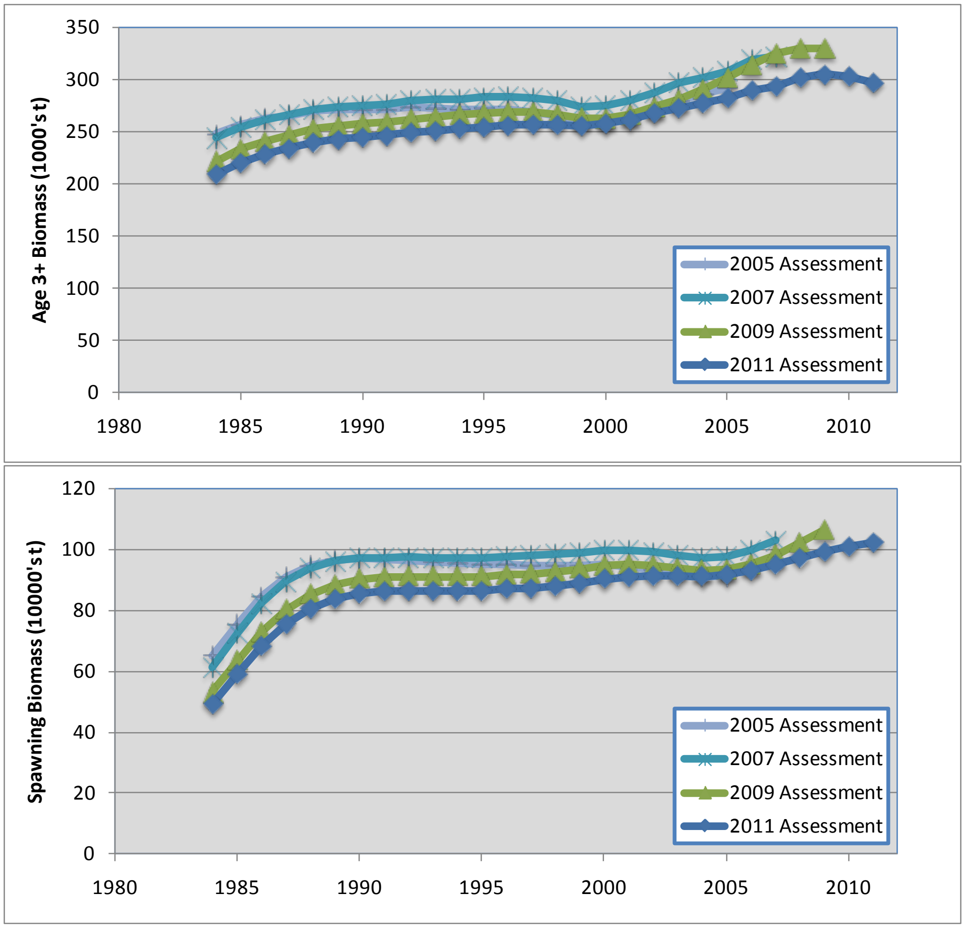


Figure 8.19. Upper: : Comparison of total (age 3+) biomass estimates from the current assessment with results from the 2009, 2007, and 2005 assessments. Lower: Comparison of spawning biomass estimates from the current assessment with results from the 2009, 2007, and 2005 assessments..

