5. Assessment of the Deepwater Flatfish Stock in the Gulf of Alaska

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Executive Summary

Changes in the Input Data

1) The last full assessment was in 2007. The fishery catches for 2008 and 2009 (through Sept. 26, 2009) were incorporated in the age-structured assessment model for Dover sole.
2) The 2008 and 2009 fishery size compositions for Dover sole were added to the assessment model. Fishery size compositions for all available years (1991-2009) were recalculated.
3) Survey biomass and length composition data for Dover sole from the 2009 GOA groundfish survey were added to the model. Survey biomass for Dover sole increased from 71,624 t in 2007 to 76,277 t in 2009.
4) Survey age compositions for Dover sole from the 1987 and 2007 surveys were added to the model. The corresponding size compositions were substantially de-weighted to avoid "double counting".

Changes in the Assessment Model

Two types of options for selectivity functions were incorporated in the assessment model for Dover sole this year. First, options for estimating male scaling parameters for either (or both) fishery and survey selectivity functions was incorporated into the assessment model. Under these options, the fishing mortality or survey selectivity experienced by fully-selected males may now differ from that experienced by fully-selected females. The nominal fishing mortality is reported relative to fully-selected females. Second, a "double normal" function was developed as an option to describe either fishery or survey selectivity. While these options were explored in this assessment, none was used in the preferred model--which was structurally the same as that adopted in the 2007 assessment.

We also changed the age bins used to calculate the survey age composition likelihood component. Previously, we had binned ages 3-20 by 1-year intervals and ages 25-40+ by 5-year intervals prior to computing the likelihood. This year, we binned ages 3-35 by 1-year intervals and ages 35-40+ by 5-year intervals.

Changes in the Assessment Results

1. The recommended ABCs for the deepwater flatfish complex, based on an $F_{40\%}$ harvest level of 0.119 for Dover sole and 0.75 *x* mean historic catch for Greenland turbot and deepsea sole, are 6,190 t for 2010 and 6,325 t for 2011.
2. The OFLs, based on an $F_{35\%}$ harvest level of 0.149 for Dover sole and mean historic catch for Greenland turbot and deepsea sole, are 7,680 t for 2010 and 7,847 t for 2009.
3. Projected female spawning biomass for Dover sole is estimated at 32,218 t for 2010.
4. Projected total biomass (age 3+) for Dover sole is estimated at 89,682 t for 2010.

A summary of the recommended ABCs from the 2009 assessment, relative to the 2008 SAFE projections, is as follows:

Species	Quantity	2009 Assessment for 2010	2009 Assessment for 2011	2008 Assessment for 2009	2008 Assessment for 2010
Dover sole	**Tier**	**3a**	**3a**	**3a**	**3a**
	Total biomass (Age 3+; t)	89,682	89,870	133,025	133,360
	Female Spawning Biomass (t)	32,218	32,673	44,540	46,095
	ABC (t)	6,007	6,142	8,985	9,610
	Overfishing (t)	7,436	7,603	11,334	12,123
	$F_{ABC} = F_{40\%}$	0.119	0.119	0.137	0.137
	$F_{OFL} = F_{35\%}$	0.149	0.149	0.176	0.176
Greenland turbot	**Tier**	**6**	**6**	**6**	**6**
	ABC (t)	179	179	179	179
	Overfishing (t)	238	238	238	238
Deepsea sole	**Tier**	**6**	**6**	**6**	**6**
	ABC (t)	4	4	4	4
	Overfishing (t)	6	6	6	6
Entire complex	ABC (t)	6,190	6,325	9,168	9,793
	Overfishing (t)	7,680	7,847	11,578	12,367

<u>SSC Comments Specific to the Deepwater Flatfish Assessments</u>

SSC comment: "*Because adjacent age-classes are likely to overlap in size and spatial distribution, the fishery selectivity curves estimated by the model seem implausibly steep, possibly indicating mis-specification of the age-length transition matrices. The SSC requests that the growth model and age-length transition matrices be re-evaluated in the next assessment.*"

Author response: In the previous full assessment (2007), we felt that the problem with the fishery selectivity curves was a result of misspecification of the functional form for selectivity. We have continued to investigate this issue in this assessment. However, we recognize that the SSC's suggestion is a good one and we will address it prior to the next assessment. We have started analyzing new size-at-age data that has become available to update the age-length conversion matrices, but the analysis was incomplete at the time this document was prepared.

SSC comment: "*The SSC also requests that the next assessment provide likelihood profiles or similar analyses that illustrate the consistency of the model fits to the various input data sources.*"

Author response: We attempted to address this request using AD Model Builder's built-in likelihood profile variables. In retrospect, using an MCMC approach appears to be much more flexible than the built-in approach and will be incorporated in the next assessment.

<u>SSC Comments on Assessments in General</u>

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 can 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

The "flatfish" species complex previous to 1990 was managed as a unit in the Gulf of Alaska (GOA). It included the major flatfish species inhabiting the region, with the exception of Pacific halibut. The North Pacific Fishery Management Council divided the flatfish assemblage into four categories for management in 1990; "shallow flatfish" and "deep flatfish", flathead sole and arrowtooth flounder. This classification was made because of significant differences in halibut bycatch rates in directed fisheries targeting the shallow-water and deepwater flatfish species. Arrowtooth flounder, because of its present high abundance and low commercial value, was separated from the group and managed under a separate acceptable biological catch (ABC). Flathead sole were likewise assigned a separate ABC since they overlap the depth distributions of the shallow-water and deepwater groups. In 1993, rex sole was split out of the deepwater management category because of concerns regarding the bycatch of Pacific ocean perch in the rex sole target fishery.

The deepwater complex, the subject of this chapter, is composed of three species: Dover sole (*Microstomus pacificus*), Greenland turbot (*Reinhardtius hippoglossoides*) and deep-sea sole (*Embassichthys bathybius*). Dover sole is by far the biomass-dominant in research trawl surveys and constitutes the majority of the fishery catch in the deepwater complex (typically over 98%). Little biological information exists for Greenland turbot or deep-sea sole in the GOA. Better information exists for Dover sole, allowing the construction of an age-structured assessment model in 2003 (Turnock et al., 2003).

Greenland turbot have a circumpolar distribution and occur in both the Atlantic and Pacific Oceans. In the eastern Pacific, Greenland turbot are found from the Chukchi Sea through the Eastern Bering Sea and Aleutian Islands, in the Gulf of Alaska and south to northern Baja California. Greenland turbot are typically distributed from 200-1600 m in water temperatures from 1-4^{o} C, but have been taken at depths up to 2200 m.

Dover sole occur from Northern Baja California to the Bering Sea and the western Aleutian Islands; they exhibit a widespread distribution throughout the GOA (Miller and Lea, 1972; Hart, 1973). Adults are demersal and are mostly found at depths from 300 m to 1500 m.

Dover sole are batch spawners; spawning in the Gulf of Alaska has been observed from January through August, peaking in May (Hirschberger and Smith, 1983). The average 1 kg female may spawn it 83,000 advanced yolked oocytes in about 9 batches (Hunter et al., 1992). Although the duration of the incubation period is unknown, eggs have been collected in plankton nets east of Kodiak Island in the summer (Kendall and Dunn, 1985). Larvae are large and have an extended pelagic phase that averages about 21 months (Markle et al., 1992). They have been collected in bongo nets only in summer over mid-shelf and slope areas in the Gulf. The age or size at metamorphosis is unknown, but pelagic postlarvae as large as 48 mm have been reported and juveniles may still be pelagic at 10 cm (Hart, 1973). Juveniles less than 25 cm are rarely caught with the adult population in bottom trawl surveys (Martin and Claussen, 1995).

Dover sole move to deeper water as they age and older females may have seasonal migrations from deep water on the outer continental shelf and upper slope where spawning occurs to shallower water mid-shelf in summer time to feed (tagging data from California to British Columbia; Demory et al., 1984; Westrheim et al., 1992). Older male Dover sole may also migrate seasonally but to a lesser extent than females. The maximum observed age for Dover sole in the GOA is 54 years.

Fishery

Since passage of the MFMCA in 1977, the flatfish fishery in the GOA has undergone substantial changes. Until 1981, annual harvests of flatfish were around 15,000 t, taken primarily as bycatch by foreign vessels targeting other species. Foreign fishing ceased in 1986 and joint venture fishing began to account for the majority of the catch. In 1987, the gulf-wide flatfish catch increased nearly four-fold , with joint venture fisheries accounting for all of the increase. Since 1988, only domestic fishing fleets are allowed to harvest flatfish. As foreign fishing ended, catches decreased to a low of 2,441 t in 1986. Catches subsequently increased under the joint venture and then domestic fleets to a high of 43,107 t in 1996. Catches then declined to 23,237 t in 1998 and were 22,700 t in 2004.

Focusing more specifically now on the deepwater flatfish complex, in the GOA this trio of species is caught in a directed fishery using bottom trawls. Fewer than 20 shore-based catcher-type vessels participate in this fishery, together with about 6 catcher-processor vessels. Fishing seasons are driven by seasonal halibut PSC apportionments, with fishing occurring primarily in April and May because of higher catch rates and better prices. Annual catch in the deepwater flatfish fishery was estimated by partitioning the flatfish catch into its component species groups based on historical species composition of observed catch. The deepwater flatfish complex catch is dominated by Dover sole (over 98%, typically; Table 5.1, Figure 5.1). In recent years, Dover sole have been taken primarily in the Central Gulf, as well on the continental slope off Yakutat Bay in the eastern Gulf (based on fishery observer data; Figures 5.2-3). Dover sole recruit to the fishery starting at about age 10.

Deepwater flatfish are also caught in pursuit of other bottom-dwelling species as bycatch. They are taken as bycatch in Pacific cod, bottom pollock and other flatfish fisheries, and are caught along with these species in the deepwater flatfish-directed fishery. The gross discard rates for deepwater flatfish across all fisheries were 63% in 2008 and 75% in 2009, the highest in the time series going back to 1995 (Table 5.2).

Historically, catch of Dover sole increased dramatically from a low of 23 t in 1986 to a high of almost 10,000 t in 1991 (Table 5.1, Figure 5.1). Following that high, annual catch declined rather steadily, with perhaps a 6-year cycle imposed on the overall trend. The catch in 2009 (244 t as of Sept. 26) was the second lowest since 1987. Catch of Greenland turbot has been sporadic and has been over than 100 t only 5 times since 1978. The highest catch of Greenland turbot (3,012 t) occurred in 1992, coinciding with the second highest catch of Dover sole (8,364 t) since 1978. This was followed by a catch of 16 t for Greenland turbot the next year. Annual catch has been less than 25 t since 1995. Deepsea sole is the least caught of the three deepwater flatfish species. It has been taken only intermittently, with less than a ton of annual catch occurring 11 times since 1978. The highest annual catch occurred in 1998 (38 t), but since then annual catch has been less than 2 t for 9 out of the past 11 years. It should be noted that this year’s catch (8 t as of Sept. 26) actually exceeds the single species OFL for deepsea sole (6 t), which was based on Tier 6 considerations for this species. However, this had no implications for the fishery because it is managed on the ABC and OFL for the complex, not for the individual species.

Based on observer reports, the spatial distributions of fishery catches in 2008 and thus far in 2009 are illustrated in Figures 5.2 (annually) and 5.3 (by quarter). Most catches are made along the edge of the continental shelf off Kodiak Island. The pattern doesn’t appear to show any major changes between 2008 and 2009. Most catches occur in the second quarter of the year.

Annual catches of deepwater flatfish have been well below the TACs in recent years (Table 5.2a). Annual TACs, in turn, have been set equal to their associated ABCs. Currently, ABCs for the entire complex are based on summing ABCs for the individual species. Because population biomass estimates based on research trawl surveys are considered unreliable for Greenland turbot and deepsea sole, as well as there being an absence of basic biological information from the GOA for these two species, ABCs for Greenland turbot and deepsea sole (179 t and 4 t, respectively) are based on average historic catch levels and do not vary from year to year. Since 2003, the ABC for Dover sole has been based on an age-structured assessment mode (Turnock et al., 2003). Limits on catch in the deepwater flatfish complex are driven by within-season closures of the directed fishery due to restrictions on halibut PSC, not attainment of the TAC (Table 5.2b).

Data

Fishery Data

This assessment used fishery catches from 1978 through 26 September, 2009 (Table 5.1; Figure 5.1). ABC and OFL calculations for Greenland turbot and deepsea sole were based on the mean historical catch from 1978-1995. The age-structured model for Dover sole incorporated catch data from 1984-2009, as well as estimates of the proportion of individuals caught by length group and sex for the years 1985-2004 and 2009 (Table 5.3). Size composition data from 2005-2007 was not included in the model due to the low number of samples collected by fishery observers. Sample sizes for the size compositions are shown in Table 5.4.

Survey Data

Because deepwater flatfish are lightly exploited by the target fishery and are (relatively speaking) often taken incidentally in target fisheries for other species, CPUE data from commercial fisheries probably do not reflect trends in abundance for these species. The Alaska Fishery Science Center's Gulf of Alaska Groundfish Trawl Survey is the principal source of fishery-independent data available to assess the deepwater flatfish complex. The gulf-wide survey includes shelf and slope depth strata and has been conducted with standardized gear and a randomized design since 1984 on a triennial (1984-1999) or biennial (2001-2009) basis. The survey typically samples depth strata up to 1000 m, although the deepest strata (> 500 m) have not been sampled consistently (see Table 5.5a.1). While depth coverage to 1000 m is adequate to assess the GOA Dover sole population, it is appears to be inadequate to obtain reliable estimates of biomass for the Greenland turbot and deep-sea sole populations (Table 5.5a, Figure 5.4). In addition to inconsistent depth coverage, the 2001 GOA survey did not include the eastern portion of the Gulf. As noted below, these inconsistencies complicate the interpretation of estimates of biomass from the groundfish survey.

The age-structured model for Dover sole used in this assessment incorporates estimates of total biomass for Dover sole to provide indices of population abundance (Table 5.5a; Figure 5.4). As noted above, survey coverage in both depth range and geographical area has varied among years and requires careful consideration of the survey results. Survey coverage was limited to less than 500 m depths in 1990, 1993, 1996 and 2001 but extended to 1000 m in 1984, 1987, 1999, 2005 and 2007. The survey extended to 700 m in 2003. In 2001, the survey was not conducted in the eastern portion of the Gulf of Alaska. Turnock et al. (2003) developed correction factors to scale "raw" survey results for differences in availability caused by differences in survey coverage; "corrected" survey biomass estimates are obtained by dividing the observed biomass by assumed availability (Table 5.5a.1). On average, about 18% of Dover sole biomass is at depths greater than 500 m, while the eastern portion of the Gulf accounts for nearly 50% of the biomass (Turnock et al., 2003; Table 5.5a.1).

Since 1984, survey estimates of total biomass for Dover sole have fluctuated about a mean of ~75,000 t. After starting relatively low at 68,521 t in 1984, the survey-estimated biomass jumped to a maximum of 117,000 t (corrected for availability) in 1990, followed by declining estimates through the rest of the decade. Survey biomass increased to 99,000 t in 2003. Estimated survey biomass was 76,277 t in 2009, a 6% increase over that from 2007 (71,624 t). The spatial patterns of survey CPUE for Dover sole (Figure 5.5) generally reflect the patterns seen in the fishery data, although the survey data also indicate concentrations of Dover sole that do not appear to be targeted by the fishery, e.g. near Cape St. Elias in the northern Gulf and Cape Spencer and Cape Ommaney in the southeast (the Southeast Gulf is closed to trawl gear).

Estimates of age and size composition from the GOA groundfish surveys were also incorporated in the age-structured model. Estimates of numbers-at-age by sex were available for surveys conducted in 1987 and from 1993 to 2007 (Table 5.6). Estimates of the numbers-at-length by sex were available for each survey year and included in the model (Table 5.7); size compositions from years with corresponding age compositions were substantially de-weighted in the model to avoid "double counting", but were included to better assess model fits. Sample sizes for the survey age and size compositions are shown in Table 5.4b.

Data on individual growth was incorporated in the age-structured model using sex-specific age-length conversion matrices (Table 5.8; Stockhausen et al., 2005). Sex-specific weight-at-age and maturity-at-age schedules developed using survey data were also incorporated in the model (Table 5.9; Stockhausen et al. 2005).

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

Source	type	years
Fishery	catch	1984-2009
	length compositions	1991-2004, 2009
Survey	biomass	1984-1999 (triennial); 2001-2009 (biennial)
	length compositions	1984-1999 (triennial); 2001-2009 (biennial)
	age compositions	1987, 1993, 1996, 1999, 2001, 2003, 2005, 2007

Analytic Approach

Model structure

The assessment for Dover sole 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.

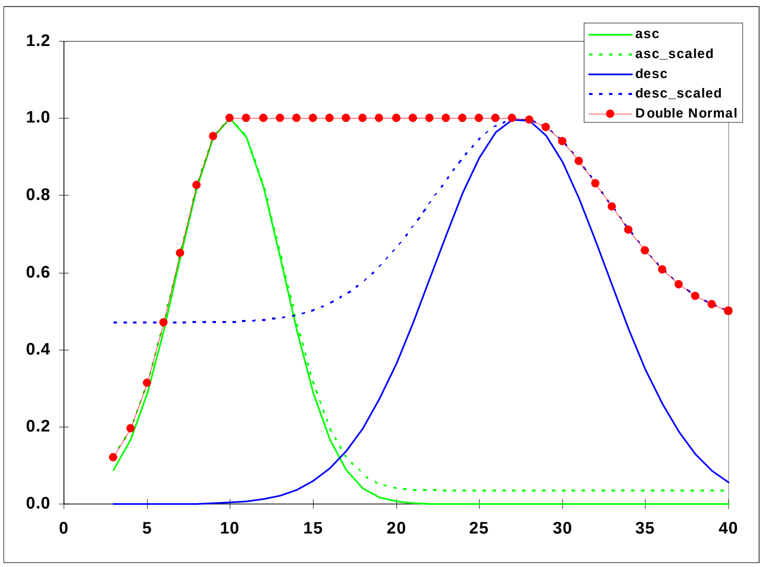
This year, we expanded the options for normalizing fishery and survey selectivity curves in the model. Previously, sex-specific selectivity curves (for both fisheries and surveys) were normalized to the maximum (unnormalized) value for female selectivity. In this assessment, we added options to estimate the maximum selectivity for males relative to females for either fisheries or surveys (or both). The maximum selectivity for females is still set to 1 and fishing mortality values are relative to fully-selected females. Thus, selectivity curves are now calculated in the following manner:

$$s_F^N(a) = s_F^U(a) / \max\{s_F^U(a)\}$$

$$s_M^N(a) = [s_M^U(a) / \max\{s_F^U(a)\}] \cdot e^r$$

where $s_F^N(a)$ is the normalized selectivity curve for females as a function of age, $s_F^U(a)$ is the corresponding unnormalized curve, $s_M^N(a)$ and $s_M^U(a)$ are the corresponding curves for males, and *r* is the log-scale parameter for the relative scale between males and females. The previous scheme for normalizing selectivities is obtained if *r* is set to 0 and not estimated.

We also added an additional function, the so-called "double normal", which can be used to describe either fishery or survey selectivity. Previously, only a logistic function and a smoothed "freeform" function were available in the model. The double normal (the red curve in the figure below) consists of a normal (Gaussian) curve describing the ascending limb of the function (green curves), an intermediate fully-selected interval, and a second normal curve describing the descending limb (blue curves) of the function. The function is defined by six parameters: one for the location of the peak (end) of the ascending limb, one for the offset of the peak (start) of the descending limb, one each for the widths of the two normal curves, and one each for the base levels of the normal curves (the dotted blue line illustrates a descending limb scaled to a base level of 0.5, while the solid blue line illustrates the unscaled descending limb).



We tested these options in a suite of alternative models (Table 5.10), but were not able to fit the data satisfactorily and adopted the same model that was selected in the 2007 assessment to complete this assessment (see below).

Age classes included in the model ran from age 3 to 40. 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 40, serves as a plus group in the model; the maximum age of Dover sole based on otolith age determinations has been estimated at 54 years (Turnock et al., 2003). 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 103 parameters were estimated in the preferred model (Table A.5).

Parameters estimated independently

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

Natural mortality

As in previous assessments, natural mortality (*M*) was fixed at 0.085 yr^{-1} for both sexes in all age classes. This estimate was based on Hoenig's (1983) method and a maximum observed age of 54 years.