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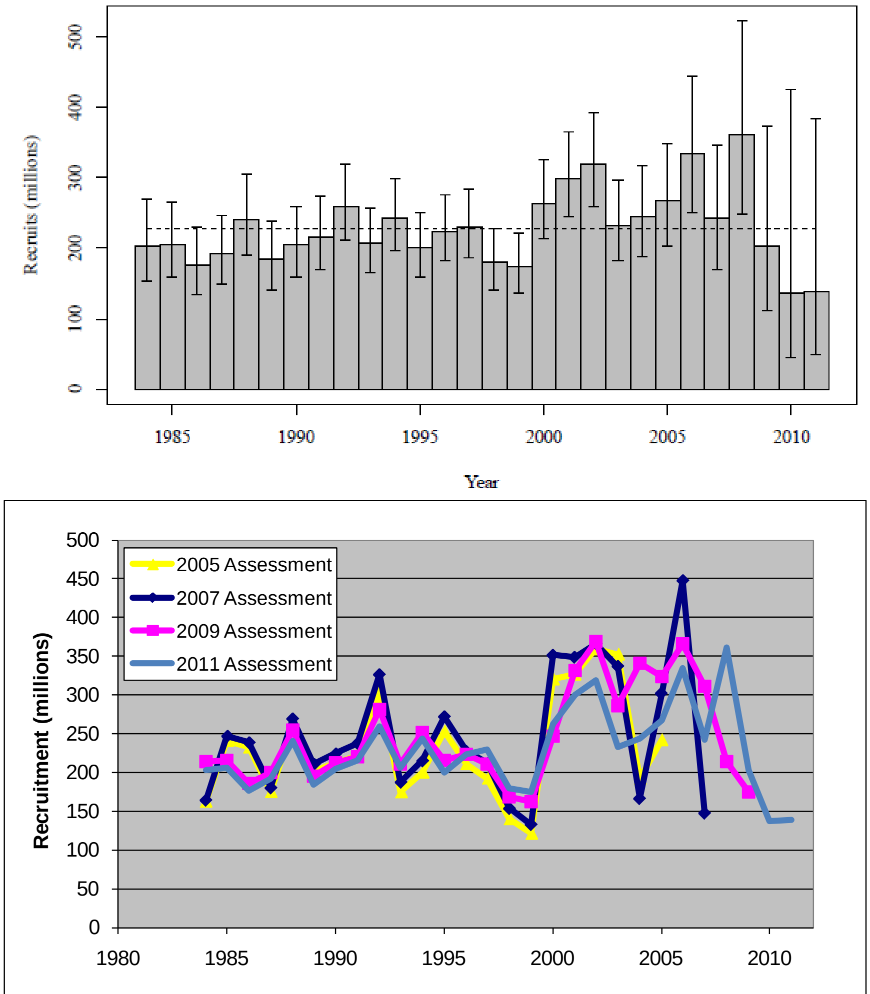

Figure 8.20. Upper: Estimated age 3 recruitments with approximate 95% lognormal confidence intervals estimated from the model hessian. Horizontal line is mean recruitment. Lower: Comparison of recruitment estimates with results from the 2009, 2007, and 2005 assessments.

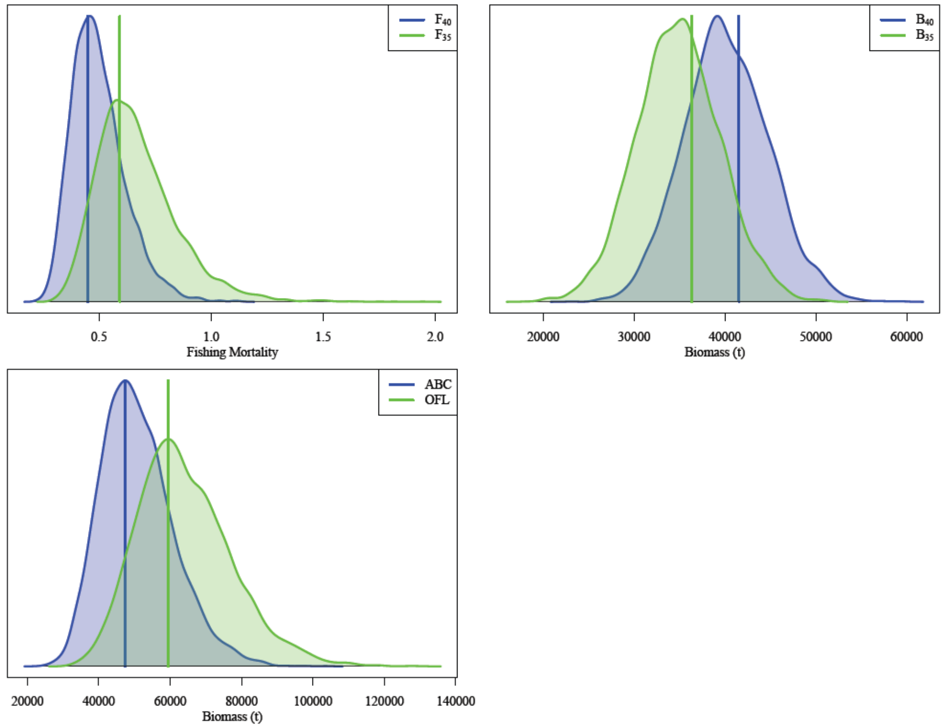

Figure 8.21. Marginal posterior distributions based on MCMC integration for several management-related quantities estimated in the model: $F_{40\%}$ and $F_{35\%}$,(upper left), $B_{40\%}$, and $B_{35\%}$ (upper right), and 2012 ABC, OFL (lower left). The value for each quantity associated with the maximum likelihood solution is indicated by the appropriately-colored vertical line.

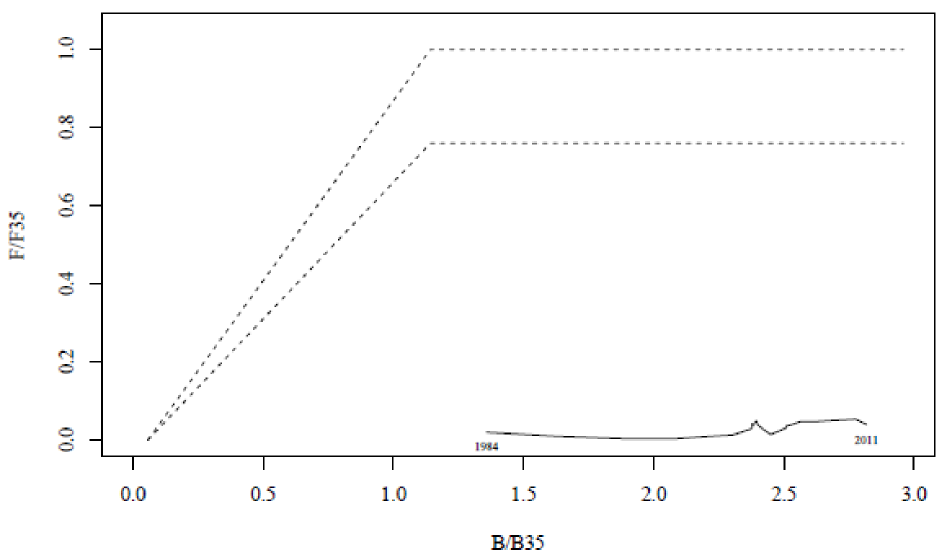

Figure 8.22. Control rule plot of estimated fishing mortality versus estimated female spawning biomass for GOA flathead sole. F_{OFL} = upper dashed line, $F_{max\ ABC}$ = lower dashed line.

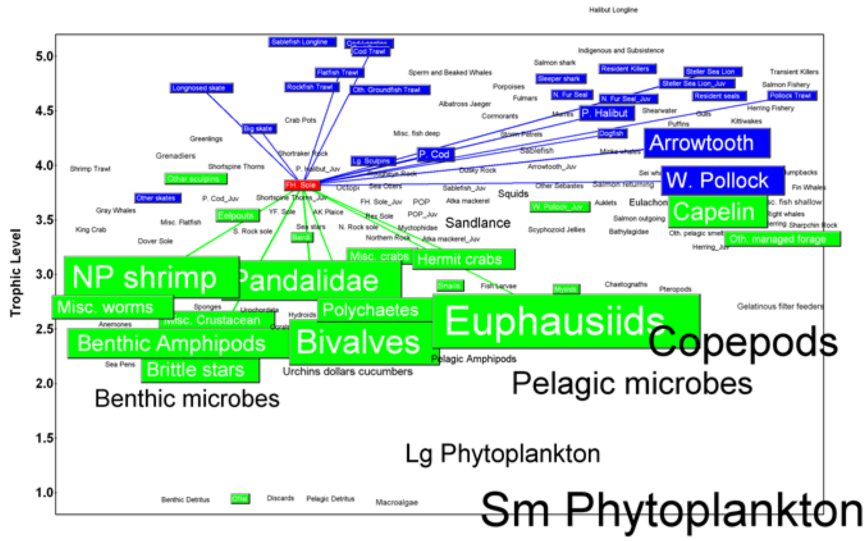

Figure 8.23a. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., 2007) highlighting adult flathead sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