Growth

Mean size-at-age, L_t, was modeled using the von Bertalanffy growth equation as:

$$L_t = L_{\inf}\left(1 - e^{-k(t-t_0)}\right)$$

Survey age and length data from 1984, 1993, 1996, 1999 and 2001 were used to estimate the parameters (Turnock et al., 2003). The parameter values used in this assessment are:

Sex	L_∞	k	t_0
Males	42.42	0.195	-1.97
Females	51.51	0.127	-2.66

The estimated size-at-age relationships (Table 5.9) was used to convert model age compositions to estimated size compositions, based on sex-specific age-length transition matrices (Table 5.8). The transition matrices used were identical to those used in assessments since 2003.

Weight-at-length

The weight-length relationship used for Dover sole was identical to that used in assessments since 2003: $W = 0.0029\ L^{3.3369}$ for both sexes (weight in grams and length in centimeters; Abookire and Macewicz, 2003). Weight-at-age (Table 5.9) was estimated using mean length-at-age and the weight-length relationship.

Maturity

The maturity schedule for Gulf of Alaska Dover sole was estimated using histological analysis of ovaries collected in 2000 and 2001 (Abookire and Macewicz, 2003; Table 5.9). A total of 273 samples were analyzed for estimation of age at maturity. Size at 50% mature was estimated to be 43.9 cm with a slope of 0.62 cm^{-1} from a sample of 108 fish. Age at 50% mature was 6.7 years with a slope of 0.880 yr^{-1}. Minimum-age at-maturity was 5 years.

Survey catchability

For this assessment, survey catchability (*Q* in Table A.1) was fixed at 1. Alternative models with *Q* allowed to vary have been explored in previous assessments (Stockhausen et al., 2005), but estimability was poor.

Parameters estimated conditionally

A total of 103 parameters were estimated in the preferred model (Table 5.10, Table A.5). These consisted primarily of parameters on the recruitment of Dover sole to the population (64 parameters total, including ones determining the initial age composition) and values related to annual fishing mortality (27 parameters total).

In the preferred model, the separable age component of fishing mortality was modeled using a two parameter ascending logistic function estimated separately for males and females (4 parameters total). The same form of curve was also used to estimate age-specific survey selectivity. However, two sets of curves were estimated: one set corresponding to surveys with full depth coverage (> 500 m; "full coverage" surveys) and the second set corresponding to surveys that only sampled shallow (1-500 m) areas ("shallow" surveys). Thus, 8 parameters were used to estimate survey selectivity. Selectivities were normalized such that the maximum female selectivity was 1.

Three different sex-specific selectivity functions were tested in various combinations in the alternative models (Table 5.10). The first was a “freeform” function consisting of independent parameters for each model age (thus 74 parameters were required to model fishery selectivities while 148 parameters were required to model selectivities for the “full” and “shallow” surveys). A substantial “roughness” penalty was imposed in the model optimization such that large second differences between parameters at adjacent ages were heavily penalized, resulting in a smooth appearance to the estimated selectivity. This also had the effect of reducing the effective number of parameters and improving estimability. The freeform parameters were defined on the natural log scale and exponentiated to provide age-specific values for selectivity. This ensured that selectivity would always be positive. Free-form selectivities were normalized in the same manner as that for logistic selectivities. Freeform selectivity functions were also tested in the previous full assessment (Stockhausen et al., 2007).

The second selectivity function tested was the so-called “double normal” function (see description above). This function has 6 estimable parameters, so 12 parameters were estimated to describe separate sex-specific curves when a double normal function was used for the fishery or a survey.

The third selectivity function consisted of a pair of standard logistic functions (one for each sex) with an additional parameter that described the relative asymptotic scaling for male selectivity vis-à-vis females. Consequently, a total of 5 parameters over both sexes were estimated when scaled logistic functions were used to describe selectivity for the fishery or a survey.

Annual recruitment to the age 3 year class was parameterized in the models using one parameter for the log-scale mean recruitment and 63 parameters for the annual log-scale deviation from the mean. Recruitments were estimated back to 1947 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 models using one parameter for the log-scale mean and 26 parameters for the annual log-scale deviation from the mean.

Parameters in each 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 contributed to the overall (-log) likelihood included 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 size and age compositions were assumed to be drawn from different sex-specific multinomial distributions. The recruitment deviation parameters were incorporated directly into the overall likelihood via three temporal components: “early” recruitment, “ordinary” recruitment and “late” recruitment (Table A.3). This allowed different weights to be applied in the likelihood function to recruitment estimates that were not well observed in the data (i.e., recruitments prior to the model period or the most recent ones). The “early” recruitment component incorporated deviations from 1947 to 1983 (i.e., prior to the modeled age structure), “ordinary” recruitment incorporated deviations from 1984-2006 and “late” recruitment incorporated deviations from 2007-2009. All three components were formulated assuming a lognormal error structure.

Different weights can be assigned to each likelihood component in a model 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 known more accurately (i.e., with 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).

Weights placed on the various components of the likelihood are given in Table 5.11. We assigned a weight of 1 to the survey biomass, survey age composition and "normal" recruitment components. Model-predicted length compositions are not expected to fit the data as well as age compositions should due to a "smearing" of ages among length bins inherent in the use of age-length transition matrices to convert from age to length compositions. The length composition-associated components (fishery and survey) were thus assigned weights of 0.5, down-weighting their importance relative to the survey biomass and age composition fits. We assigned higher weights (2 and 3, respectively) to the "early" and "late" recruitment components to keep the associated recruitments close to the long-term median, but allowed more variation in the "normal" recruitment constituents by assigning the associated likelihood component a weight of 1. Finally, we assigned a weight of 30 to the catch-specific likelihood component to assure a close fit between model-predicted and input catch values, under the assumption that catch is measured with little uncertainty. All models were evaluated using the same set of weights.

Model evaluation

In performing this assessment, we investigated several alternative model configurations that considered different formulations for survey and fishery selectivity (Table 5.10 or below). The base (and preferred) model configuration used standard logistic functions to describe fishery and survey selectivities, with separate sets of selectivity parameters estimated for "full coverage" and "shallow" surveys. This is the same configuration that was selected in recent full assessments (Stockhausen et al., 2005; Stockhausen et al., 2007). In total, seven alternative models were considered in this assessment. They differed in the types of functions used to describe fishery or survey selectivity. The various models are summarized in the following table (which duplicates Table 5.10):

Model	Selectivity Models				# of parameters
	Fishery		Surveys		
	Type	Male Scaling?	Type	Male Scaling?	
Base	logistic	fixed	logistic	fixed	103
LogS-LogS	logistic	estimated	logistic	estimated	106
FF-FF	freeform	fixed	freeform	fixed	319
FF-Log	freeform	fixed	logistic	fixed	175
Log-FF	logistic	fixed	freeform	fixed	247
DN-DN	double normal	fixed	double normal	fixed	127
DN-Log	double normal	fixed	logistic	fixed	111

Most of the parameters used to initialize these models are listed in Table 5.12. All of the models were initialized using the values listed in Table 5.12a for recruitment- and fishing mortality-related parameters. For models that incorporated logistic selectivity functions, the values in Table 5.12b were used to initialize the parameters associated with each logistic function. For models that incorporated double normal selectivity functions, the values in Table 5.12c were used to initialize the parameters associated with each double normal function. Models that incorporated freeform selectivity functions were initialized by setting all the associated log-scale parameters to 0. Finally, for models that incorporated scaled logistic functions to describe selectivity, the relative male scaling parameter was always initialized to 1 (0 on the log-scale).

All seven models demonstrated at least some problem with convergence to final parameter estimates (Table 5.13), although some problems were more severe than others. The Hessian matrix (related to the inverse covariance matrix for parameter estimates) was not positive definite for the three models that incorporated freeform selectivity functions. As a consequence, variances associated with the parameters and other derived quantities could not be estimated for these three models. In addition, all the models except the FF-FF model experienced at least one selectivity function parameter coming extremely close to its acceptable limits (see Tables 10.12b, c). For models with logistic selectivity functions, upper bounds for the slope parameters associated with the fishery or lower bounds for the slope parameters associated with one of the surveys were generally approached quite closely. The pattern was less consistent for models with double normal selectivity functions: different parameters went to their bounds in different models. Thus, none of the models achieved a completely satisfactory convergence. The least serious convergence problems were judged to be associated with the base model, which resulted in essentially knife-edge fishery selectivity (see parameter estimates in Table 5.14).

Based on overall (negative) log-likelihood scores, the base model exhibited the poorest fit to the data while the FF-FF model exhibited the best (Table 5.13). These results are not surprising, given that the base model has the fewest number of parameters available to fit the data while the FF-FF model has the most. However, these results are not consistent across the different data components of the likelihood. While the base model exhibited the poorest fit of all the models to the fishery size compositions and survey biomass, it performed somewhat better with respect to survey age and size compositions. Conversely, the FF-FF model had the best fit among models only with respect to survey biomass, although it only dropped to second or third rank among the other data components. Interestingly, no single model fit had the best fit to more than one data component.

Overall, all seven models fit the observed catch history well (Figure 5.7), although none managed to match the two years of highest catch (1991 and 1992) particularly well. This is not surprising given the relative weight placed on the catch component of the likelihood.

The selectivity curves resulting from all the models are shown in Figure 5.8. All the models show an extremely steep increase in fishery selectivity for both males and females near age 11. For the three models that incorporated logistic functions for fishery selectivity (the base, LogS-LogS, and Log-FF models), this essentially resulted in knife-edge selection. The two models that incorporated double normal functions for fishery selectivity (the DN-DN and DN-Log models) also exhibited rapid decreases in selectivity at older ages after an interval of fully-selected ages, resulting in slot-type selectivity curves for both sexes. The two models with freeform fishery selectivities (the FF-FF and FF-Log models) also rose sharply near age 11, but not as sharply as the models with logistic or double normal curves because the freeform curves were constrained to exhibit continuous first derivatives (i.e., no sharp kinks) by large penalty functions applied in the model likelihood. In these models, male selectivity rose to a peak around ages 18-22 and subsequently declined again. In the FF-FF model, selectivity for males remained low at the oldest ages whereas it increased once again in the FF-Log model. On the whole, though, these models also exhibited slot-type selectivity curves similar to, although not as sharply changing as, the models incorporating the double normal curves. Other than a rapid increase in selectivity near age 12, the female fishery selectivity curves did not exhibit as much similarity as the males among the various models. In the FF-FF model, selectivity fluctuates slowly around an increasing trend with age whereas the trend is decreasing in the FF-Log model. In the models that used double normal curves, female fishery selectivity was similar to male selectivity in that both were slot-like curves, but the female curves began to descend more gradually and at earlier ages than did the male curves.

The survey selectivity curves resulting from the seven models are also shown in Figure 5.8. The estimated curves exhibited a variety of shapes, although there was some consistency to be found among the model results. In all the models, female selectivity in the full coverage surveys increased gradually with age such that only the oldest females were fully selected. This tended to also be true of female selectivity in the shallow surveys for all models, although several of the models that used logistic curves (the base, FF-Log and DN-Log models) exhibited full selection at somewhat younger ages (but still above age 20). On the other hand, the curves estimated for male selectivity varied quite a bit between models and survey type. For the models with freeform survey selectivity functions, (the FF-FF and Log-FF models), the male selectivity curves for both survey types were similar to their female counterparts: i.e., they rose gradually with age to attain full selectivity only at the oldest ages. For the models that incorporated logistic survey selectivity functions, male selectivity tended to rise very quickly with age to full selection for both survey types (the base, LogS-LogS, and FF-Log models), although one model (the DN-Log model) had male selectivity rise quickly for the shallow surveys but over an extended age range for the full coverage surveys. The model that used double normal functions to describe survey selectivity estimated a slot-type curve for male selectivity in the shallow surveys but a gradually increasing, logistic-like curve for the full coverage survey. *A priori*, the selectivity curves might be expected to differ between the two survey types, given the ontogenetic shift by Dover sole to deeper habitats with age and the differences in depth coverage between the shallow and full coverage surveys. Since older fish are found deeper, they should be less available to the shallow surveys and thus the shallow survey selectivity curves might appear to be composed of a slot-type function superimposed on the full coverage selectivity curves. This could not be observed in the models that used logistic functions to describe survey selectivity (because logistic functions can't be hump-shaped), but it is also not observed in the freeform models that could fit a slot-type response. Thus, the difference in selectivity between the shallow and full coverage surveys is more subtle than one might expect--or else the available data is inadequate to discern the difference. Confounding effects between survey timing and seasonal feeding migrations on availability of older fish may also play a role in obscuring differences.

On the whole, all the models fit the survey biomass time series reasonably well. The FF-FF model exhibited the best fit to the survey biomass time series, while the base model exhibited the poorest fit (Table 5.13; Figure 5.9). Interestingly, none of the models was able to capture the jump in survey biomass in 2003. The model fits were mainly distinguished by whether or not they were able to come close to fitting the initial two biomass values (in 1984 and 1987). Three of the four models that incorporated logistic survey selectivity functions (the base, LogS-LogS, and FF-Log models) overestimated the 1984 and 1987 survey biomasses to a substantial degree; the DN-Log model came the closest to fitting these points. The DN-DN model performed similarly to the latter model. The two models that incorporated freeform functions for survey selectivities only slightly overestimated these values.

The time series for estimated total (age 3+) and spawning stock biomass are illustrated for the various models in Figure 5.10. The curves differed in overall scale among models but had very similar shapes. The FF-FF model exhibited the highest estimates for both total biomass and spawning biomass across the time series, about twice as high as the models exhibiting the lowest estimates (the base, FF-Log, and DN-Log models). This result is partly a consequence of the estimated survey selectivity curves for the FF-FF model; these exhibited low selectivity across all age classes except the oldest, thus requiring relatively high numbers-at-age at most ages to achieve a good fit to the observed survey biomass time series (Figure 5.9). The models with the lowest estimates all incorporate logistic selectivity functions to describe survey selectivities. The survey selectivity curves for these models exhibit relatively high selectivity across a wide range of ages, so lower numbers-at-age (and hence lower population biomasses) are required to fit the observed survey biomass time series.

In all the models, recent spawning biomass declined very gradually across the time series, with the trend bottoming out in most of the models (although perhaps not the DN-DN model). Also, estimated total biomass declined from the beginning of the time series (1984) until about 2000, after which it remained fairly constant. The DN-DN model, in which spawning biomass continued to decline, was the lone exception.

The time series for estimated age 3 recruitments are illustrated in Figure 5.11 for all the models. Once again, the curves differ in overall scale among the models but the pattern was extremely similar for all.

The highest (mean) recruitment occurred in the DN-DN model while the lowest occurred in the FF-Log model. All the models estimated above average recruitment in the mid 1980's and early 2000's, as well as below average recruitment in the late 1980's to mid 1990's and again in the mid 2000's.

In terms of reference fishing mortality rates, the lowest estimates for F_{40} and F_{35} were obtained from the LogS-LogS and base models, while the highest (over twice as high as the smallest) were obtained from the FF-FF model. The FF-Log and base models had the lowest estimates for virgin biomass (B_{100}), B_{40} and B_{35}. The FF-FF model exhibited the highest estimates for these quantities, over a factor of two larger than the smallest estimates.

None of the models considered here provides a clear choice as the preferred model. The base model was the accepted model in the last three assessments (Turnock et al., 2003; Stockhausen et al., 2005, Stockhausen et al., 2007), and thus functions as our "null hypothesis". In this assessment, the three models that incorporated freeform selectivity functions (the FF-FF, FF-Log, and Log-FF models) appeared to be overparameterized, reflected in an inability to calculate suitable Hessians for these models. Variance estimates associated with estimated parameters and other quantities (e.g., population biomass) were unavailable for these models. Consequently, these models were rejected. The remaining models all exhibited a number of parameter estimates that ended up at one of the bounds placed on allowable values. Because the base model provided relatively conservative reference point values from among the models considered (Figure 5.12) and because no other model was demonstrably "better", we adopted it as the "preferred" model for calculation of reference values and evaluation of harvest scenarios.

Final parameter estimates

The base model described above was considered the "preferred" model for this assessment. The parameter estimates from this model are given in Table 5.14.

Schedules implied by parameter estimates

The estimated selectivity curves for the fishery and surveys are shown in Figure 5.8a for the preferred model. For the fishery, the estimated logistic selectivity curves rise extremely steeply and approximate knife-edge selection. The age at 50% selection was 12.5 yrs for females and 10.5 yrs for males. Very similar results were obtained in the 2005 and 2007 assessments (Stockhausen et al., 2005; Stockhausen et al., 2007).

The logistic selectivity curves estimated for the two survey types (shallow and full coverage) were quite similar for males but differ for females. For both survey types, recruits (age 3) of either sex were ~20% selected and selectivity for males increased rapidly with age: age at 50% selection was 3.7 yrs for the shallow surveys while it was 4.5 yrs for the full coverage surveys. For females, selectivity increased more slowly with age than males for both survey types, but age at 50% selection for the full coverage surveys (10.0 yrs) was older than that for the shallow surveys (6.9 yrs).

Similar results were obtained for the shallow survey selectivity curves in the 2005 and 2007 assessments (Stockhausen et al., 2005; Stockhausen et al., 2007). In contrast, the full coverage survey selectivity curves obtained in this assessment differed from those obtained in the 2005 and 2007 assessments, although they are qualitatively more similar to those obtained in the 2005 assessment than they are to those from the 2007 assessment. All three assessments used logistic functions to describe survey selectivity. In both this and the 2005 assessments, the age at 50% selection was within the range of modeled ages for both males and females, yielding curves that were past the inflection point at the oldest ages. The curves estimated for full coverage survey female selectivity were similar in both assessments (ages at 95% selection for the 2005 and 2009 assessments were 43.4 and 39.5 yrs, respectively) whereas the curve estimated in the 2005 assessment for full coverage male selectivity rose much more slowly to its asymptote than in this assessment (ages at 95% selection were 34.9 yrs and 7.1 yrs, respectively, for the 2005 and 2009 assessments). In contrast, the logistic selectivity curves for the full coverage surveys in the 2007 assessment did not reach their inflection points within the model's age range.

Results

Fits of the base model to fishery catch and survey biomass time series are discussed above under "Model Evaluation". Model fits to the fishery size compositions appeared to be reasonably good in most years (Figure 5.13). Fits to the fishery size compositions were poorest when the observed size composition was dominated by a single size class and thus sharply peaked (e.g., 1991 in Figure 5.13a). The smoothing inherent in using an age-length conversion matrix to convert age classes to size classes precludes close fits to peaked size compositions.

As with the fishery size compositions, model fits to the survey size compositions were poorest when the observed size compositions were sharply peaked, but still generally reasonable (Figure 5.14). Finally, the model also fits the survey age composition reasonably well (Figure 5.15), although more so in the 10-30 year age interval. The model appears to mainly underestimate the size fraction at older ages. Part of the lack of fit at the oldest ages may be due to the 5-year age bins used for ages ≥ 35.

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 and spawning biomass is female spawning biomass. Model estimates indicate that total biomass began relatively high in the 1980s (~157,000 t) but declined gradually through the 1990's, reaching a low of 87,000 t in 2001 (Table 5.16 and Figure 5.16). Since 2001, total biomass appears to almost constant and was estimated at 90,000 t for 2009. Total biomasses estimated in this assessment are about 30% smaller than that estimated in the 2005 and 2007 assessments. This is due primarily to differences between the estimated male selectivity curves for the "full coverage" survey in the preferred model here and those from the preferred models in the 2005 and 2007 assessments. Selectivities for the full coverage survey tend to be larger in the current preferred model over the 10-26 year age range, relative to those from the models in the earlier assessments. Since all three models achieved reasonable fits to the available survey data, the consequence of these differences in selectivity was that the current preferred model had to estimate smaller numbers-at-age over the 10-26 year age range than had been estimated in the earlier assessments.

Model estimates of spawning biomass show a pattern somewhat different from that of total biomass (Table 5.16, Figure 5.16). Spawning biomass remained unchanged through the 1980's and began to decline in 1992 from 58,000 t. Subsequently, spawning biomass declined slowly and has appeared to level off again; the estimate for 2009 (32,000 t) is the lowest in the model time period, corresponding to a decrease of 34% from the maximum in 1991, but has remained the same for the past 4 years. Recent spawning biomass values estimated in the current assessment are about 25% smaller than those estimated in the 2007 assessment. As with the discrepancy in total biomass, this discrepancy is also due to the differences among the full coverage survey selectivities estimated in the preferred model and the previous two assessments.