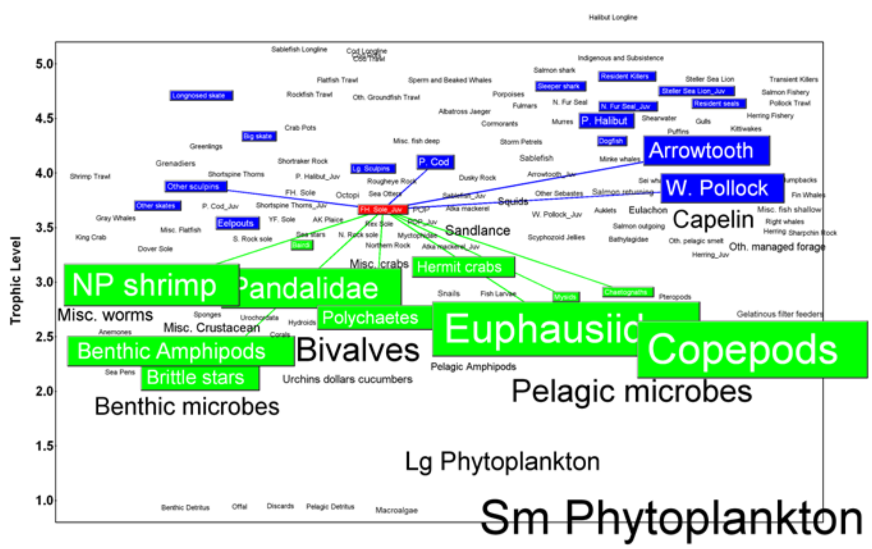

Figure 8.23b. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., 2007) highlighting juveile flathead sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

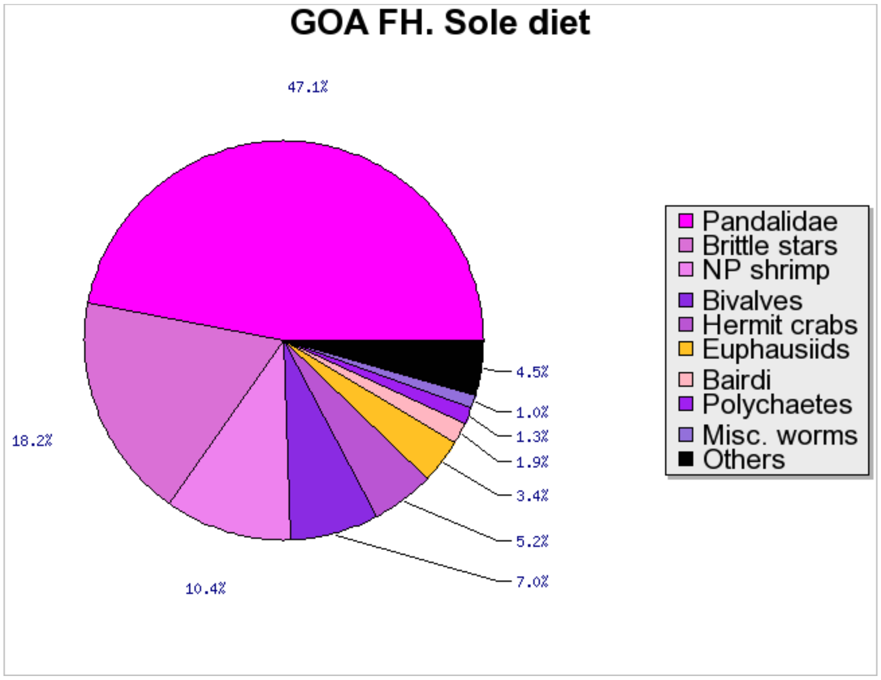

Figure 8.24a. Diet composition for Gulf of Alaska adult flathead sole from the GOA ecosystem model (Aydin et al., 2007).

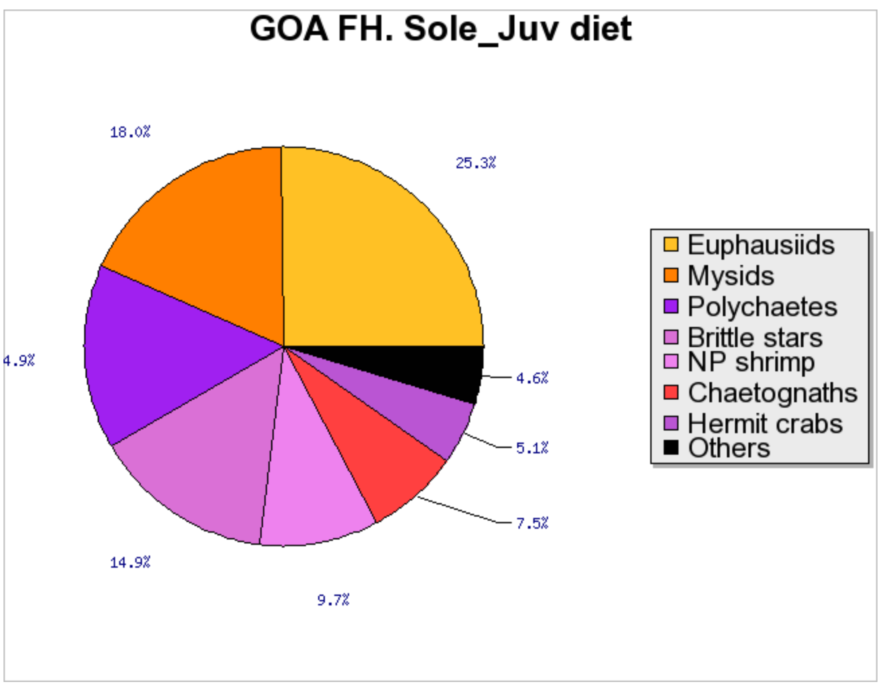

Figure 8.24b. Diet composition for Gulf of Alaska juvenile flathead sole from the GOA ecosystem model (Aydin et al., 2007).

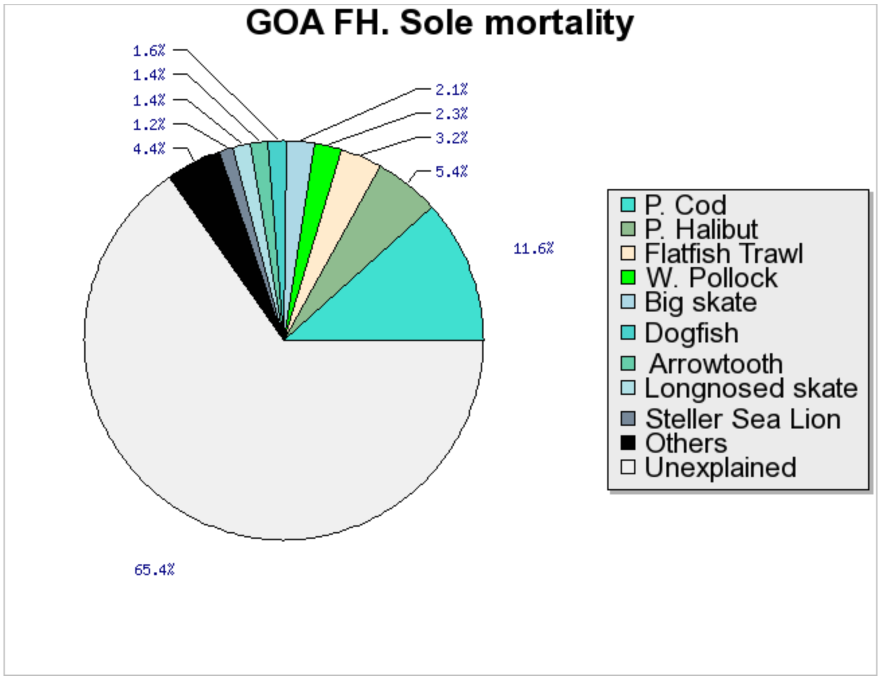

Figure 8.25a. Decomposition of natural mortality for Gulf of Alaska adult flathead sole from the GOA ecosystem model (Aydin et al., 2007).