Model estimates of annual recruitment (age 3 numbers) ranged from a low of 6.1 million in 1995 to a high of 22.8 million in 2002 (Table 5.17, Figure 5.17). Turnock et al. (2003) suggested that the 2003 survey length compositions indicated a potentially large recruitment event which may also have been reflected by the increase in survey biomass from 2001 to 2003 (77,200 [corrected for availability] and 99, 297, respectively; Table 5.5a). However, the uncertainty associated with the 2002 recruitment estimate was large as well (the cv for the estimate was 0.66). Although survey biomass and model estimates of total biomass and spawning biomass have declined since 2003, subsequent assessment models have continued to identify 2002 as a strong year for recruitment (at age 3). This is further supported by peaks in the 2005 and 2007 survey age composition data that corresponds to recruits entering the model in 2002, providing additional evidence to support Turnock et al.'s (2003) suggestion. The recruitment estimates from this assessment are somewhat smaller than those from the previous two assessments, particularly since 1995 and especially for the peak recruitment in 2002.

A control rule plot showing the temporal trajectory of estimated fishing mortality and spawning biomass is illustrated in Figure 5.18. Based on the trajectory, the stock does not appear to have been overfished or to have experienced overfishing in the past.

Projections and Harvest Alternatives

The reference fishing mortality rate for Dover 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 $SPR_{40\%}$ obtained from a spawner-per-recruit analysis are considered reliable. An estimate of $B_{40\%}$ can be calculated as the product of $SPR_{40\%}$ times the equilibrium number of recruits. Assuming that the average recruitment from the 1981-2006 year classes (1984-2009 age 3 recruits) estimated in this assessment represents a reliable estimate of equilibrium recruitment, then $B_{40\%}$ is 14,249 t. The estimated 2009 spawning stock biomass is 31,831 t. Since reliable estimates of the 2009 spawning biomass (*B*), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (31,831 t > 14,249 t), the Dover 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 2009 SSB	=	31,831 t
$B_{40\%}$	=	14,249 t
$F_{40\%}$	=	0.119
F_{ABC}	≤	0.119
$B_{35\%}$	=	12,468 t
$F_{35\%}$	=	0.149
F_{OFL}	=	0.149

Because the Dover sole stock has not been overfished in recent years, the stock biomass is relatively high, and the reference points from the selected assessment model was very conservative relative to the alternative models, we do not recommended to adjust F_{ABC} downward from its upper bound.

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

For each scenario, the projections begin with the vector of 2009 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch 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 2010, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2009 recommended in the assessment to the *max* F_{ABC} for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2005-2009 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, so scenarios 1 and 2 yield identical results. The 14-year projections of the mean harvest, spawning stock biomass and fishing mortality using the base model results for the five scenarios are shown in Table 5.18-20.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Dover 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 2010, then the stock is not overfished.)
>
> *Scenario 7*: In 2008 and 2009, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2022 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the Dover sole stock is not overfished and is not approaching an overfished condition (Tables 5.18-20). With regard to assessing the current stock level, the expected stock size in the year 2010 of scenario 6 (32,218) is over twice its $B_{35\%}$ value of 12,468 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 2022 of scenario 7 (14,444 t) is greater than $B_{35\%}$; thus the stock is not approaching an overfished condition.

Acceptable Biological Catch and Overfishing Level

Because little biological information exists for Greenland turbot and deepsea sole, and because survey biomass estimates are not considered reliable indicators of population status, these two species fall into Tier 6 for ABC and OFL determination. For species in Tier 6, ABC is $0.75 x \overline{C}$ and OFL is $\overline{C}$, where $\overline{C}$ is the average historical catch from 1978-1995. Thus, ABC and OFL for Greenland turbot and deepsea sole are

Tier 6 Species	Mean catch (t)	2010 ABC (t)	2010 OFL (t)	2011 ABC (t)	2011 OFL (t)
Greenland turbot	238	179	238	179	238
Deepsea sole	6	4	6	4	6

Because Dover sole is in Tier 3a, the maximum value for F_{ABC} is defined to be equal to $F_{40\%}$ while F_{OFL} is defined to be equal to $F_{35\%}$. Because the model we selected yielded very conservative reference points relative to the alternative models considered, there does not seem to be compelling reasons to recommend a lower value for F_{ABC}, so we recommend using $F_{40\%}$ as F_{ABC}. Under this recommendation, ABC in 2010 for Dover sole is 6,007 t and OFL is 7,436 t. For 2010, female spawning biomass is projected to be 32,218 t while total biomass (i.e., age 3+ biomass) is projected to be 89,682 t.

Estimating an ABC and OFL for 2011 is somewhat problematic, as these values depend on the catch that will be taken in 2010. The actual catch taken in the GOA Dover sole fishery has been substantially smaller than the TAC for the past several years. We assumed that a reasonable estimate of the catch to be taken in 2010 was the five-year average of recent catches (405 t). Using this value and the estimated population size at the start of 2010, we projected the stock ahead through 2010 and calculated an ABC and OFL for 2011. ABC for 2011 is 6,142 t and OFL is 7,603 t. For 2011, female spawning biomass is projected to be 32,673 t while total biomass (i.e., age 3+ biomass) is projected to be 89,870 t.

ABC allocation by management area

TACs for deepwater flatfish in the Gulf of Alaska are divided among four smaller management areas (Eastern, Central, West Yakutat and Southeast Outside). As in previous assessments, the proportion of historical catch among the management areas is used to apportion the total ABCs for Greenland turbot and deepsea sole. Area-specific ABCs for Dover sole are divided up over the four management areas by applying the fraction of 2009 survey biomass estimated for each area (relative to the total over all areas) to the 2010 and 2011 ABCs. The area-specific allocations for 2010 and 2011 are:

Greenland turbot	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
apportionment	68.2%	22.3%	5.0%	4.5%	100.0%
2010 ABC (t)	122	40	9	8	179
2011 ABC (t)	122	40	9	8	179

Deepsea sole	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
apportionment	0.0%	100.0%	0.0%	0.0%	100.0%
2010 ABC (t)	0	4	0	0	4
2011 ABC (t)	0	4	0	0	4

Dover sole	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
apportionment	6.6%	47.0%	33.9%	12.5%	100.0%
2010 ABC (t)	399	2,821	2,035	752	6,007
2011 ABC (t)	408	2,884	2,080	770	6,142

All	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
2010 ABC (t)	521	2,865	2,044	760	6,190
2011 ABC (t)	530	2,928	2,089	778	6,325

Ecosystem Considerations

Ecosystem effects on the stock

Based on results from an ecosystem model for the Gulf of Alaska (Aydin et al., 2007), Dover sole adults occupy an intermediate trophic level (Figure 5.19). Dover sole commonly feed on brittle stars, polychaetes and other miscellaneous worms (Figure 5.20; Buckley et al., 1999). Trends in prey abundance for Dover sole are unknown.

Important predators identified in the GOA ecosystem model include walleye pollock and Pacific halibut; however, the major source of Dover sole mortality is from the flatfish fishery (Figure 5.21). The ecosystem model was developed using food habits data from the early 1990s when GOA pollock biomass was much larger than it is currently. Biomass of GOA pollock has been declining and is at historically low levels, thus the ecosystem model results may not reflect the current impact of pollock on Dover sole.

Little is known regarding the roles of Greenland turbot or deepsea sole in the Gulf of Alaska ecosystem. Within the 200-mile limits of the Exclusive Economic Zone of the United States, Greenland turbot are mainly found in the Bering Sea and the Aleutian Islands (Ianelli et al., 2006). Although the Gulf of Alaska component of Greenland turbot may represent a marginal stock, the species range in the eastern Pacific extends to northern Baja California. It thus seems somewhat unlikely that stock size in the Gulf is limited by simple environmental factors such as temperature, rather it seems more likely that substantial biomass exists beyond the depth range of the fishery and the surveys. Greenland turbot are epibenthic feeders and prey on crustaceans and fishes. Walleye pollock are important predators on turbot in the Bering Sea, but it is unknown whether this holds true as well in the Gulf.

Fishery effects on ecosystem

Only small amounts of protected species (halibut, salmon and crab) are typically taken in the deepwater flatfish directed fishery (Table5.21). In 2008 and thus far in 2009, no halibut, crab, or salmon were caught in this fishery.

Catches of Dover sole have been concentrated along the shelf edge east and southeast of Kodiak Island in the Gulf of Alaska over the past few years (Figures 5.2 and 5.3). It is unknown whether this level of spatial concentration by the fishery will have any effects on the stocks making up this complex, but it seems unlikely. In addition to deepwater flatfish, the directed fishery has also caught small amounts of arrowtooth flounder, sablefish, and thornyheads as bycatch in recent years (Table 5.22).

Effects of discards and offal production on the ecosystem are unknown for the deepwater flatfish fishery.

Data gaps and research priorities

We are concerned that not enough length samples for Dover sole size compositions are being collected by fishery observers in the Observer Program. Fishery size compositions were not included in the Dover sole assessment model for 2005-2008 because so few length samples were reported during this time period. This may, however, simply be a consequence of the overall low total catches in the deepwater flatfish fishery.

Thanks to the industrious work of the AFSC's Age and Growth Program, the amount of age data for Dover sole in the Gulf of Alaska that is available from the groundfish survey has improved remarkably in the past few years. However, complementary data from the fishery is does not exist. Although the current assessment model can not incorporate fishery age compositions, we anticipate adding this capability in the future. Additional age data, from both the surveys and the fishery, should improve future stock assessments through improved estimates of individual growth and age-length conversion matrices, and by filling in missing years with age composition data. Existing age/length data will be used in the upcoming year to re-evaluate current growth models and the associated age-length conversion matrices used in the model. We also plan to modify the assessment model to estimate growth rates directly within the model, rather than using conversion matrices estimated outside the model. This approach will further allow us to naturally incorporate ageing error into the estimates of growth.

Further modeling research should address the use of length-based, rather than age-based, approaches to fishery and survey selectivity in the assessment model. This may alleviate some of the problems demonstrated in this assessment with age-based approaches. In addition, research should be continued into alternative functional forms to describe selectivity.

Finally, given the dearth of biological knowledge regarding Greenland turbot and deepsea sole in the Gulf of Alaska, a concerted effort should be made to obtain more samples from the GOA survey. This would probably entail expanding the survey into deeper strata than currently sampled, however, and thus may not be feasible.

Summary

Tier 6 Species	Mean catch (t)	2010 ABC (t)	2010 OFL (t)	2011 ABC (t)	2011 OFL (t)
Greenland turbot	238	179	238	179	238
Deepsea sole	6	4	6	4	6

Tier 3a Dover sole (only)		
Reference mortality rates		
M	0.085	
$F_{35\%}$	0.149	
$F_{40\%}$	0.119	
Equilibrium female spawning biomass		
$B_{100\%}$	35,622 t	
$B_{40\%}$	14,249 t	
$B_{35\%}$	12,468 t	
Fishing rates		
F_{OFL}	0.149	
F_{ABC} (maximum permissible)	0.119	
F_{ABC} (recommended)	0.119	
2009 biomass		
Age 3+ biomass (t)	89,536 t	
Female spawning biomass (t)	31,831 t	
Projected biomass	**2010**	**2011**
Age 3+ biomass (t)	89,682	89,870
Female spawning biomass (t)	32,218	32,673
Harvest limits	**2010**	**2011**
OFL (t)	7,436	7,603
ABC (maximum permissible; t)	6,007	6,142
ABC (recommended; t)	6,007	6,142

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Tables

Table 5.1. Annual catch of deepwater flatfish species (Greenland turbot, Dover sole and deep-sea sole) in the Gulf of Alaska from 1978. 2009 catch is through Sept. 26.

Year	Greenland turbot	Dover sole	Deepsea sole	Total
1978	51	827	5	883
1979	24	530	5	559
1980	57	570	2	629
1981	8	457	8	473
1982	23	457	31	511
1983	145	354	11	510
1984	18	132	1	151
1985	0	43	3	47
1986	0	23	0	23
1987	44	56	0	100
1988	256	1,087	0	1,343
1989	56	1,521	0	1,577
1990	0	2,348	30	2,378
1991	446	9,741	2	10,189
1992	3,012	8,364	3	11,379
1993	16	3,804	3	3,823
1994	17	3,108	4	3,129
1995	116	2,096	1	2,213
1996	15	2,177	0	2,193
1997	11	3,652	1	3,664
1998	18	2,230	38	2,286
1999	14	2,270	0	2,285
2000	23	961	1	985
2001	4	800	0	804
2002	5	554	0	559
2003	10	936	0	946
2004	1	679	1	680
2005	5	407	0	412
2006	12	390	3	405
2007	1	286	0	287
2008	1	561	1	563
2009	2	365	8	375

Table 5.2a. Time series of recent reference points (ABC, OFL), TACs, total catch and retention rates for the deepwater flatfish complex. All values are in metric tons.

Year	ABC	TAC	OFL	Total Catch	Retained	Discarded	Percent Retained
1995	14,590	11,080	17,040	2,213	1,746	467	79%
1996	14,590	11,080	17,040	2,193	1,584	609	72%
1997	7,170	7,170	9,440	3,664	3,006	658	82%
1998	7,170	7,170	9,440	2,286	2,064	222	90%
1999	6,050	6,050	8,070	2,285	1,824	461	80%
2000	5,300	5,300	6,980	985	701	284	71%
2001	5,300	5,300	6,980	804	607	197	75%
2002	4,880	4,880	6,430	559	357	202	64%
2003	4,880	4,880	6,430	946	470	476	50%
2004	6,070	6,070	8,010	680	549	131	81%
2005	6,820	6,820	8,490	412	171	241	42%
2006	8,665	8,665	11,008	405	162	243	40%
2007	8,707	8,707	10,431	287	116	171	41%
2008	8,903	8,903	11,343	563	210	353	37%
2009	9,168	9,168	11,578	375	95	280	25%

Table 5.2b. Status of the deepwater flatfish fishery in recent years.

Year	Dates	Status
2005	Jan 20	open
	Mar 23	halibut bycatch status
	Apr 1	open
	Apr 8	halibut bycatch status
	Apr 24	open
	May 3	halibut bycatch status
	Jul 5	open
	Jul 24	halibut bycatch status
	Sep 1	open
	Sep 4	halibut bycatch status
	Sep 8	open
	Sep 10	halibut bycatch status
	Oct 1	open
	Oct 1	halibut bycatch status
2006	Jan 20	open
	Apr 27	halibut bycatch status
	Jul 1	open
	Sep 5	halibut bycatch status
	Oct 1	open
	Oct. 8	halibut bycatch status
2007	Jan 20	open
	May 17	halibut bycatch status
	Jul 1	open
	Aug 10	halibut bycatch status
	Sep 1	open
	Oct 8	halibut bycatch status
	Oct 10	open
	Oct 15	halibut bycatch status
	Oct 22	open
2008	Jan 20	open
	Apr 21	halibut bycatch status
	Jul 1	open
	Sep 9	A80 vessels subject to sideboard limits
	Sep 11	halibut bycatch status
	Oct 1	open
	Nov 6	halibut bycatch status
	Nov 16	open
2009	Jan 20	open
	Mar 3	halibut bycatch status
	Apr 1	open
	Apr 23	halibut bycatch status
	Jul 1	open

Table 5.3. Annual normalized fishery size compositions for Dover sole (only) from the domestic fishery. The 2009 composition is based on observer reports through Sept. 26. Normalization is over both sexes.

a) Females

year	Length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0013	0.0182	0.0556	0.1203	0.0721	0.0831	0.0292	0.0162	0.0012	0.0008	0.0001	0.0000	0.0000	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0060	0.0187	0.0158	0.0503	0.0601	0.0986	0.1005	0.0635	0.0666	0.0207	0.0136	0.0142	0.0184	0.0000
1993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0163	0.0456	0.0294	0.0488	0.0332	0.0489	0.0514	0.0320	0.0172	0.0216	0.0123	0.0084	0.0103	0.0022	0.0036
1994	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0016	0.0047	0.0200	0.0352	0.0442	0.0560	0.0442	0.0177	0.0135	0.0014	0.0024	0.0026	0.0005	0.0005
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0021	0.0047	0.0189	0.0473	0.0701	0.0676	0.0645	0.0267	0.0396	0.0060	0.0209	0.0071	0.0000	0.0049	0.0000
1996	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0125	0.0293	0.0414	0.0442	0.0923	0.0855	0.0685	0.0402	0.0238	0.0115	0.0029	0.0000	0.0000	0.0005
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0024	0.0040	0.0188	0.0234	0.0393	0.0468	0.0690	0.0683	0.0319	0.0450	0.0272	0.0235	0.0088	0.0068	0.0016
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0027	0.0047	0.0098	0.0216	0.0420	0.0765	0.1195	0.0883	0.0517	0.0331	0.0122	0.0076	0.0007	0.0013
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0070	0.0135	0.0181	0.0480	0.0560	0.0596	0.0775	0.0587	0.0519	0.0502	0.0283	0.0089	0.0065	0.0052	0.0026	0.0030
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0027	0.0016	0.0044	0.0091	0.0143	0.0210	0.0378	0.0631	0.0850	0.0578	0.0405	0.0566	0.0121	0.0089	0.0013	0.0017
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0129	0.0345	0.0328	0.0115	0.0256	0.0544	0.0541	0.0512	0.0522	0.0292	0.0088	0.0150	0.0009	0.0080
2002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0040	0.0000	0.0041	0.0071	0.0248	0.0043	0.0602	0.0562	0.0347	0.0233	0.0201	0.0000	0.0000	0.0059
2003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0000	0.0052	0.0008	0.0013	0.0083	0.0037	0.0039	0.0118	0.0410	0.0497	0.0452	0.0199	0.0157	0.0165	0.0072	0.0005
2004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0063	0.0054	0.0180	0.0407	0.0547	0.0423	0.0357	0.0584	0.0253	0.0163	0.0089	0.0351	0.0031
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0082	0.0335	0.0104	0.0264	0.0255	0.0203	0.0665	0.0879	0.0547	0.0000	0.0000	0.0000	0.0352

b) Males.

year	Length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0010	0.0238	0.0598	0.1009	0.1942	0.1262	0.0525	0.0327	0.0095	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0010	0.0087	0.0013	0.0209	0.0632	0.0565	0.0907	0.1175	0.0336	0.0296	0.0221	0.0020	0.0038	0.0000	0.0000	0.0000	0.0000
1993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0040	0.0892	0.1841	0.1588	0.0790	0.0367	0.0288	0.0107	0.0146	0.0050	0.0015	0.0011	0.0022	0.0008	0.0000	0.0000
1994	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0056	0.0679	0.1615	0.1895	0.1598	0.0853	0.0608	0.0092	0.0116	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0008	0.0000	0.0187	0.0850	0.1557	0.1059	0.1168	0.0691	0.0439	0.0123	0.0001	0.0098	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0033	0.0394	0.1627	0.1030	0.0916	0.0758	0.0469	0.0144	0.0035	0.0019	0.0004	0.0015	0.0000	0.0000	0.0000	0.0000
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0015	0.0187	0.0539	0.0686	0.1179	0.0907	0.1153	0.0733	0.0318	0.0069	0.0018	0.0008	0.0000	0.0000	0.0004	0.0000
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0151	0.0333	0.0764	0.1022	0.1284	0.0945	0.0470	0.0205	0.0048	0.0012	0.0011	0.0000	0.0000	0.0000	0.0004
1999	0.0000	0.0000	0.0001	0.0000	0.0005	0.0036	0.0029	0.0101	0.0381	0.0594	0.0917	0.0819	0.0824	0.0526	0.0486	0.0196	0.0066	0.0023	0.0006	0.0007	0.0000	0.0000	0.0000
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0016	0.0003	0.0074	0.0282	0.0772	0.1229	0.0979	0.1035	0.0694	0.0485	0.0156	0.0025	0.0040	0.0013	0.0002	0.0000	0.0000
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0016	0.0043	0.0032	0.0350	0.0972	0.1398	0.0786	0.1147	0.0435	0.0301	0.0192	0.0105	0.0269	0.0016	0.0019	0.0000	0.0000
2002	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0009	0.0005	0.0000	0.0118	0.0709	0.0686	0.1499	0.2341	0.1220	0.0596	0.0337	0.0014	0.0010	0.0000	0.0000	0.0000	0.0000
2003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0218	0.0935	0.1611	0.1150	0.1698	0.0725	0.0843	0.0287	0.0058	0.0073	0.0021	0.0049	0.0000	0.0000	0.0000
2004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0296	0.0881	0.0781	0.0880	0.1194	0.1186	0.0704	0.0307	0.0073	0.0128	0.0019	0.0000	0.0000	0.0000
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0151	0.0897	0.1216	0.1354	0.1501	0.0602	0.0123	0.0360	0.0000	0.0075	0.0034	0.0000	0.0000	0.0000

Table 5.4. Sample sizes for Dover sole (only): a) sample sizes for size compositions from the domestic fishery and b) sample sizes for estimated biomass, age and size compositions from the GOA groundfish survey.

a). Fishery size compositions.

year	Size compositions			
	hauls	total indiv.s	females	males
1990	35	3041	24	225
1991	36	2539	443	636
1992	53	3071	197	171
1993	44	2045	631	823
1994	64	3027	433	1353
1995	116	4069	561	904
1996	40	2678	730	693
1997	47	2524	866	1460
1998	72	2483	863	1193
1999	62	1225	625	595
2000	52	964	347	556
2001	44	811	280	433
2002	15	277	69	208
2003	27	415	140	275
2004	33	625	230	395
2005	2	12	10	2
2006	5	48	18	30
2007	2	40	20	20
2008	5	44	11	33
2009	10	131	54	77

b). GOA groundfish surveys.

year	biomass	Size compositions				Age compositions			
	total hauls	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males
1984	929	284	11298	3828	6271	5	233	155	78
1987	783	80	5180	2308	2872	5	189	102	87
1990	708	195	7435	4034	3401	27	270	156	114
1993	775	321	10491	4866	5316	29	332	193	139
1996	807	406	7125	3239	3886	77	370	212	158
1999	764	363	6580	2573	3961				
2001	489	183	1940	965	975	57	290	167	122
2003	809	387	6729	2893	3785	95	596	328	266
2005	839	440	7272	3003	4269	102	588	310	278
2007	820	426	5929	2466	3461	55	416	220	196
2009	823	415	6356	2633	3718				

Table 5.5a. Biomass estimates (t) for GOA deepwater flatfish by NPFMC regulatory area from the NMFS groundfish trawl surveys. Note that the Eastern Gulf (West Yakutat + Southeast) was not surveyed in 2001. Maximum survey depth coverage and the assumed availability of Dover sole to each survey are given in the first table, as well.