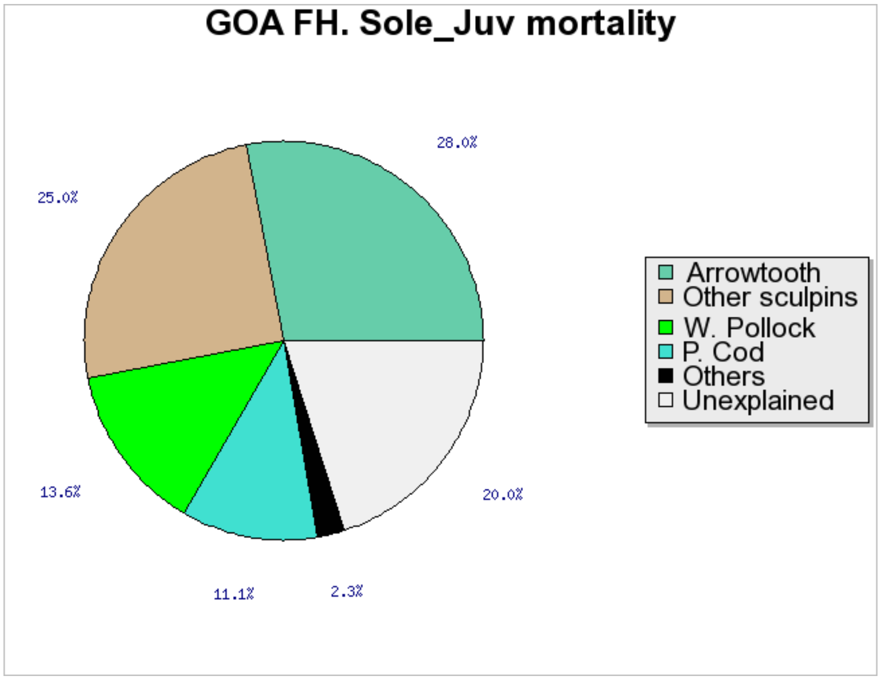

Figure 8.25b. Decomposition of natural mortality for Gulf of Alaska juvenile flathead sole from the GOA ecosystem model (Aydin et al., 2007).

Chapter 8 Appendix A: Model Equations

Table A.1. List of quantities and their definitions as used in the model.

Quantity	Definition
T	number of years in the model.
A	number of age classes (18).
L	number of length classes (18).
T_{min}	model start year (1984).
T_{max}	assessment year (2011).
t	time index.
a	age index ($1 \le a \le A$; a=1 corresponds to age at recruitment).
x	sex index ($1 \le x \le 2$; 1=female, 2=male).
l	length index ($1 \le l \le L$; l=1 corresponds to minimum length class).
$\{t^S\}$	set of years for which survey biomass data is available.
$\{t^{F,A}\}$	set of years for which fishery age composition data is available.
$\{t^{F,L}\}$	set of years for which fishery length composition data is available.
$\{t^{S,A}\}$	set of years for which survey age composition data is available.
$\{t^{S,L}\}$	set of years for which survey length composition data is available.
$L^x_{l,a}$	elements of length-age conversion matrix (proportion of sex x fish in age class a that are in length class l). (fixed)
$w_{x,a}$	mean body weight (kg) of sex x fish in age group a. (fixed)
ϕ_a	proportion of females mature at age a. (fixed)
$\overline{\ln R_0}$	mean value of log-transformed recruitment. (estimable)
τ_t	recruitment deviation in year t. (estimable)
M_x	instantaneous natural mortality rate. (fixed)
$\overline{\ln F}$	mean value of log-transformed fishing mortality. (estimable)
ε_t	deviations in fishing mortality rate in year t. (estimable)
R_t	recruitment in year t.
$N_{t,x,a}$	number of fish of sex x and age class a in year t.
$C_{t,x,a}$	catch (number) of fish of sex x and age class a in year t.
$p^{F,A}_{t,x,a}$	proportion of the total catch in year t that is sex x and in age class a.
$p^{F,L}_{t,x,l}$	proportion of the total catch in year t that is sex x and in length class l.
$p^{S,A}_{t,x,a}$	proportion of the survey biomass in year t that is sex x and in age group a.
$p^{S,L}_{t,x,l}$	proportion of the survey biomass in year t that is sex x and in age group a.
C_t	total catch (yield) in tons in year t.
$F_{t,x,a}$	instantaneous fishing mortality rate for sex x and age group a in year t.
$Z_{t,x,a}$	instantaneous total mortality for sex x and age group a in year t.
$s^{FU}_{x,a}$	unnormalized fishery selectivity for sex x and age group a.
$s^{SU}_{x,a}$	unnormalized survey selectivity for sex x and age group a.
$s^{FN}_{x,a}$	normalized fishery selectivity for sex x and age group a.
$s^{SN}_{x,a}$	normalized survey selectivity for sex x and age group a.

Table A.2. Model equations describing the model populations dynamics.