1) Dover sole.

Year	Western Gulf	Central Gulf	West Yakutat	Southeast	Total	Std. Dev	Max Depth (m)	Assumed availability
1984	4,460	52,469	7,516	4,076	68,521	6,136	1000	1
1987	2,623	34,577	21,067	5,127	63,394	7,388	1000	1
1990	1,649	71,109	18,699	5,140	96,597	12,375	500	0.82
1993	2,371	43,515	26,877	12,787	85,549	6,441	500	0.82
1996	1,458	37,144	29,766	11,162	79,531	5,624	500	0.82
1999	1,442	34,155	25,647	13,001	74,245	5,236	1000	1
2001	895	31,529	--	--	32,424	3,758	500	0.42
2003	3,149	49,283	31,609	15,256	99,297	10,544	700	1
2005	2,832	38,881	25,177	13,647	80,538	6,794	1000	1
2007	2,325	43,490	13,690	12,120	71,624	7,112	1000	1
2009	5,067	35,820	25,838	9,551	76,277	6,437	1000	1

2) Greenland turbot

Year	Western Gulf	Central Gulf	West Yakutat	Southeast	Total	Std. Dev
1984	108	184	0	0	292	87
1987	76	67	0	0	143	61
1990	0	0	0	0	0	0
1993	0	0	0	0	0	0
1996	0	0	0	0	0	0
1999	0	0	0	0	0	0
2001	0	0	--	--	0	0
2003	109	0	0	0	109	108
2005	0	0	0	0	0	0
2007	122	0	0	0	122	122
2009	0	0	0	0	0	0

3) Deepsea sole.

Year	Western Gulf	Central Gulf	West Yakutat	Southeast	Total	Std. Dev
1984	0	28	0	190	218	15
1987	0	5	8	147	160	45
1990	0	0	0	0	0	0
1993	0	0	0	0	0	0
1996	0	0	0	0	0	0
1999	0	97	0	0	97	34
2001	0	52	--	--	52	52
2003	12	117	32	19	180	122
2005	0	140	102	20	262	133
2007	0	208	35	30	274	88
2009	0	188	0	60	249	112

Table 5.5b. Biomass estimates (t) for GOA deepwater flatfish by depth strata from the NMFS groundfish trawl surveys. Note that the Eastern Gulf (West Yakutat + Southeast) was not surveyed in 2001.

1) Dover sole.

year	Depth strata (m)				
	1-100	100-200	200-300	300-500	>500
1984	2,829	30,220	7,928	6,822	20,723
1987	4,401	25,831	12,039	8,934	12,189
1990	12,290	57,774	19,985	6,549	--
1993	4,760	43,999	19,930	16,861	--
1996	6,561	37,856	18,101	17,013	--
1999	6,431	28,549	19,576	12,317	7,372
2001	3,803	16,294	7,491	4,836	--
2003	10,154	45,181	17,832	13,593	12,537
2005	6,654	32,613	17,675	17,774	5,823
2007	2,814	29,709	19,598	11,335	8,168
2009	6,534	26,486	23,685	9,300	10,271

2) Greenland turbot

year	Depth strata (m)				
	1-100	100-200	200-300	300-500	>500
1984	0	0	1	204	87
1987	0	25	0	19	99
1990	0	0	0	0	--
1993	0	0	0	0	--
1996	0	0	0	0	--
1999	0	0	0	0	0
2001	0	0	0	0	--
2003	0	0	0	109	0
2005	0	0	0	0	0
2007	0	0	0	0	122
2009	0	0	0	0	0

3) Deepsea sole.

year	Depth strata (m)				
	1-100	100-200	200-300	300-500	>500
1984	0	0	0	0	218
1987	0	0	0	0	160
1990	0	0	0	0	--
1993	0	0	0	0	--
1996	0	0	0	0	--
1999	0	0	0	0	97
2001	0	0	0	52	--
2003	0	0	0	0	180
2005	0	0	0	0	262
2007	0	0	0	8	265
2009	0	0	0	0	249

Table 5.6. Survey age compositions for Dover sole (only).

a) Females.

year	Age bin 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40
1987	0	232	2,627	590	2,151	5,095	5,014	3,728	2,193	1,162	1,326	930	1,578	708	383	2,230	1,102	1,310	212	492	223	0
1993	175	590	1,973	1,332	1,500	886	1,869	2,525	2,439	2,356	2,691	3,036	2,262	64	1,190	1,292	140	1,915	1,457	1,064	547	415
1996	307	501	2,117	507	544	1,224	2,313	643	1,854	2,664	2,178	751	2,756	1,695	1,228	1,092	1,665	1,235	496	471	386	223
1999	115	1,053	3,131	1,612	751	1,085	1,386	524	1,594	762	1,820	994	2,732	2,765	1,184	854	854	662	319	756	0	271
2001	153	602	969	1,166	692	680	249	505	180	0	189	168	304	38	616	553	188	721	177	429	418	78
2003	2,009	5,285	4,851	4,606	2,516	3,176	1,385	2,121	1,849	1,624	1,063	1,359	1,180	1,083	250	973	1,219	1,023	680	306	232	0
2005	1,586	992	3,370	5,721	2,695	3,718	839	1,642	1,928	367	811	1,030	462	686	356	922	1,296	806	418	554	261	0
2007	198	1,397	1,083	1,789	1,988	2,905	2,586	1,070	879	1,451	875	853	950	199	964	867	594	487	794	54	1,231	0

b) Males.

year	Age bin 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40
1987	68	371	1,676	3,717	2,261	6,598	7,440	2,213	975	929	286	1,187	321	810	816	1,202	1,212	1,565	0	0	0	0
1993	1,538	2,408	4,084	2,699	4,722	5,201	2,811	3,355	1,102	2,306	1,311	1,144	2,185	1,168	963	663	595	2,820	135	0	0	0
1996	275	1,125	3,362	2,317	2,126	2,167	2,813	1,523	1,381	4,437	5,056	3,900	2,832	2,450	629	1,552	1,792	0	1,641	0	66	0
1999	551	2,910	3,415	2,456	804	2,017	880	750	1,026	1,235	531	1,452	76	1,392	624	2,541	76	2,935	1,136	524	1,675	0
2001	300	989	1,710	1,529	1,311	680	521	448	187	57	0	210	449	311	396	122	436	333	0	662	441	0
2003	1,746	7,903	5,282	7,926	4,847	4,343	1,027	2,933	1,663	1,470	2,487	1,763	1,502	0	2,298	640	1,666	1,448	713	644	651	134
2005	1,236	1,000	6,882	8,562	3,913	1,676	2,898	1,667	1,847	584	1,878	947	1,141	1,389	976	702	305	411	386	786	473	299
2007	803	648	2,571	1,502	2,809	3,000	3,915	1,574	2,076	1,969	2,842	1,145	852	880	876	945	476	490	326	725	692	317

Table 5.7. Survey length compositions for Dover sole (only). Survey length compositions from 1987, 1993, 1996, 1999, 2001, 2003, 2005 and 2007 were downweighted in fitting the assessment model because age compositions were available for these years.

a) Females.

year	Length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1984	0	0	0	46	56	437	449	1,416	1,828	2,151	2,760	3,335	2,548	1,979	1,805	1,077	770	312	437	71	55	41	0	0	0
1987	0	45	88	69	86	162	250	543	1,035	1,657	2,661	3,406	2,679	3,158	1,775	1,820	740	545	134	279	202	0	0	0	0
1990	23	23	23	14	18	123	318	493	619	1,372	1,759	2,857	4,158	5,473	4,357	3,748	3,240	1,533	384	449	106	18	50	2	0
1993	0	0	11	21	122	150	338	532	824	965	1,199	2,059	2,903	3,828	4,627	3,041	2,387	1,456	720	378	192	65	38	19	6
1996	0	81	100	217	166	273	343	583	784	775	974	1,196	1,588	2,316	2,993	2,956	3,042	2,200	987	660	221	137	24	55	0
1999	35	115	83	272	445	551	955	661	929	1,098	1,214	1,417	1,746	1,775	1,897	1,960	2,403	1,496	859	494	311	28	42	0	0
2001	51	32	33	47	164	227	185	271	325	372	198	316	229	348	629	841	701	913	770	544	302	363	122	135	60
2003	1,273	764	824	762	884	1,208	1,247	1,240	1,396	2,256	1,970	2,027	2,106	1,842	2,090	2,002	2,632	1,685	1,230	835	392	118	68	45	12
2005	80	61	456	323	489	974	1,119	1,368	1,862	1,937	1,784	1,639	1,506	1,492	1,622	1,411	1,425	1,364	1,073	775	425	74	151	50	7
2007	60	104	212	397	420	533	550	659	798	1,293	1,151	1,575	1,863	1,662	1,750	1,269	1,195	1,519	841	693	414	270	135	28	11
2009	187	207	279	331	243	406	899	1,352	1,491	1,532	1,282	1,567	1,369	1,943	1,881	1,602	1,639	807	829	637	406	212	49	29	0

b) Males.

year	Length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1984	0	0	42	227	560	1,298	2,000	4,402	6,869	6,780	4,366	2,193	998	546	94	48	17	112	5	102	0	0	48	0	0
1987	0	0	84	54	203	564	676	1,700	3,520	4,291	4,572	3,122	1,452	860	294	236	92	0	0	0	0	0	0	0	0
1990	0	14	20	42	67	365	570	1,340	2,068	3,920	5,093	5,579	4,570	1,612	428	604	347	326	2	0	0	0	0	0	0
1993	13	36	50	91	67	417	601	1,096	2,695	3,754	5,226	5,046	3,614	2,007	804	491	158	41	33	0	6	0	0	0	0
1996	25	115	76	209	344	335	827	1,156	2,061	3,659	4,409	4,492	3,388	1,520	707	275	144	26	8	5	0	0	0	0	0
1999	72	18	363	540	705	1,120	1,459	1,720	1,783	3,353	4,415	4,702	3,409	2,456	1,309	504	180	57	26	10	0	0	0	0	0
2001	33	26	26	77	118	356	539	467	775	510	1,006	1,369	1,239	966	628	92	165	88	37	0	0	0	0	0	17
2003	1,098	638	1,007	713	1,497	1,826	1,757	1,957	2,407	3,337	5,073	5,098	5,490	4,067	2,354	1,319	632	189	42	28	0	0	0	0	0
2005	37	204	436	433	769	1,063	1,832	2,360	2,754	3,671	4,096	4,257	3,629	2,991	1,435	774	530	63	81	0	0	0	0	0	0
2007	0	228	232	375	314	938	895	1,372	1,629	2,845	3,629	3,489	2,919	2,293	1,818	883	323	44	56	0	0	0	0	0	0
2009	144	143	324	252	563	878	1,687	2,001	2,078	2,736	3,313	4,566	3,584	3,001	1,698	919	405	109	44	0	0	0	0	0	0

Table 5.8a. Age-length transition matrix for female Dover 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 cutpoints (cm)																								
age	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
3	0.0265	0.0654	0.1430	0.2188	0.2343	0.1756	0.0922	0.0338	0.0087	0.0016	0.0002	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
4	0.0053	0.0170	0.0493	0.1074	0.1750	0.2135	0.1951	0.1335	0.0683	0.0262	0.0075	0.0016	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0013	0.0048	0.0165	0.0439	0.0915	0.1495	0.1913	0.1915	0.1502	0.0922	0.0443	0.0167	0.0049	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0004	0.0016	0.0060	0.0181	0.0439	0.0863	0.1370	0.1757	0.1821	0.1524	0.1031	0.0563	0.0249	0.0089	0.0026	0.0006	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0002	0.0006	0.0025	0.0080	0.0215	0.0477	0.0874	0.1327	0.1664	0.1725	0.1478	0.1047	0.0613	0.0297	0.0119	0.0039	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0001	0.0003	0.0011	0.0039	0.0111	0.0268	0.0544	0.0929	0.1334	0.1610	0.1636	0.1397	0.1004	0.0607	0.0308	0.0132	0.0047	0.0014	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0001	0.0006	0.0020	0.0062	0.0158	0.0344	0.0639	0.1013	0.1368	0.1576	0.1547	0.1294	0.0923	0.0561	0.0291	0.0128	0.0048	0.0016	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0001	0.0003	0.0012	0.0037	0.0098	0.0224	0.0444	0.0758	0.1115	0.1412	0.1540	0.1447	0.1171	0.0817	0.0491	0.0254	0.0113	0.0043	0.0014	0.0004	0.0001	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0002	0.0007	0.0023	0.0064	0.0152	0.0317	0.0572	0.0896	0.1222	0.1446	0.1487	0.1329	0.1031	0.0695	0.0407	0.0207	0.0092	0.0035	0.0012	0.0003	0.0001	0.0000	0.0000
12	0.0000	0.0000	0.0001	0.0005	0.0015	0.0044	0.0108	0.0232	0.0438	0.0723	0.1043	0.1317	0.1454	0.1405	0.1187	0.0877	0.0567	0.0321	0.0159	0.0069	0.0026	0.0009	0.0002	0.0001	0.0000
13	0.0000	0.0000	0.0001	0.0003	0.0011	0.0031	0.0079	0.0175	0.0343	0.0588	0.0889	0.1182	0.1382	0.1421	0.1286	0.1023	0.0716	0.0441	0.0239	0.0114	0.0048	0.0018	0.0006	0.0002	0.0001
14	0.0000	0.0000	0.0001	0.0002	0.0008	0.0023	0.0060	0.0137	0.0274	0.0486	0.0763	0.1057	0.1294	0.1401	0.1340	0.1133	0.0846	0.0559	0.0326	0.0168	0.0077	0.0031	0.0011	0.0003	0.0001
15	0.0000	0.0000	0.0000	0.0002	0.0006	0.0018	0.0047	0.0109	0.0224	0.0408	0.0660	0.0946	0.1204	0.1359	0.1360	0.1209	0.0953	0.0666	0.0413	0.0228	0.0111	0.0048	0.0019	0.0006	0.0003
16	0.0000	0.0000	0.0000	0.0001	0.0005	0.0014	0.0038	0.0090	0.0187	0.0349	0.0578	0.0852	0.1118	0.1306	0.1359	0.1258	0.1037	0.0761	0.0497	0.0289	0.0149	0.0069	0.0028	0.0010	0.0005
17	0.0000	0.0000	0.0000	0.0001	0.0004	0.0012	0.0032	0.0075	0.0160	0.0302	0.0511	0.0772	0.1040	0.1251	0.1343	0.1287	0.1101	0.0841	0.0573	0.0349	0.0189	0.0092	0.0040	0.0015	0.0008
18	0.0000	0.0000	0.0000	0.0001	0.0003	0.0010	0.0027	0.0064	0.0138	0.0266	0.0458	0.0705	0.0971	0.1197	0.1320	0.1302	0.1150	0.0908	0.0642	0.0406	0.0230	0.0116	0.0053	0.0021	0.0011
19	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0023	0.0056	0.0122	0.0238	0.0415	0.0649	0.0911	0.1146	0.1292	0.1307	0.1185	0.0963	0.0702	0.0459	0.0269	0.0141	0.0066	0.0028	0.0016
20	0.0000	0.0000	0.0000	0.0001	0.0002	0.0008	0.0020	0.0050	0.0109	0.0215	0.0379	0.0602	0.0858	0.1099	0.1263	0.1305	0.1210	0.1008	0.0754	0.0507	0.0306	0.0166	0.0081	0.0035	0.0021
21	0.0000	0.0000	0.0000	0.0001	0.0002	0.0007	0.0018	0.0045	0.0099	0.0196	0.0351	0.0563	0.0813	0.1057	0.1235	0.1298	0.1228	0.1044	0.0799	0.0550	0.0340	0.0190	0.0095	0.0043	0.0027
22	0.0000	0.0000	0.0000	0.0001	0.0002	0.0006	0.0017	0.0041	0.0091	0.0181	0.0327	0.0530	0.0774	0.1019	0.1208	0.1289	0.1240	0.1074	0.0837	0.0588	0.0372	0.0212	0.0109	0.0050	0.0033
23	0.0000	0.0000	0.0000	0.0001	0.0002	0.0006	0.0015	0.0038	0.0084	0.0169	0.0307	0.0502	0.0741	0.0985	0.1182	0.1279	0.1248	0.1097	0.0870	0.0622	0.0401	0.0233	0.0122	0.0058	0.0039
24	0.0000	0.0000	0.0000	0.0000	0.0002	0.0005	0.0014	0.0035	0.0078	0.0159	0.0290	0.0478	0.0712	0.0956	0.1159	0.1268	0.1252	0.1116	0.0898	0.0652	0.0427	0.0253	0.0135	0.0065	0.0045
25	0.0000	0.0000	0.0000	0.0000	0.0002	0.0005	0.0013	0.0033	0.0074	0.0150	0.0276	0.0458	0.0687	0.0930	0.1138	0.1257	0.1255	0.1132	0.0922	0.0678	0.0451	0.0271	0.0147	0.0072	0.0051
26	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0012	0.0031	0.0070	0.0143	0.0264	0.0441	0.0665	0.0907	0.1118	0.1247	0.1256	0.1144	0.0942	0.0701	0.0472	0.0287	0.0158	0.0078	0.0057
27	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0012	0.0030	0.0067	0.0137	0.0254	0.0426	0.0646	0.0887	0.1101	0.1236	0.1256	0.1154	0.0959	0.0721	0.0490	0.0302	0.0168	0.0084	0.0063
28	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0011	0.0028	0.0064	0.0132	0.0246	0.0413	0.0630	0.0870	0.1086	0.1227	0.1255	0.1162	0.0974	0.0738	0.0507	0.0315	0.0177	0.0090	0.0069
29	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0011	0.0027	0.0062	0.0128	0.0238	0.0403	0.0616	0.0854	0.1072	0.1218	0.1254	0.1169	0.0986	0.0754	0.0522	0.0327	0.0185	0.0095	0.0074
30	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0010	0.0026	0.0060	0.0124	0.0232	0.0393	0.0604	0.0841	0.1060	0.1211	0.1253	0.1174	0.0997	0.0767	0.0534	0.0337	0.0193	0.0100	0.0078
31	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0010	0.0026	0.0058	0.0121	0.0226	0.0385	0.0593	0.0829	0.1049	0.1203	0.1251	0.1178	0.1006	0.0779	0.0546	0.0347	0.0200	0.0104	0.0083
32	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0010	0.0025	0.0057	0.0118	0.0222	0.0378	0.0584	0.0818	0.1040	0.1197	0.1249	0.1182	0.1014	0.0789	0.0556	0.0355	0.0206	0.0108	0.0087
33	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0010	0.0024	0.0056	0.0116	0.0218	0.0372	0.0576	0.0809	0.1031	0.1191	0.1248	0.1185	0.1021	0.0797	0.0565	0.0363	0.0211	0.0112	0.0091
34	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0024	0.0055	0.0114	0.0214	0.0367	0.0569	0.0801	0.1024	0.1186	0.1246	0.1188	0.1027	0.0805	0.0573	0.0370	0.0216	0.0115	0.0094
35	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0023	0.0054	0.0112	0.0211	0.0362	0.0563	0.0794	0.1017	0.1181	0.1245	0.1190	0.1032	0.0812	0.0580	0.0375	0.0221	0.0118	0.0097
36	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0023	0.0053	0.0110	0.0208	0.0358	0.0558	0.0788	0.1011	0.1177	0.1243	0.1192	0.1036	0.0818	0.0586	0.0381	0.0224	0.0120	0.0100
37	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0023	0.0052	0.0109	0.0206	0.0354	0.0553	0.0783	0.1006	0.1173	0.1242	0.1193	0.1040	0.0823	0.0591	0.0385	0.0228	0.0122	0.0102
38	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0022	0.0052	0.0108	0.0204	0.0351	0.0549	0.0778	0.1001	0.1170	0.1241	0.1194	0.1044	0.0828	0.0596	0.0389	0.0231	0.0124	0.0104
39	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0022	0.0051	0.0107	0.0202	0.0349	0.0545	0.0774	0.0997	0.1167	0.1240	0.1195	0.1046	0.0832	0.0600	0.0393	0.0234	0.0126	0.0106
40	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0009	0.0022	0.0051	0.0106	0.0201	0.0346	0.0542	0.0770	0.0994	0.1164	0.1239	0.1196	0.1049	0.0835	0.0604	0.0396	0.0236	0.0128	0.0108

Table 5.8b. Age-length transition matrix for male Dover 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 cutpoints (cm)																								
age	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
3	0.0296	0.0688	0.1453	0.2171	0.2298	0.1723	0.0915	0.0344	0.0092	0.0017	0.0002	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
4	0.0063	0.0192	0.0541	0.1141	0.1804	0.2139	0.1900	0.1266	0.0632	0.0237	0.0066	0.0014	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0017	0.0061	0.0202	0.0523	0.1050	0.1639	0.1988	0.1872	0.1370	0.0778	0.0343	0.0118	0.0031	0.0006	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0006	0.0022	0.0083	0.0246	0.0578	0.1081	0.1608	0.1900	0.1785	0.1333	0.0791	0.0373	0.0140	0.0042	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0002	0.0009	0.0038	0.0124	0.0327	0.0695	0.1192	0.1650	0.1845	0.1665	0.1214	0.0715	0.0340	0.0130	0.0040	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0001	0.0005	0.0019	0.0068	0.0195	0.0456	0.0869	0.1352	0.1717	0.1779	0.1505	0.1038	0.0585	0.0269	0.0101	0.0031	0.0008	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0001	0.0002	0.0011	0.0040	0.0123	0.0310	0.0642	0.1093	0.1529	0.1758	0.1662	0.1291	0.0825	0.0433	0.0187	0.0066	0.0019	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0001	0.0006	0.0025	0.0082	0.0220	0.0487	0.0889	0.1342	0.1674	0.1724	0.1467	0.1031	0.0599	0.0287	0.0114	0.0037	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0001	0.0004	0.0017	0.0057	0.0162	0.0379	0.0734	0.1179	0.1569	0.1730	0.1581	0.1196	0.0750	0.0390	0.0168	0.0060	0.0018	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0001	0.0003	0.0012	0.0042	0.0123	0.0302	0.0617	0.1044	0.1465	0.1707	0.1650	0.1324	0.0881	0.0487	0.0223	0.0085	0.0027	0.0007	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0002	0.0008	0.0031	0.0096	0.0247	0.0527	0.0933	0.1370	0.1671	0.1691	0.1421	0.0991	0.0574	0.0276	0.0110	0.0036	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0001	0.0006	0.0024	0.0077	0.0207	0.0458	0.0843	0.1287	0.1631	0.1715	0.1496	0.1083	0.0650	0.0324	0.0134	0.0046	0.0013	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0001	0.0005	0.0019	0.0063	0.0176	0.0404	0.0770	0.1216	0.1592	0.1728	0.1554	0.1158	0.0716	0.0366	0.0156	0.0055	0.0016	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0001	0.0004	0.0015	0.0053	0.0152	0.0361	0.0710	0.1156	0.1557	0.1736	0.1601	0.1221	0.0771	0.0403	0.0174	0.0062	0.0018	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0001	0.0003	0.0012	0.0045	0.0133	0.0326	0.0660	0.1105	0.1527	0.1742	0.1640	0.1274	0.0817	0.0433	0.0189	0.0068	0.0020	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0002	0.0010	0.0038	0.0117	0.0296	0.0619	0.1062	0.1501	0.1747	0.1673	0.1319	0.0856	0.0457	0.0201	0.0073	0.0022	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0002	0.0008	0.0033	0.0104	0.0272	0.0583	0.1025	0.1480	0.1752	0.1703	0.1358	0.0888	0.0477	0.0210	0.0076	0.0022	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0001	0.0007	0.0028	0.0093	0.0251	0.0552	0.0994	0.1462	0.1759	0.1730	0.1391	0.0915	0.0492	0.0216	0.0078	0.0023	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0001	0.0006	0.0025	0.0084	0.0233	0.0526	0.0967	0.1448	0.1767	0.1756	0.1421	0.0937	0.0503	0.0220	0.0078	0.0023	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0001	0.0005	0.0021	0.0076	0.0217	0.0502	0.0943	0.1437	0.1776	0.1781	0.1448	0.0955	0.0511	0.0222	0.0078	0.0022	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	0.0000	0.0001	0.0004	0.0019	0.0069	0.0202	0.0480	0.0922	0.1428	0.1787	0.1805	0.1472	0.0970	0.0515	0.0221	0.0077	0.0021	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.0001	0.0003	0.0016	0.0062	0.0189	0.0461	0.0903	0.1422	0.1799	0.1830	0.1495	0.0981	0.0518	0.0219	0.0075	0.0020	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	0.0000	0.0000	0.0003	0.0014	0.0056	0.0177	0.0443	0.0886	0.1417	0.1813	0.1854	0.1516	0.0991	0.0518	0.0216	0.0072	0.0019	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
26	0.0000	0.0000	0.0000	0.0000	0.0002	0.0013	0.0051	0.0166	0.0426	0.0870	0.1414	0.1828	0.1878	0.1535	0.0998	0.0516	0.0212	0.0069	0.0018	0.0004	0.0001	0.0000	0.0000	0.0000	0.0000
27	0.0000	0.0000	0.0000	0.0000	0.0002	0.0011	0.0046	0.0155	0.0410	0.0855	0.1412	0.1844	0.1903	0.1554	0.1003	0.0512	0.0206	0.0066	0.0017	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0002	0.0010	0.0042	0.0145	0.0394	0.0841	0.1411	0.1861	0.1929	0.1571	0.1006	0.0506	0.0200	0.0062	0.0015	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
29	0.0000	0.0000	0.0000	0.0000	0.0001	0.0008	0.0038	0.0136	0.0379	0.0828	0.1411	0.1879	0.1955	0.1588	0.1008	0.0500	0.0194	0.0059	0.0014	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0034	0.0127	0.0365	0.0815	0.1411	0.1898	0.1981	0.1604	0.1009	0.0492	0.0186	0.0055	0.0012	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
31	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0031	0.0118	0.0351	0.0802	0.1412	0.1918	0.2008	0.1620	0.1008	0.0483	0.0178	0.0051	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	0.0000	0.0000	0.0001	0.0005	0.0027	0.0110	0.0337	0.0788	0.1413	0.1939	0.2035	0.1636	0.1006	0.0473	0.0170	0.0047	0.0010	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
33	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0025	0.0102	0.0323	0.0775	0.1415	0.1960	0.2064	0.1650	0.1003	0.0463	0.0162	0.0043	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
34	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0022	0.0094	0.0309	0.0762	0.1416	0.1983	0.2093	0.1665	0.0998	0.0451	0.0154	0.0039	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
35	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0019	0.0087	0.0296	0.0749	0.1417	0.2006	0.2123	0.1679	0.0993	0.0439	0.0145	0.0036	0.0007	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
36	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0017	0.0080	0.0282	0.0735	0.1418	0.2030	0.2153	0.1693	0.0987	0.0426	0.0137	0.0032	0.0006	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
37	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0015	0.0074	0.0269	0.0720	0.1419	0.2054	0.2185	0.1707	0.0980	0.0413	0.0128	0.0029	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0013	0.0067	0.0255	0.0706	0.1420	0.2079	0.2217	0.1720	0.0972	0.0399	0.0119	0.0026	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
39	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0011	0.0061	0.0242	0.0690	0.1420	0.2105	0.2250	0.1733	0.0962	0.0385	0.0111	0.0023	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0055	0.0229	0.0674	0.1420	0.2132	0.2284	0.1746	0.0952	0.0370	0.0103	0.0020	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 5.9. Age-specific schedules for Dover sole in the Gulf of Alaska. Maturity ogive is based on Abookire and Macewicz (2003).

	Length (cm)		Weight (kg)		Maturity
Age	Males	Females	Males	Females	ogive
3	26.3	26.4	0.16	0.16	0
4	29.2	29.4	0.22	0.21	0.0001
5	31.5	32.0	0.31	0.32	0.0006
6	33.5	34.4	0.38	0.42	0.0027
7	35.0	36.4	0.44	0.51	0.0094
8	36.3	38.2	0.49	0.60	0.0281
9	37.4	39.8	0.53	0.68	0.0719
10	38.3	41.2	0.57	0.75	0.1556
11	39.0	42.4	0.61	0.82	0.2834
12	39.6	43.5	0.63	0.88	0.4366
13	40.1	44.5	0.66	0.94	0.5836
14	40.5	45.3	0.68	0.99	0.7026
15	40.9	46.0	0.70	1.04	0.7891
16	41.1	46.7	0.71	1.08	0.8487
17	41.4	47.3	0.72	1.12	0.8891
18	41.6	47.8	0.74	1.16	0.9165
19	41.7	48.2	0.74	1.19	0.9354
20	41.8	48.6	0.75	1.23	0.9487
21	41.9	49.0	0.76	1.25	0.9582
22	42.0	49.3	0.77	1.28	0.9652
23	42.1	49.5	0.77	1.31	0.9703
24	42.2	49.8	0.78	1.33	0.9743
25	42.2	50.0	0.78	1.35	0.9773
26	42.2	50.2	0.78	1.37	0.9797
27	42.3	50.3	0.79	1.39	0.9816
28	42.3	50.5	0.79	1.40	0.9832
29	42.3	50.6	0.79	1.42	0.9844
30	42.3	50.7	0.79	1.43	0.9854
31	42.4	50.8	0.79	1.44	0.9863
32	42.4	50.9	0.79	1.46	0.987
33	42.4	51.0	0.80	1.47	0.9876
34	42.4	51.0	0.80	1.48	0.9881
35	42.4	51.1	0.80	1.49	0.9885
36	42.4	51.1	0.80	1.49	0.9888
37	42.4	51.2	0.80	1.50	0.9892
38	42.4	51.2	0.80	1.51	0.9894
39	42.4	51.3	0.80	1.51	0.9896
40	42.4	51.3	0.80	1.52	0.9898

Table 5.10. Alternative models evaluated in this assessment.

Model	Selectivity Models				# of parameters
	Fishery		Surveys		
	Type	Male Scaling?	Type	Male Scaling?	
Base	logistic	fixed	logistic	fixed	103
LogS-LogS	logistic	estimated	logistic	estimated	106
FF-FF	freeform	fixed	freeform	fixed	319
FF-Log	freeform	fixed	logistic	fixed	175
Log-FF	logistic	fixed	freeform	fixed	247
DN-DN	double normal	fixed	double normal	fixed	127
DN-Log	double normal	fixed	logistic	fixed	111

Table 5.11. Likelihood component multipliers for all Dover sole models.

Fishery		Survey			Recruitment		
catch	size compositions	biomass	size compositions	age compositions	early	ordinary	late
30	0.5	1	0.5	1	2	1	3

Table 5.12. Initial parameter values for the models.
a) Recruitment and fishing mortality parameters.

$\overline{\ln R_0}$			recruitment deviations			$\overline{\ln F}$			fishing mortality deviations		
value	min	max	value	min	max	value	min	max	value	min	max
17	10	20	0	-15	15	-4	-5	5	0	-5	5

b) Logistic selectivity parameters.

slope			A_{50}		
value	min	max	value	min	max
0.5	0.1	25	5	1	40

c) Double normal selectivity parameters.

Ascending limb									Descending limb								
peak location			width			scale			peak offset			width			scale		
value	min	max	value	min	max	value	min	max	value	min	max	value	min	max	value	min	max
10	4	40	2	-1	7	-2	-5	5	2	-5	5	0	-1	7	0	-5	-5

Table 5.13. Summary of results for the various models.

Model	# of parameters	Likelihood components					Hessian OK?	Parameters at Bounds
		Fishery Size Comps	Survey Biomass	Survey Size Comps	Survey Age Comps	Total		
Base	103	671.669	45.3636	83.1795	307.227	813.55	yes	logistic slopes
LogS-LogS	106	608.35	25.0923	86.5822	317.078	766.14	yes	logistic slopes
FF-FF	319	609.724	9.35898	82.2354	256.518	716.2	no	none
FF-Log	175	647.141	44.7074	81.821	300.687	812.25	no	logistic slopes
Log-FF	247	648.586	9.64692	81.9807	251.362	717.49	no	logistic slopes
DN-DN	127	573.434	22.8387	96.222	284.764	726.32	yes	double normal params
DN-Log	111	613.915	24.9209	88.2125	298.272	752.04	yes	double normal params, logistic slopes

Table 5.14. Final parameter estimates for the preferred (base) model.

Recruitment										
$\overline{\ln R_0}$	15.774864									
$\boldsymbol{t_t}$						1947-2009:	-0.710901	-0.05685	-0.066503	-0.076695
	-0.0654366	-0.0746939	-0.084343	-0.094355	-0.1047512	0.0147523	0.2314676	0.110113	0.0124236	0.201724
	0.1422903	0.36974828	0.6379375	0.6161802	0.2576456	0.8419644	0.704338	-0.016333	0.5844379	0.6886519
	0.297517	0.58753229	0.0685965	0.0066675	0.255652	0.0340721	-0.087078	0.298877	0.4123947	0.5659956
	0.7150502	0.46649822	0.0430759	0.1972539	0.2059367	0.124119	-0.078489	-0.406846	-0.452547	-0.623927
	-0.6337	-0.8940	-0.8008	-0.5843	-0.8498	-0.6686	-0.2714	-0.1815	-0.3391	-0.1318
	0.0078	0.4755	0.0660	-0.6081	-0.3102	-0.5063	-0.4150	-0.0377	-0.0100	
Fishing mortality										
$\overline{\ln F}$	-4.5178159									
$\boldsymbol{e_t}$	1984-2009:			-2.018797	-3.0955314	-3.695799	-2.83101	0.002763	0.3047583	0.7046848
	1.9806	1.9228	1.2786	1.1289	0.8004	0.8662	1.3777	0.9940	1.0697	0.3167
	0.1839	-0.1290	0.4171	0.1445	-0.3201	-0.3479	-0.6419	0.0027	-0.4158	
Fishery Selectivity										
	females	**males**								
slope	24.9872	24.9922								
$\mathbf{A_{50}}$	12.5	10.5								
Survey Selectivity										
	"Full Coverage" Surveys			**"Shallow" Surveys**						
	females	**males**		**females**	**males**					
slope	0.1000	1.1233		0.2497	2.2378					
$\mathbf{A_{50}}$	10.0	4.5		6.9	3.7					

Table 5.15. Model-estimated catch and survey biomass.

year	catch (t)			survey biomass (t)		
	estimated	std dev	observed	estimated	std dev	observed
1984	141	18	132	122,470	4,855	68,521
1985	48	6	43	123,190	4,635	
1986	26	3	23	123,540	4,436	
1987	61	8	56	123,500	4,276	63,394
1988	1,053	132	1,087	122,950	4,124	
1989	1,440	179	1,521	121,040	3,951	
1990	2,153	266	2,348	107,990	3,865	96,597
1991	7,466	865	9,741	114,410	3,585	
1992	6,613	776	8,364	105,630	3,335	
1993	3,283	397	3,804	89,259	3,150	85,549
1994	2,743	334	3,108	92,715	2,963	
1995	1,924	238	2,096	88,201	2,829	
1996	1,993	246	2,177	77,208	2,644	79,531
1997	3,171	385	3,652	81,012	2,607	
1998	2,035	251	2,230	76,740	2,502	
1999	2,081	258	2,270	73,833	2,431	74,245
2000	929	117	961	71,333	2,379	
2001	781	98	800	32,669	1,149	32,424
2002	549	69	554	69,887	2,307	
2003	908	114	936	70,059	2,312	99,297
2004	668	84	679	70,163	2,345	
2005	410	52	407	70,556	2,391	80,538
2006	393	50	390	70,740	2,470	
2007	292	37	286	70,641	2,589	71,624
2008	560	71	561	70,583	2,725	
2009	370	47	365	70,321	2,854	76,277

Table 5.16. Estimated age 3+ population biomass and female spawning biomass.

year	Age 3+ Biomass (1000's t)						Female Spawning Stock Biomass (1000's t)					
	2009 Assessment		2007 Assessment		2005 Assessment		2009 Assessment		2007 Assessment		2005 Assessment	
	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
1984	157	5	172	7	172	8	58	2	60	3	58	3
1985	157	5	172	7	172	8	58	2	61	3	59	3
1986	157	5	173	7	173	7	58	2	62	3	60	3
1987	156	4	173	7	173	7	58	2	63	3	62	3
1988	154	4	172	7	172	7	58	2	64	3	63	3
1989	151	4	169	7	169	7	58	2	64	3	64	3
1990	146	4	165	6	166	7	58	2	64	3	64	3
1991	141	4	160	6	161	7	58	2	64	3	64	3
1992	130	4	148	6	149	7	54	2	60	3	60	3
1993	120	4	138	6	139	7	51	2	57	3	57	3
1994	113	4	133	6	133	6	49	2	55	2	56	3
1995	108	3	127	6	127	6	48	2	54	2	54	3
1996	103	3	123	6	123	6	47	2	53	2	53	3
1997	99	3	120	6	121	6	45	2	52	2	52	3
1998	94	3	117	6	118	6	43	1	50	2	50	3
1999	91	3	115	6	116	7	41	1	48	2	48	3
2000	88	3	115	6	116	7	39	1	46	2	46	3
2001	87	3	117	7	115	7	37	1	45	2	45	3
2002	89	3	122	8	121	9	36	1	44	2	44	2
2003	89	4	126	8	124	9	35	1	43	2	43	2
2004	89	4	128	9	127	10	34	1	42	2	42	2
2005	89	4	129	9	130	11	33	1	42	2	42	2
2006	89	5	131	10			32	1	42	2		
2007	89	5	132	10			32	1	42	2		
2008	89	5					32	1				
2009	90	5					32	1				

Table 5.17. Estimated age 3 recruitment.