Equation	**Description**
$\tau_t \sim N(0,\sigma_R^2)$	Random deviate associated with recruitment.
$N_{t,x,1} = R_t = \exp\left(\overline{\ln R_0} + \tau_t\right)$	Recruitment (assumed equal for males and females).
$N_{t+1,x,a+1} = N_{t,x,a} e^{-Z_{t,x,a}}$	Numbers at age.
$N_{t+1,x,A} = N_{t,x,A-1} e^{-Z_{t,x,A-1}} + N_{t,x,A} e^{-Z_{t,x,A}}$	Numbers in “plus” group.
$C_{t,x,a} = \frac{F_{t,x,a}}{Z_{t,x,a}}(1-e^{-Z_{t,x,a}})N_{t,x,a}$	Catch at age (in numbers caught).
$C_t = \sum_{x=1}^{2}\sum_{a=1}^{A} w_{x,a} C_{t,x,a}$	Total catch in tons (i.e., yield).
$FSB_t = \sum_{a=1}^{A} w_{1,a} \phi_a N_{t,1,a}$	Female spawning biomass.
$Z_{t,x,a} = F_{t,x,a} + M$	Total mortality.
$F_{t,x,a} = s_{x,a}^F \cdot \exp\left(\overline{\ln F} + \varepsilon_t\right)$	Fishing mortality.
$\varepsilon_t \sim N(0,\sigma_F^2)$	Random deviate associated with fishing mortality.
$s_{x,a}^{FU} = \frac{1}{1+e^{(-b_x^F(age-{}_{50}A_x^F))}}$	Unnormalized fishery selectivity- 2 parameter ascending logistic - separate for males and females.
$s_{x,a}^{SU} = \frac{1}{1+e^{(-b_x^S(age-{}_{50}A_x^S))}}$	Unnormalized survey selectivity- 2 parameter ascending logistic - separate for males and females.
$s_{x,a}^{FN} = \exp(r_x^F)\frac{s_{x,a}^{FU}}{\max\{s_{1,a}^{FU}\}}$	Normalized fishery selectivity. $r^F{}_1 \equiv 0$.
$s_{x,a}^{SN} = \exp(r_x^S)\frac{s_{x,a}^{SU}}{\max\{s_{1,a}^{SU}\}}$	Normalized survey selectivity. $r^S{}_1 \equiv 0$.
$N^S{}_{t,x,a} = Q\, s^S_{x,a} N_{t,x,a}$	Survey numbers for sex *x*, age *a* at time *t*.
$SB_t = \sum_{x=1}^{2}\sum_{a=1}^{A} w_{x,a}\, N^S{}_{t,x,a}$	Total survey biomass.
$p_{t,x,a}^{F,A} = C_{t,x,a} / \sum_{x=1}^{2}\sum_{a=1}^{A} C_{t,x,a}$	Proportion at age in the catch.
$p_{t,x,l}^{F,L} = \sum_{a=1}^{A} L_{l,a}^x \cdot p_{t,x,a}^{F,A}$	Proportion at length in the catch.
$p_{t,x,a}^{S,A} = N^S{}_{t,x,a} / \sum_{x=1}^{2}\sum_{a=1}^{A} N^S{}_{t,x,a}$	Proportion at age in the survey.
$p_{t,x,l}^{S,L} = \sum_{a=1}^{A} L_{l,a}^x \cdot p_{t,x,a}^{S,A}$	Proportion at length in the survey.

Table A.3. Likelihood components.

Component	Description
$\sum_{t=1}^{T}\left[\log(C_t^{obs})-\log(C_t)\right]^2$	Catch; assumes a lognormal distribution.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_t^{samp}\cdot p_{t,x,a}^{F,A,obs}\cdot\log(p_{t,x,a}^{F,A})$ - offset	Fishery age composition; assumes a multinomial distribution. Observed sample size is n_t^{samp}.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_t^{samp}\cdot p_{t,x,l}^{F,L,obs}\cdot\log(p_{t,x,l}^{F,L})$ - offset	Fishery length composition; assumes a multinomial distribution. Observed sample size is n_t^{samp}.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_t^{samp}\cdot p_{t,x,a}^{S,A,obs}\cdot\log(p_{t,x,a}^{S,A})$ - offset	Survey age composition; assumes a multinomial distribution. Observed sample size is n_t^{samp}.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_t^{samp}\cdot p_{t,x,l}^{S,L,obs}\cdot\log(p_{t,x,l}^{S,L})$ - offset	Survey length composition; uses a multinomial distribution. Observed sample size is n_t^{samp}.
offset $=\sum_{t}\sum_{x=1}^{2}\sum_{a=1}^{A} n_t^{samp}\cdot p_{t,x,a}^{obs}\cdot\log(p_{t,x,a}^{obs}))$	The offset constants for age composition components are calculated from the observed proportions and the sample sizes. A similar formula is used for length composition component offsets.
$\sum_{t\in\{t^{S}\}}\left[\frac{\log\left[\frac{SB_t^{obs}}{SB_t}\right]}{\sqrt{2}\cdot s.d.(\log(SB_t^{obs}))}\right]^2$	Survey biomass; assumes a lognormal distribution.
$\sum_{t=T_{\min}}^{T_{\max}-3}(\tau_t)^2$	Recruitment; assumes a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=T_{\max}-2}^{T_{\max}}(\tau_t)^2$	"Late" recruitment; assumes a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=T_{\min}-A+1}^{T_{\min}-1}(\tau_t)^2$	"Early" recruitment; assumes a lognormal distribution, since τ_t is on a log scale. Determines age composition at starting year of model.