Year	2009 Assessment		2007 Assessment		2005 Assessment	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1984	17.3	2.4	22.7	4.0	23.5	4.2
1985	17.4	2.4	17.4	3.3	17.1	3.3
1986	16.1	2.2	22.8	3.5	21.7	3.6
1987	13.1	1.9	17.3	2.7	17.2	2.8
1988	9.4	1.5	12.2	2.2	12.7	2.4
1989	9.0	1.4	11.5	2.0	10.4	2.0
1990	7.6	1.3	9.9	1.8	10.4	2.0
1991	7.5	1.2	10.6	1.9	10.6	2.1
1992	5.8	1.1	8.3	1.7	7.2	1.7
1993	6.4	1.1	9.1	1.8	8.5	2.0
1994	7.9	1.3	13.2	2.5	13.8	3.0
1995	6.1	1.1	9.5	2.0	7.0	2.0
1996	7.3	1.3	11.8	2.3	13.0	3.0
1997	10.8	1.7	17.3	3.1	23.1	4.6
1998	11.8	1.7	19.0	3.3	21.2	4.5
1999	10.1	1.6	16.2	3.1	15.0	4.0
2000	12.4	2.0	26.8	5.1	19.2	6.7
2001	14.3	2.4	24.0	4.9	12.8	5.8
2002	22.8	3.5	43.6	7.8	45.4	29.9
2003	15.2	2.8	22.6	5.0	30.1	13.3
2004	7.7	2.1	9.0	3.4	17.6	7.0
2005	10.4	2.7	12.3	3.5	17.3	6.5
2006	8.6	3.1	15.7	5.9		
2007	9.4	2.8	16.1	5.8		
2008	13.7	5.1				
2009	14.0	5.2				

Table 5.18. 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**
2009	379	379	379	379	379	379	379
2010	6,007	6,007	3,091	423	0	7,436	6,007
2011	5,555	5,555	3,016	432	0	6,691	5,555
2012	5,244	5,244	2,982	445	0	6,171	6,492
2013	4,871	4,871	2,894	449	0	5,610	5,868
2014	4,372	4,372	2,719	440	0	4,924	5,131
2015	4,025	4,025	2,598	436	0	4,455	4,621
2016	3,767	3,767	2,507	434	0	4,115	4,248
2017	3,578	3,578	2,440	434	0	3,871	3,977
2018	3,469	3,469	2,405	437	0	3,736	3,821
2019	3,391	3,391	2,380	440	0	3,642	3,709
2020	3,271	3,271	2,330	440	0	3,494	3,551
2021	3,172	3,172	2,286	439	0	3,350	3,405
2022	3,088	3,088	2,246	439	0	3,218	3,264

Table 5.19. Female spawning biomass (t) for the seven projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 14,249 t and 12,468 t, respectively.

	Female spawning biomass (t)						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2009	31,831	31,831	31,831	31,831	31,831	31,831	31,831
2010	32,218	32,218	32,218	32,218	32,218	32,218	32,218
2011	29,774	29,774	31,283	32,664	32,883	29,035	29,774
2012	27,655	27,655	30,392	33,036	33,467	26,371	27,655
2013	25,585	25,585	29,381	33,235	33,880	23,874	24,927
2014	23,635	23,635	28,305	33,280	34,133	21,611	22,468
2015	21,964	21,964	27,293	33,248	34,296	19,745	20,439
2016	20,589	20,589	26,406	33,217	34,446	18,257	18,817
2017	19,537	19,537	25,688	33,229	34,623	17,160	17,611
2018	18,749	18,749	25,117	33,276	34,820	16,374	16,736
2019	18,092	18,092	24,616	33,323	35,008	15,734	16,024
2020	17,502	17,502	24,147	33,350	35,168	15,166	15,398
2021	16,992	16,992	23,714	33,354	35,296	14,689	14,873
2022	16,552	16,552	23,315	33,337	35,394	14,303	14,444

Table 5.20. Fishing mortality for the seven projection scenarios.

	Fishing mortality						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2009	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074
2010	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1186
2011	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1186
2012	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2013	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2014	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2015	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2016	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2017	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2018	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2019	0.1186	0.1186	0.0593	0.0079	0.0000	0.1489	0.1489
2020	0.1186	0.1186	0.0593	0.0079	0.0000	0.1488	0.1489
2021	0.1186	0.1186	0.0593	0.0079	0.0000	0.1473	0.1479
2022	0.1186	0.1186	0.0593	0.0079	0.0000	0.1451	0.1458

Table 5.21. Prohibited species catch (PSC) in the deep-water flatfish target fishery.

year	Halibut (kg)	Salmon (#'s) Chinook	non-Chinook	Total	Crab (#'s) Opilio Tanner	Bairdi Tanner	Red King	Blue King	Golden King	Total
2003	34,519	0	0	0	0	0	0	0	0	0
2004	101,460	0	2	2	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0
2007	593	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0

Table 5.22. Catch of non-prohibited species in the deepwater flatfish target fishery.

	2009		2008		2007		2006	
species	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**
arrowtooth flounder	4	100%	8	100%	2	33%	1	84%
deep water flatfish	18	100%	110	100%	4	47%	66	100%
flathead sole	0	0%	0	0%	0	0%	0	0%
longnose skate	0	0%	0	100%	0	0%	0	0%
northern rockfish	0	0%	0	0%	0	0%	1	100%
all sharks, squid, sculpin, octopus	0	0%	0	100%	0	0%	0	0%
Pacific cod	0	0%	0	0%	0	0%	1	100%
pelagic rockfish complex	0	0%	0	0%	0	0%	1	100%
pollock	0	0%	0	100%	0	0%	0	0%
rex sole	0	100%	2	100%	0	3%	0	0%
rougheye	0	100%	0	100%	0	100%	0	0%
sablefish	1	100%	8	100%	15	1%	3	100%
shallow water flatfish	0	0%	0	0%	0	0%	2	100%
shortraker	0	100%	0	100%	0	0%	0	0%
thornyheads	2	100%	9	100%	1	96%	5	100%

Figures

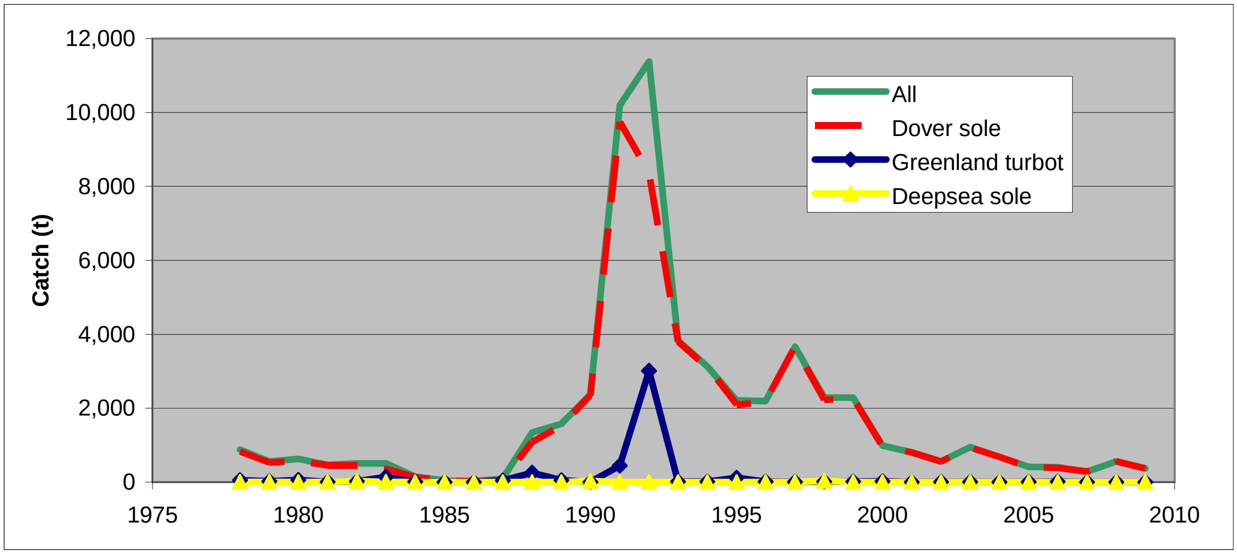


Figure 5.1. Fishery catches for GOA deepwater flatfish (Dover sole, Greenland turbot and deepsea sole), 1978-2009.

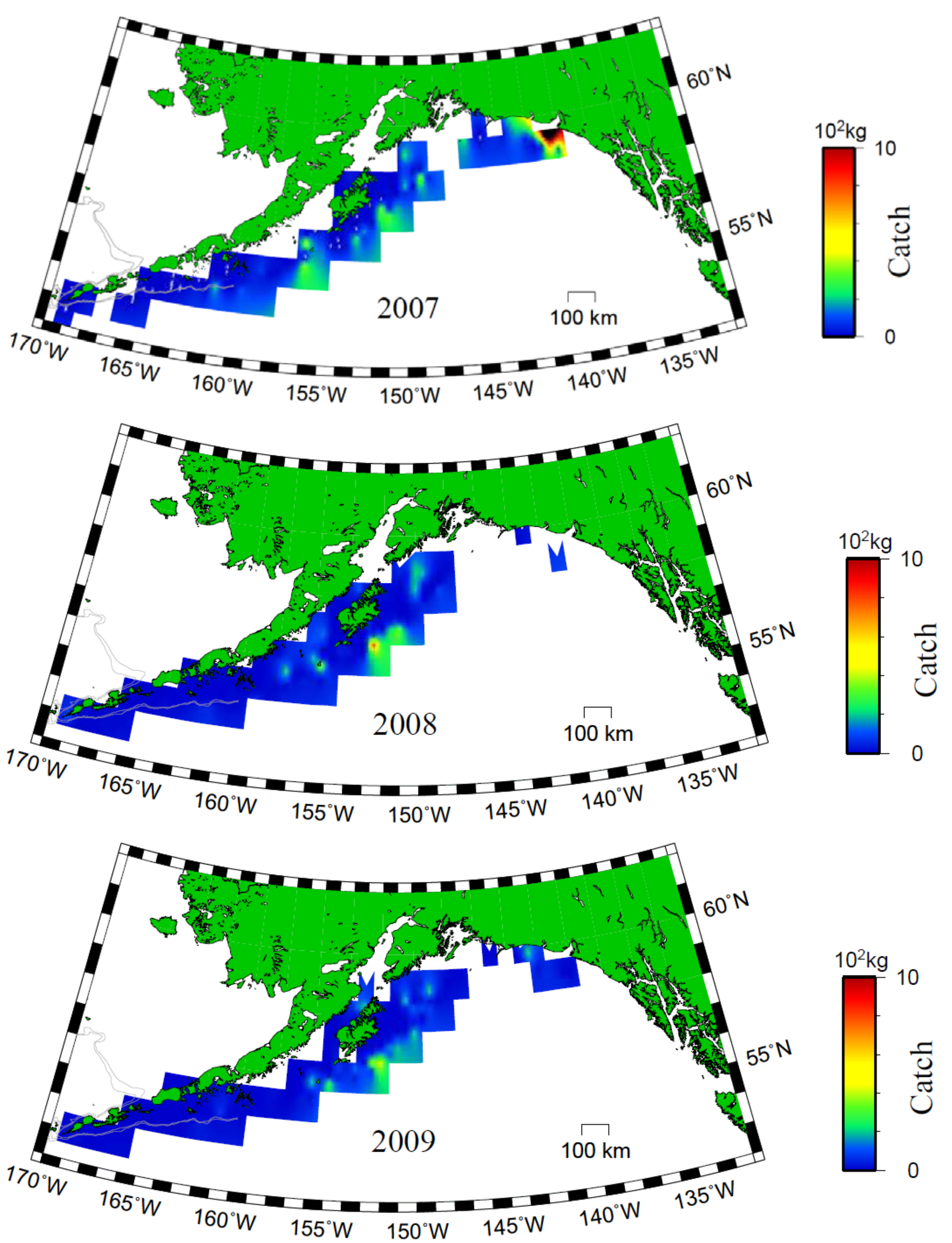


Figure 5.2. Spatial patterns of fishery catches for GOA Dover sole, 2007-2009.

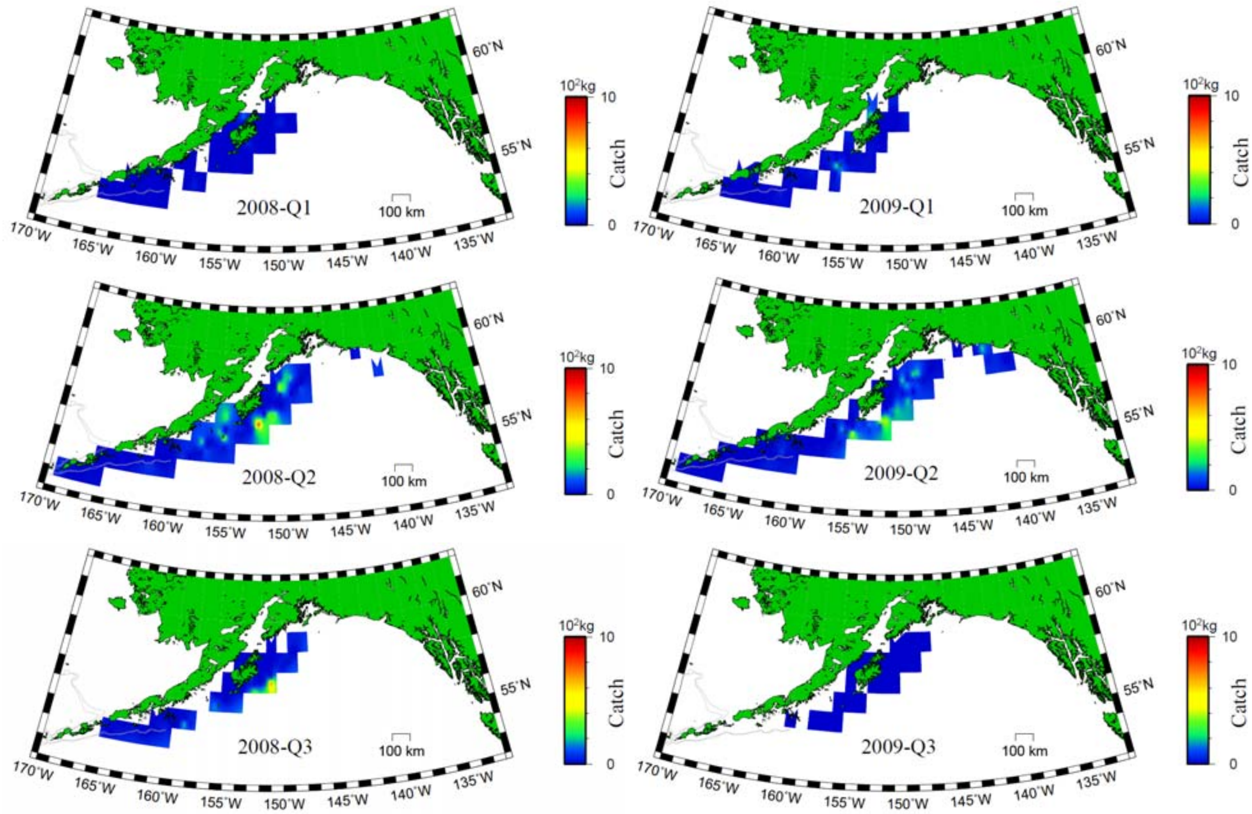


Figure 5.3. Spatial patterns of fishery catches for GOA Dover sole from the first three quarters of 2008 and 2009. Little to no Dover sole is caught in the fourth quarter.

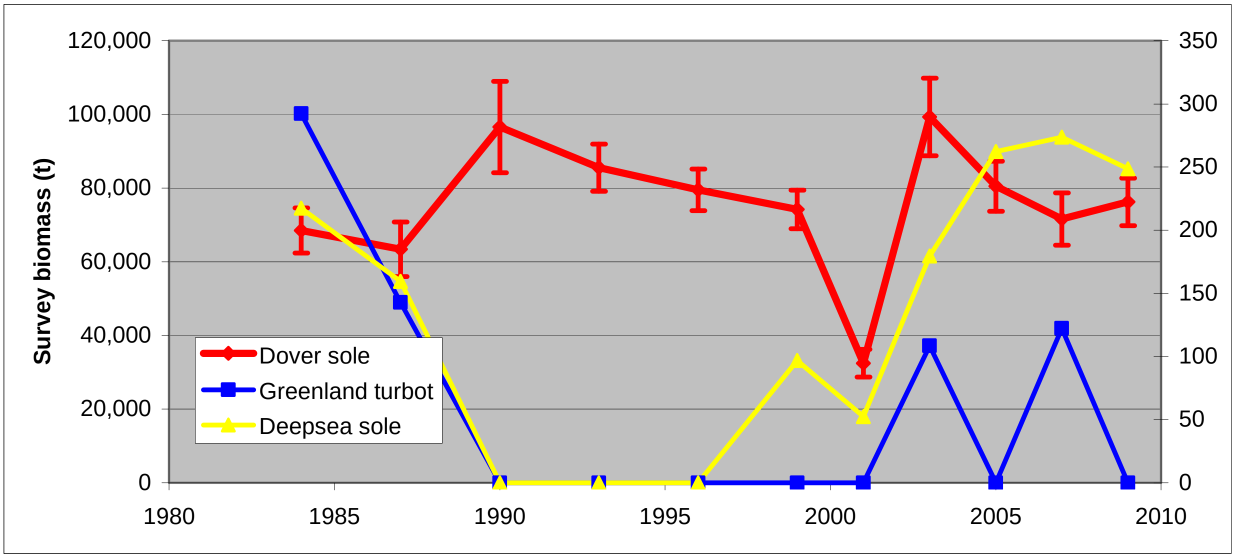


Figure 5.4. GOA survey biomass for the deepwater flatfish. Dover sole is plotted against the left-hand y-axis, while Greenland turbot and deepsea sole are plotted against the righthand y-axis. Error bars are ± 1 standard deviation (shown for Dover sole only). The 2001 GOA survey did not survey the Eastern Gulf. Survey coverage was limited to < 500 m in 1990, 1993, 1996, and 2001.

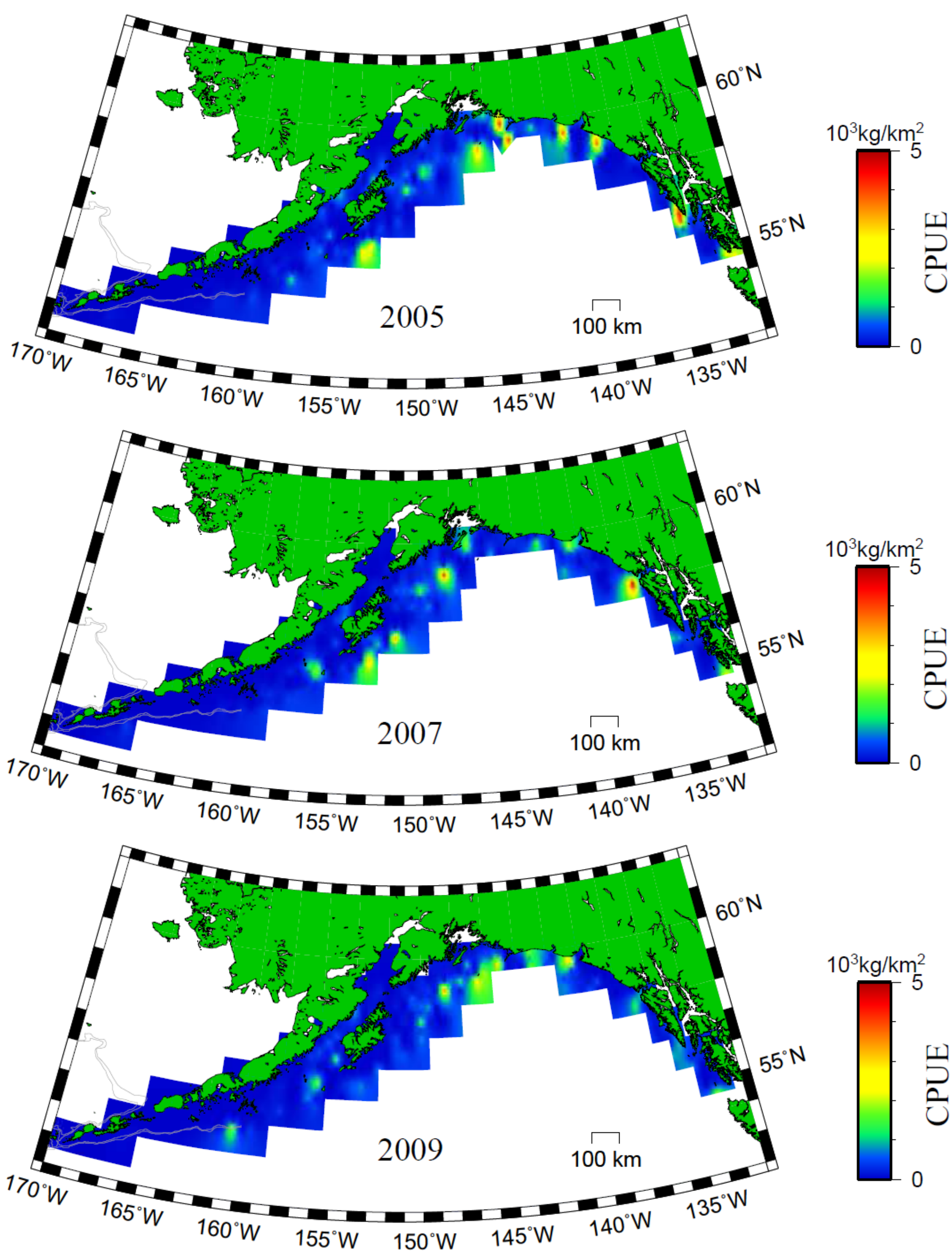
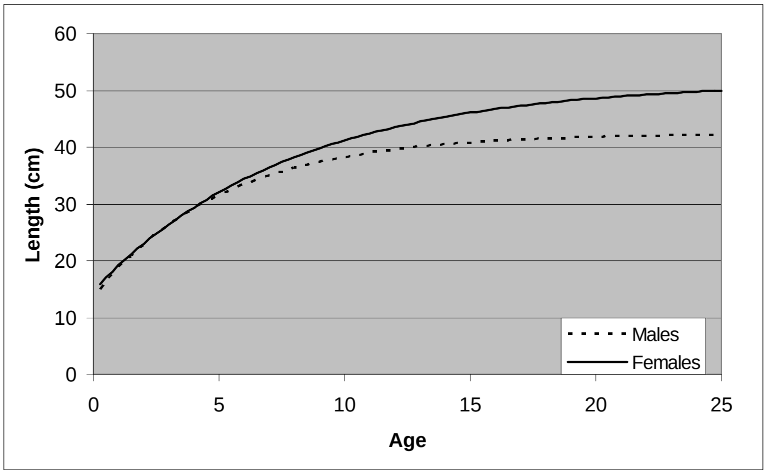
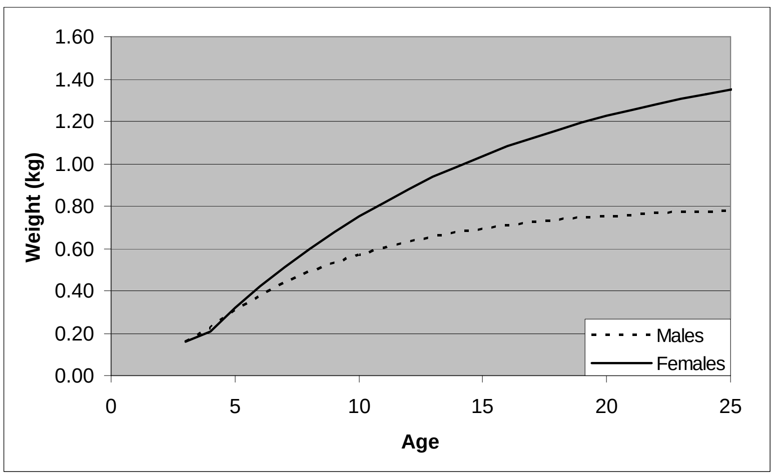


Figure 5.5. Spatial patterns of CPUE for Dover sole in the GOA groundfish surveys for 2005-2009.

a) Length-at-age.



b) Weight-at-age.



c) Maturity-at-age (females).

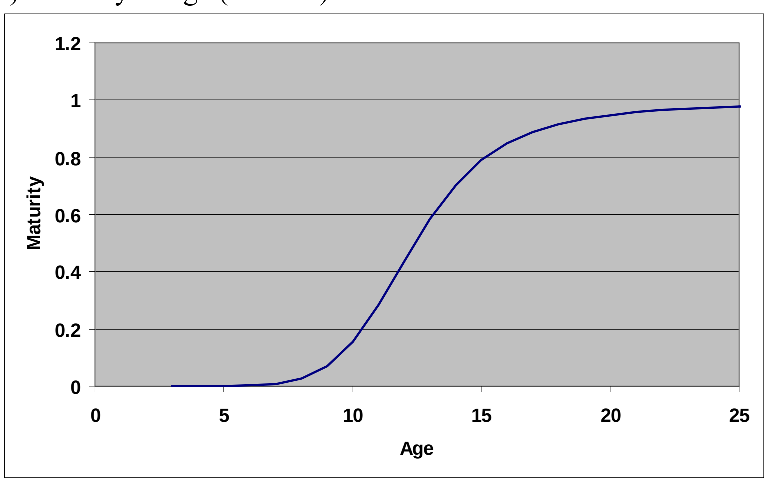
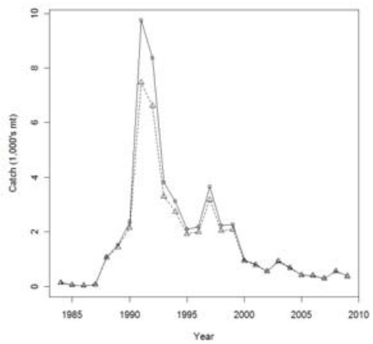
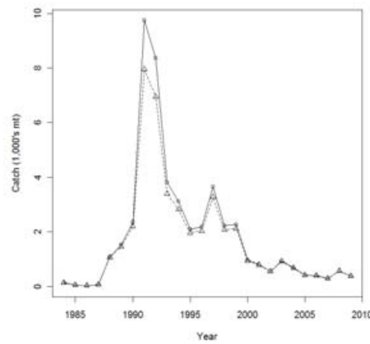


Figure 5.6. Age-specific schedules for GOA Dover sole: females solid line, males dotted line.

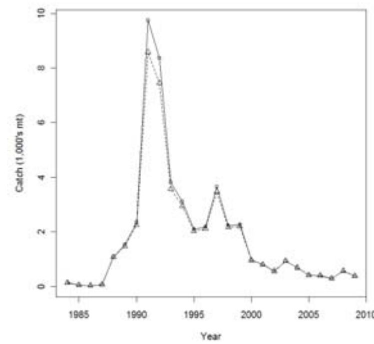
a) Base model.



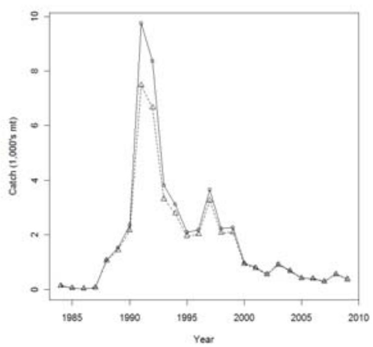
b) LogS-LogS model.



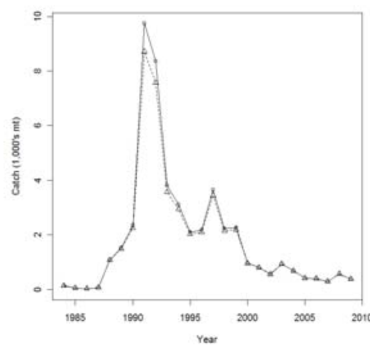
c) FF-FF model.



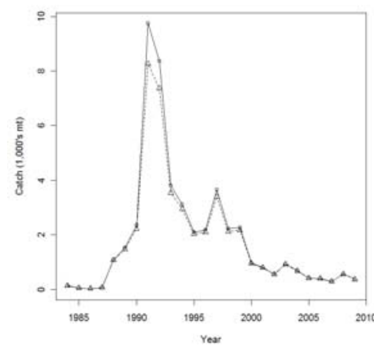
d) FF-Log model.



e) Log-FF model.



f) DN-DN model.



g) DN-Log model.

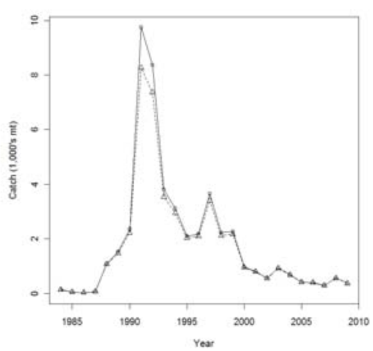
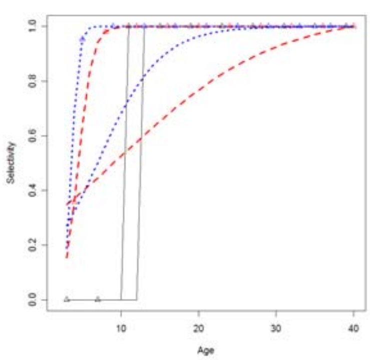
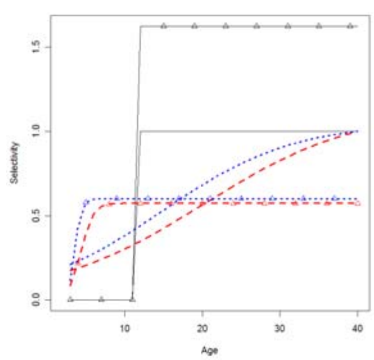


Figure 5.7. Estimated and observed annual catches for GOA Dover sole for the various models. Estimated catch = dotted line with circles, observed catch = solid line.

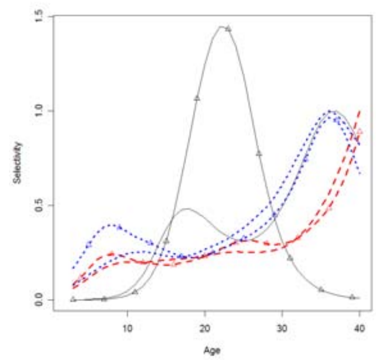
a) Base model.



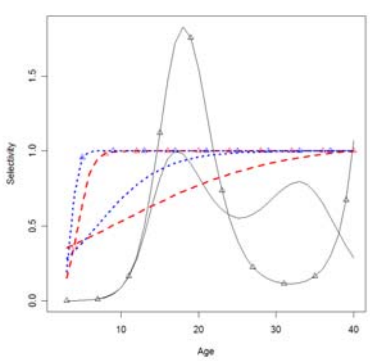
b) LogS-LogS model.



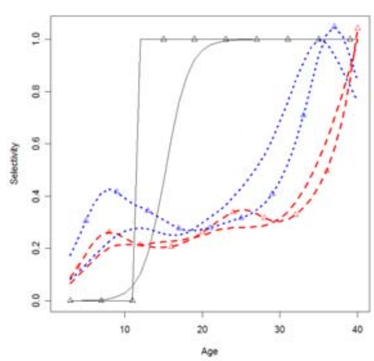
c) FF-FF model.



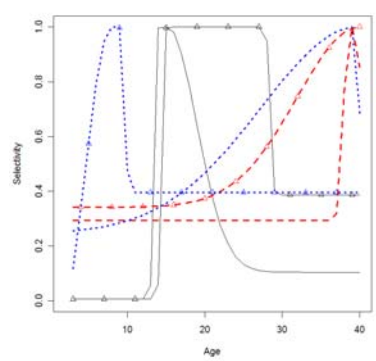
d) FF-Log model.



e) Log-FF model.



f) DN-DN model.



g) DN-Log model.

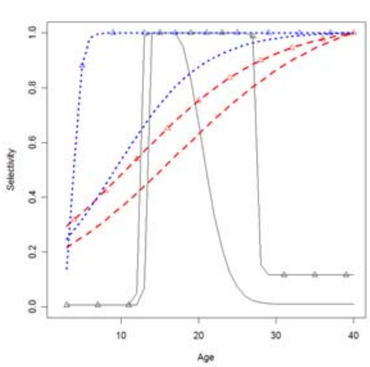
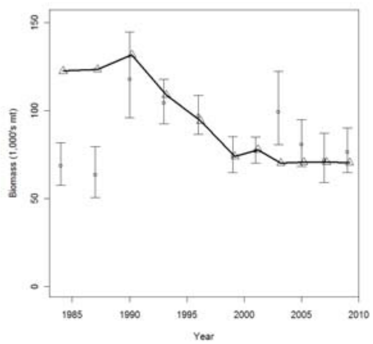
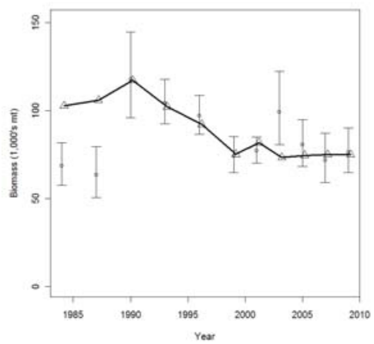


Figure 5.8. Model selectivities for GOA Dover sole for the various models. Red dashed line: “full coverage” surveys; blue dotted lines: “shallow” surveys; solid black line: fishery. Triangle symbol: males; no symbol: females. Note that y-axis scales differ among graphs.

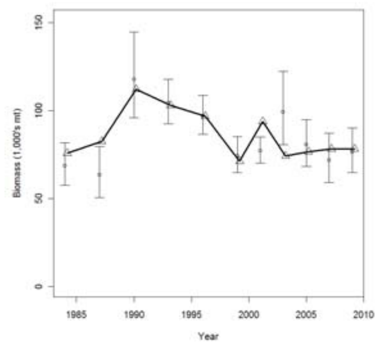
a) Base model.



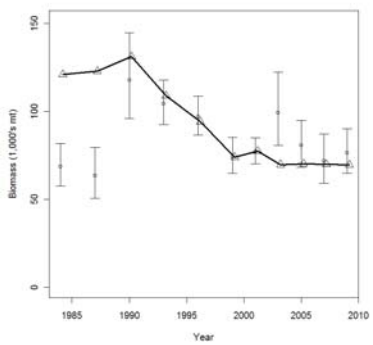
b) LogS-LogS model.



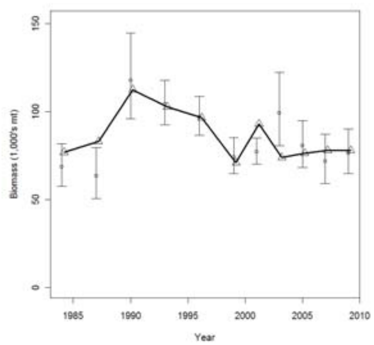
c) FF-FF model.



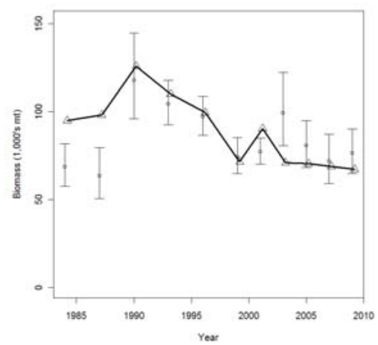
d) FF-Log model.



e) Log-FF model.



f) DN-DN model.



g) DN-Log model.

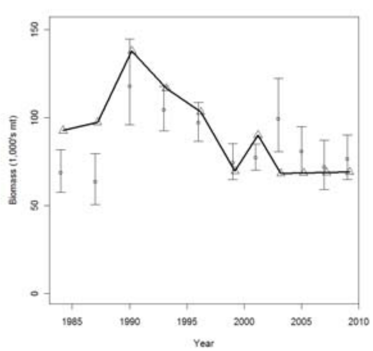
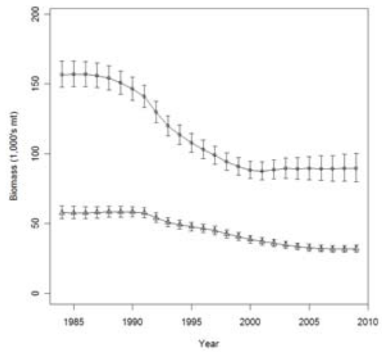
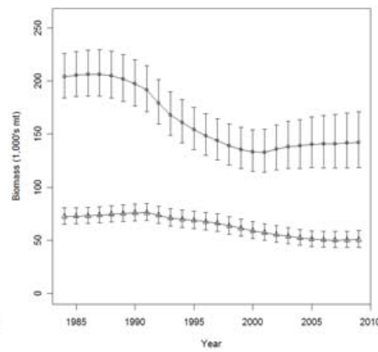


Fig. 5.9. Predicted and observed survey biomass for GOA Dover sole for the various models. Predicted survey biomass = triangles, observed survey biomass = circles (error bars are approximate lognormal 95% confidence intervals; survey estimates have been corrected for assumed differences in availability).

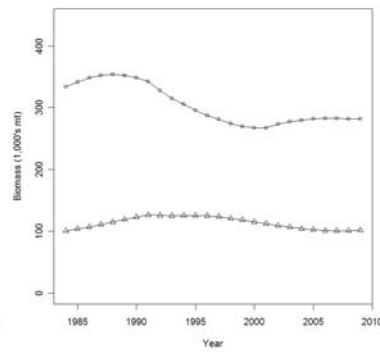
a) Base model.



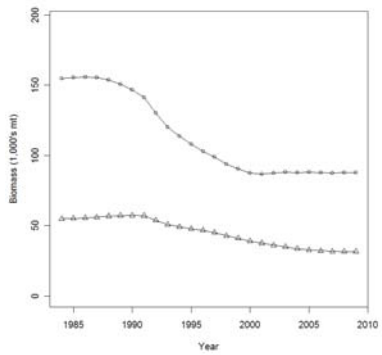
b) LogS-LogS model.



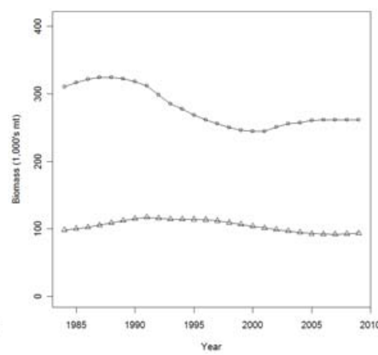
c) FF-FF model.



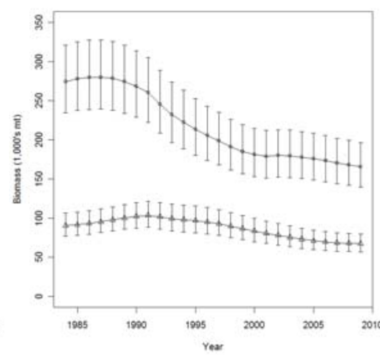
d) FF-Log model.



e) Log-FF model.



f) DN-DN model.



g) DN-Log model.

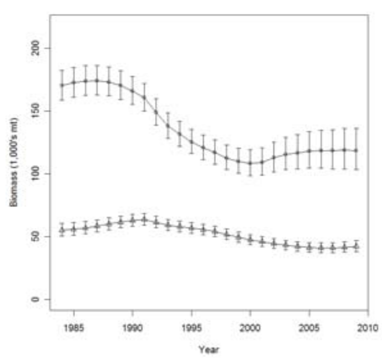
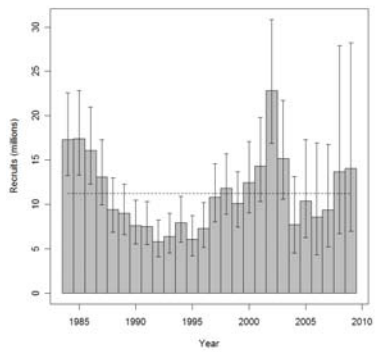
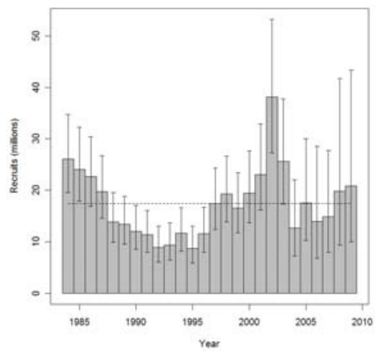


Fig. 5.10. Estimated population (age 3+) and female spawning biomass for GOA Dover sole for the various models. Upper curve: population biomass; lower curve: female spawning biomass. Error bars (where available) are 95% confidence intervals. Note that y-axis scales differ among graphs.

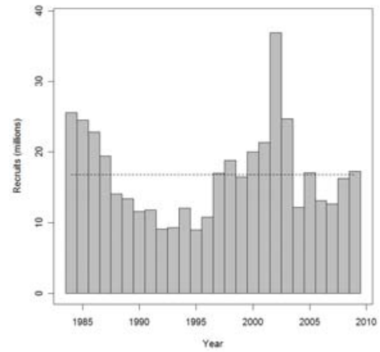
a) Base model.



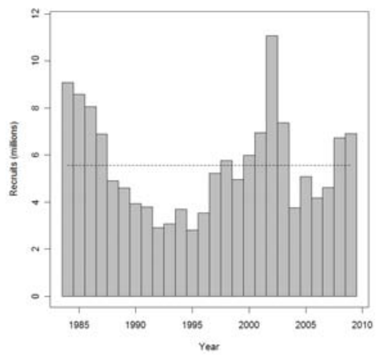
b) LogS-LogS model.