Table A.4. Parameters fixed in the model.

Parameter	Description
$M_x = 0.2$	sex-specific natural mortality rate.
$Q = 1.0$	survey catchability.
$L^x_{l,a}$	sex-specific length-at-age conversion matrix.
$w_{x,a}$	sex-specific weight-at-age.
ϕ_a	proportion of females mature at age *a*.

Table A.5. Parameters estimated in the model. A total of 83 parameters were estimated.

Parameter	Subscript range	Total no. of Parameters	Description
$\ln(R_0)$	NA	1	natural log of the geometric mean value of age 3 recruitment.
τ_t	$T_{\min} - A + 1 \le t \le T_{\max}$	45	log-scale recruitment deviation in year *t*.
$\ln(f_0)$	NA	1	natural log of the geometric mean value of fishing mortality.
ε_t	$T_{\min} \le t \le T_{\max}$	28	log-scale deviations in fishing mortality rate in year *t*.
r^F_2	NA	1	scaling from female to male fishery selectivity (log-scale).
b^F_x, ${}_{50}A^F_x$	$1 \le x \le 2$	4	sex-specific selectivity parameters (slope and age at 50% selected) for the fishery.
r^S_2	S=1	1	scaling from female to male survey selectivity (log-scale).
b^S_x, ${}_{50}A^S_x$	$1 \le x \le 2$ S=1	4	sex-specific selectivity parameters (slope and age at 50% selected) for the survey.

Chapter 8 Appendix B: 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 (Table 8B.1). 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 the GOA flathead sole stock, these estimates (currently available only for 2010) can be compared to research removals that have occurred in conjunction with the Gulf of Alaska Groundfish Surveys (Table 8B.2). Compared with the 2010 ABC (47,422 t), these non-commercial catches are miniscule (< 0.2% ABC) and do not present a risk to the GOA flathead sole stock.

The second dataset, the 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), although the extent to which this occurs for flathead sole is unknown. 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 flathead sole catch by the halibut fishery in the Gulf of Alaska are miniscule compared with recent ABC's for the GOA stock (Table 8B.3). Based on these values, the risk to the stock from the halibut IFQ fishery is nil.

References:

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

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

Tables

Table 8B.1. Non-commercial use catches of flathead sole in the Gulf of Alaska for 2010. Non-commercial use includes catches for research, recreation, subsistence, personal use and exempted fishing permits. The ABC for 2010 was 47,422 t.

Source	Flathead Sole (t)
2010 Shelikof Acoustic Survey	0.0
2010 Shumigans Acoustic Survey	0.2
IPHC	0.0
large-mesh trawl	87.6
NMFS long line survey	0.1
Scallop dredge	0.0
small-mesh trawl	12.0
Structure of GOA Forage Fish Communities	0.0
Western GOA Pollock Acoustic Cooperative Survey	0.0
Grand Total	**100.0**

Table 8B.2. Research catches of flathead sole from the Gulf of Alaska Groundfish Surveys. The ABC for 2011 was 49,133 t.

year	Research Catch (t)
1984	31.33
1987	34.89
1990	22.40
1993	21.78
1996	14.03
1999	11.54
2001	9.90
2003	20.49
2005	15.58
2007	19.96
2009	16.47
2011	13.65

Table 8B.3. HFICE estimated catches of flathead sole in the Gulf of Alaska by the halibut fishery. The ABC for the GOA flathead sole fishery is also listed for each year. The ABC for 2011 was 49,133 t.

	Flathead sole (t)					
Year	Western	Central	West Yakutat	Southeast	Total	ABC (t)
2001	0.00	0.00	0.00	0.07	0.07	26,270
2002	0.00	0.00	0.00	0.00	0.00	22,690
2003	0.00	0.00	0.00	0.53	0.53	41,390
2004	0.00	0.22	0.00	0.00	0.22	51,270
2005	0.34	0.16	0.36	1.15	2.02	45,100
2006	0.00	0.13	0.00	0.63	0.75	37,820
2007	0.02	0.25	0.00	2.97	3.24	39,110
2008	0.47	0.28	0.00	0.09	0.84	44,735
2009	0.00	0.30	0.14	0.07	0.51	46,464
2010	0.02	0.01	0.00	0.02	0.05	47,422

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