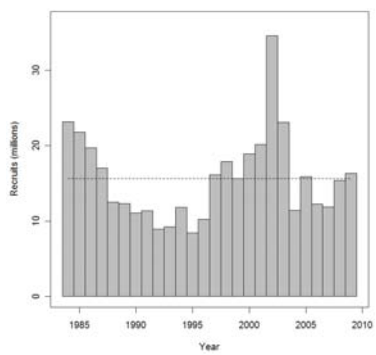
c) FF-FF model.



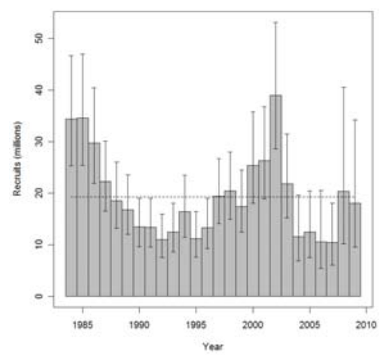
d) FF-Log model.



e) Log-FF model.



f) DN-DN model.



g) DN-Log model.

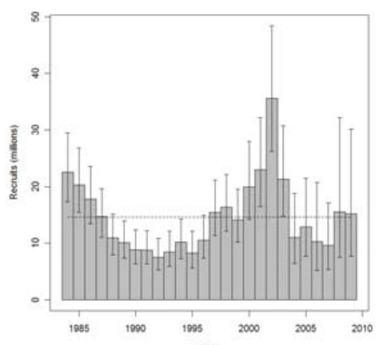


Fig. 5.11. Estimated age 3 recruitments of GOA Dover sole, with approximate 95% lognormal confidence intervals (where available), for the various models. The horizontal line is mean recruitment for each model. Note that y-axis scales differ among graphs.

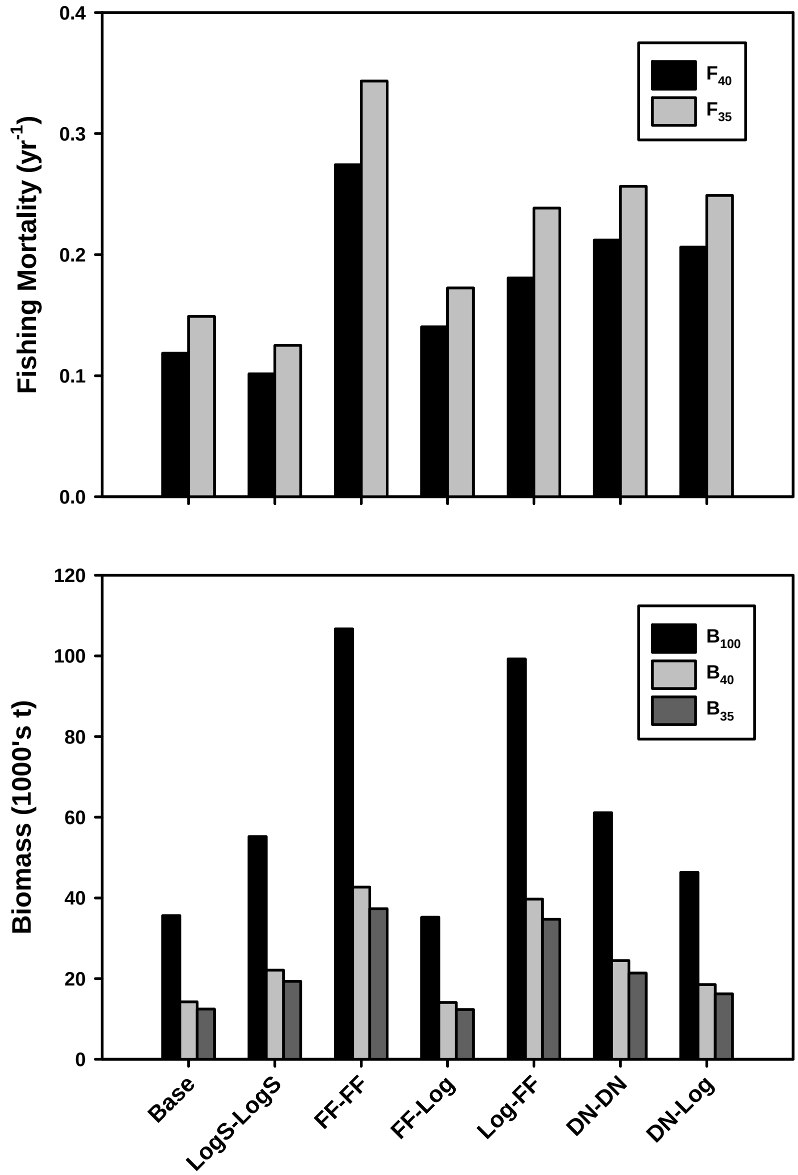


Fig. 5.12. Comparison of estimated reference points among models. Top graph: F_{40} and F_{35}; bottom graph: B_{100}, B_{40}, and B_{35}.

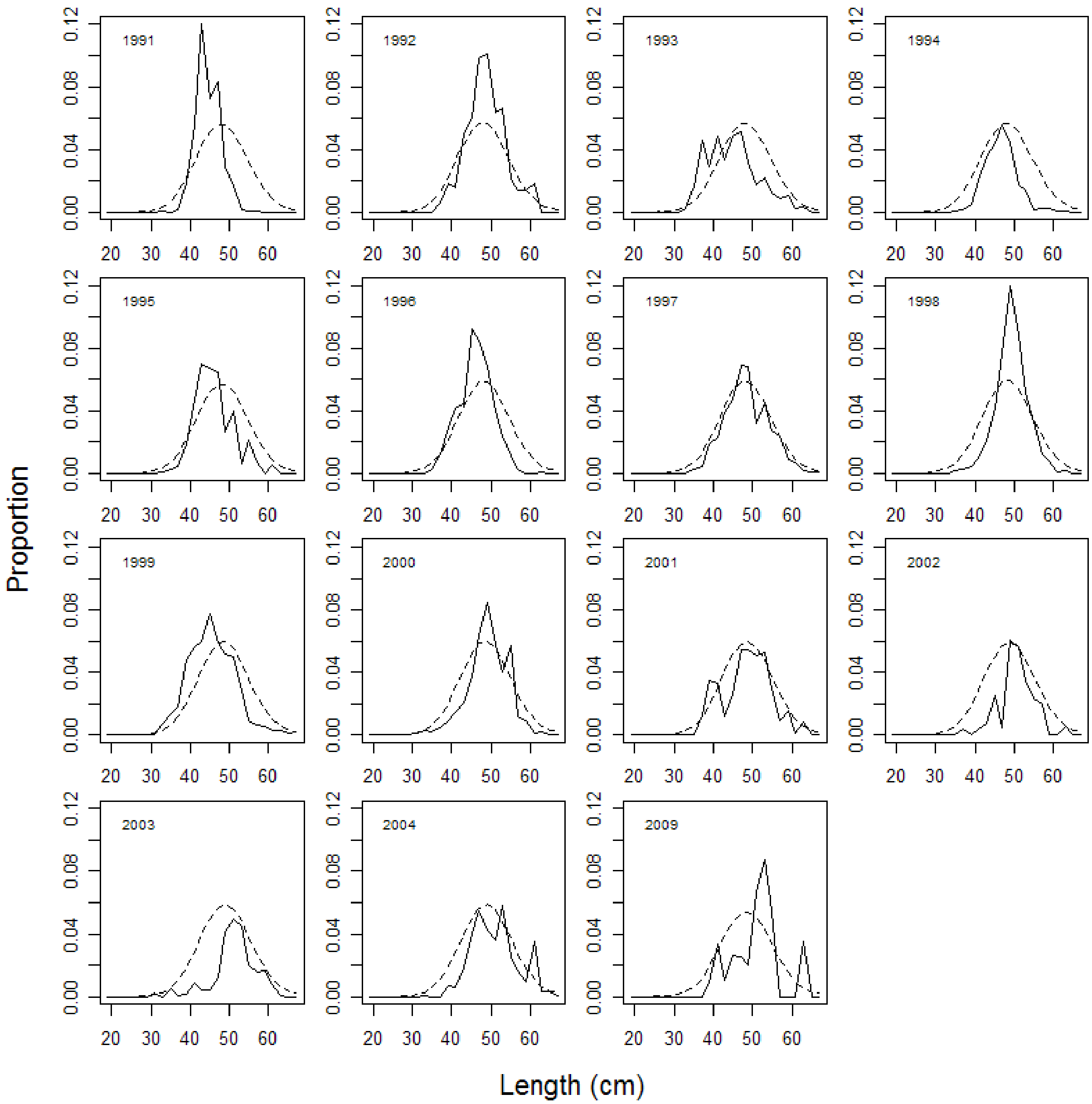


Figure 5.13a. Preferred (base) model fits to female GOA Dover sole fishery size composition data. Dashed lines represent the model estimate, solid lines represent the data.

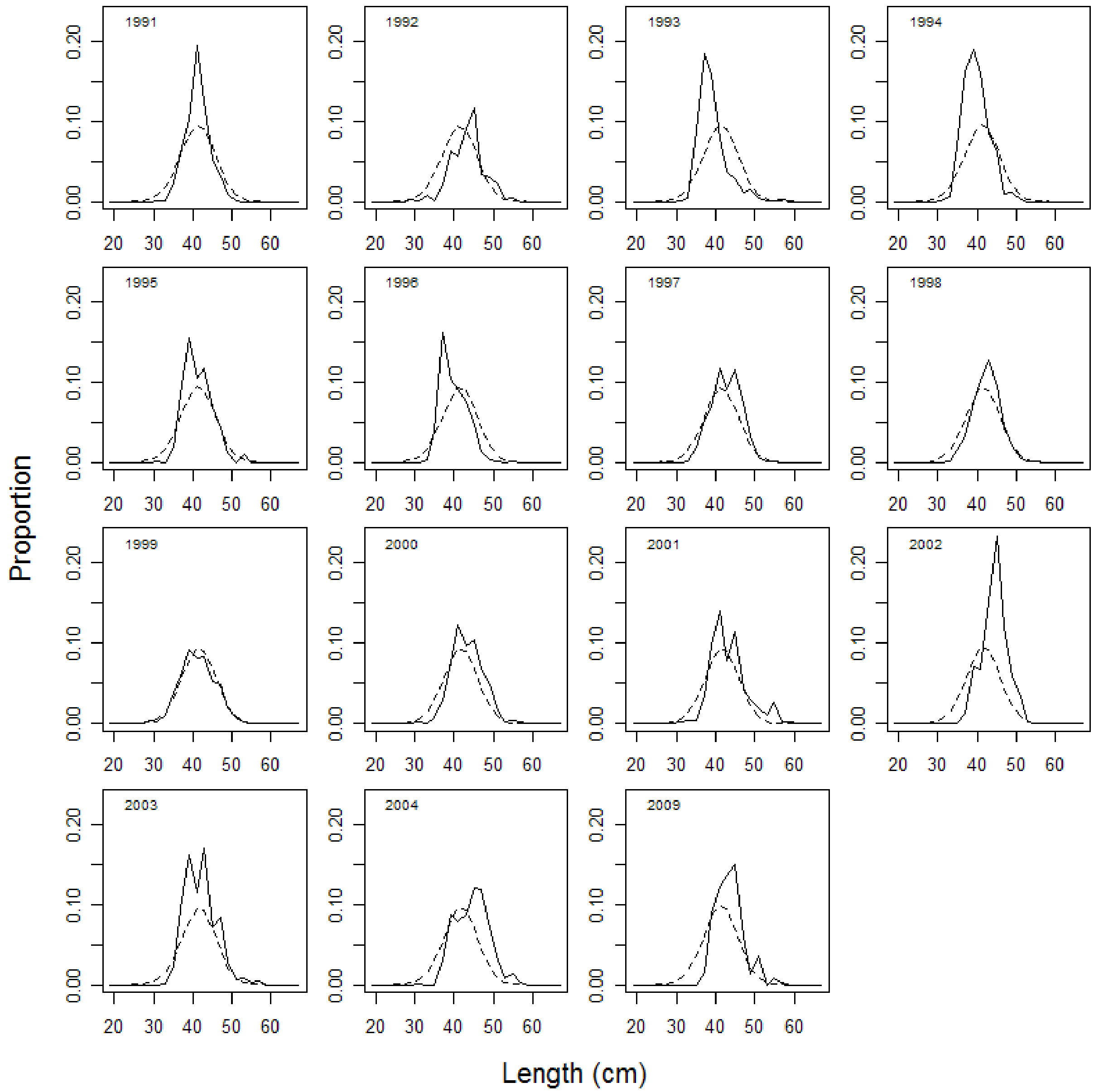


Figure 5.13b. Preferred (base) model fits to male GOA Dover sole fishery size composition data. Dashed lines represent the model estimate, solid lines represent the data.

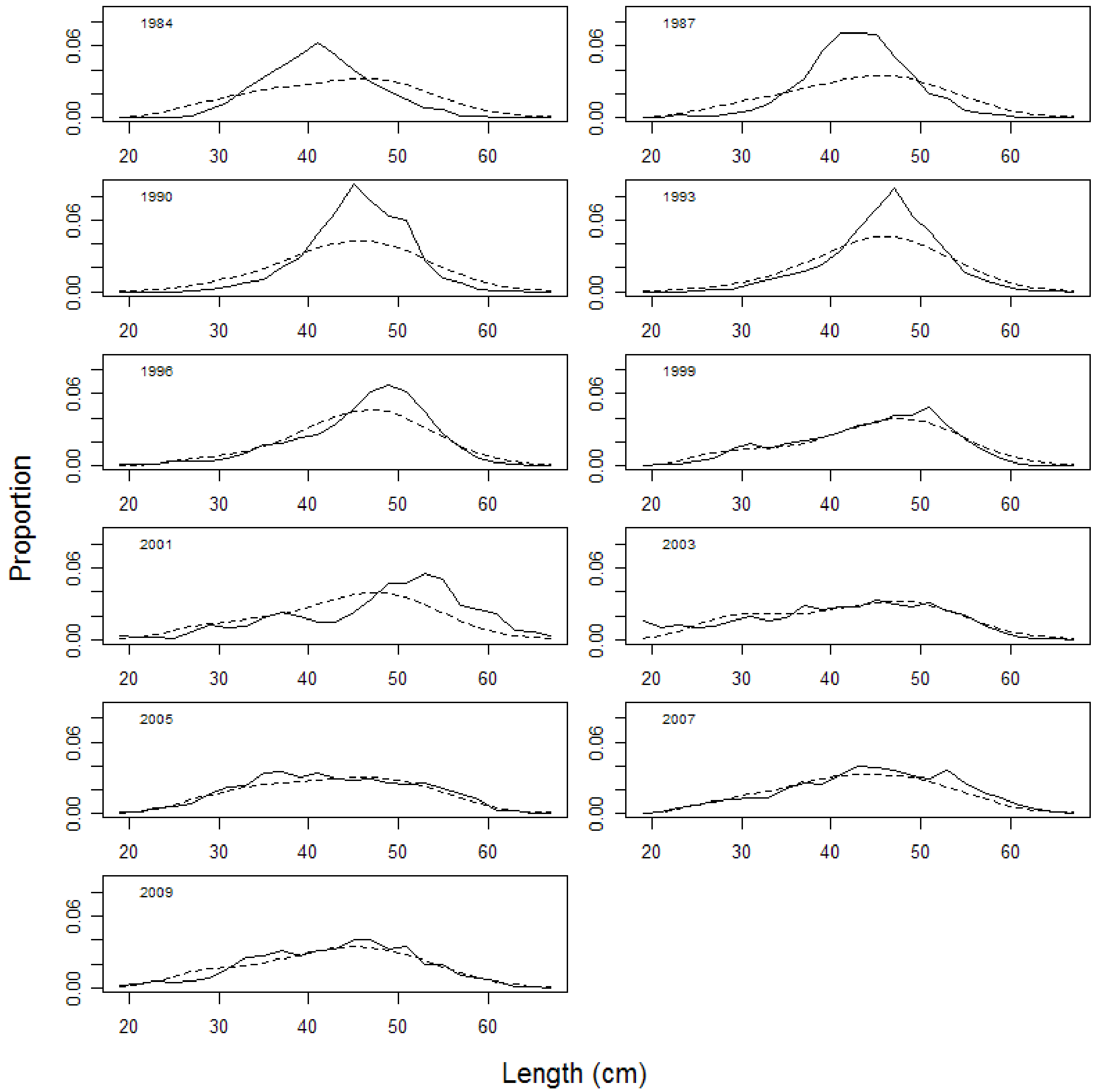


Figure 5.14a. Preferred (base) model fits to the female GOA Dover sole survey size composition data. Dashed lines represent the model estimates, solid lines represent the data.

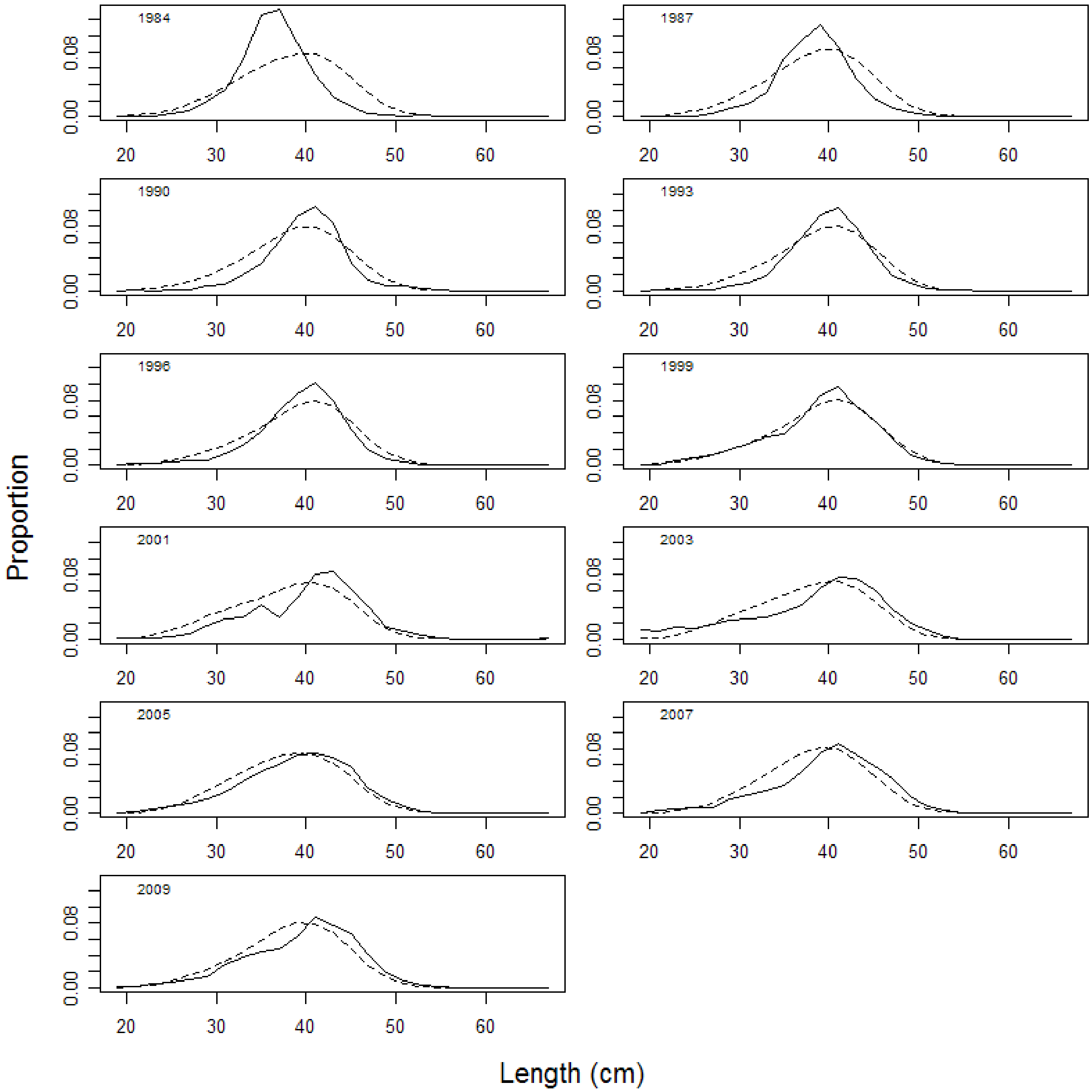


Figure 5.14b. Preferred (base) model fits to the male GOA Dover sole survey size composition data. Dashed lines represent the model estimates, solid lines represent the data.

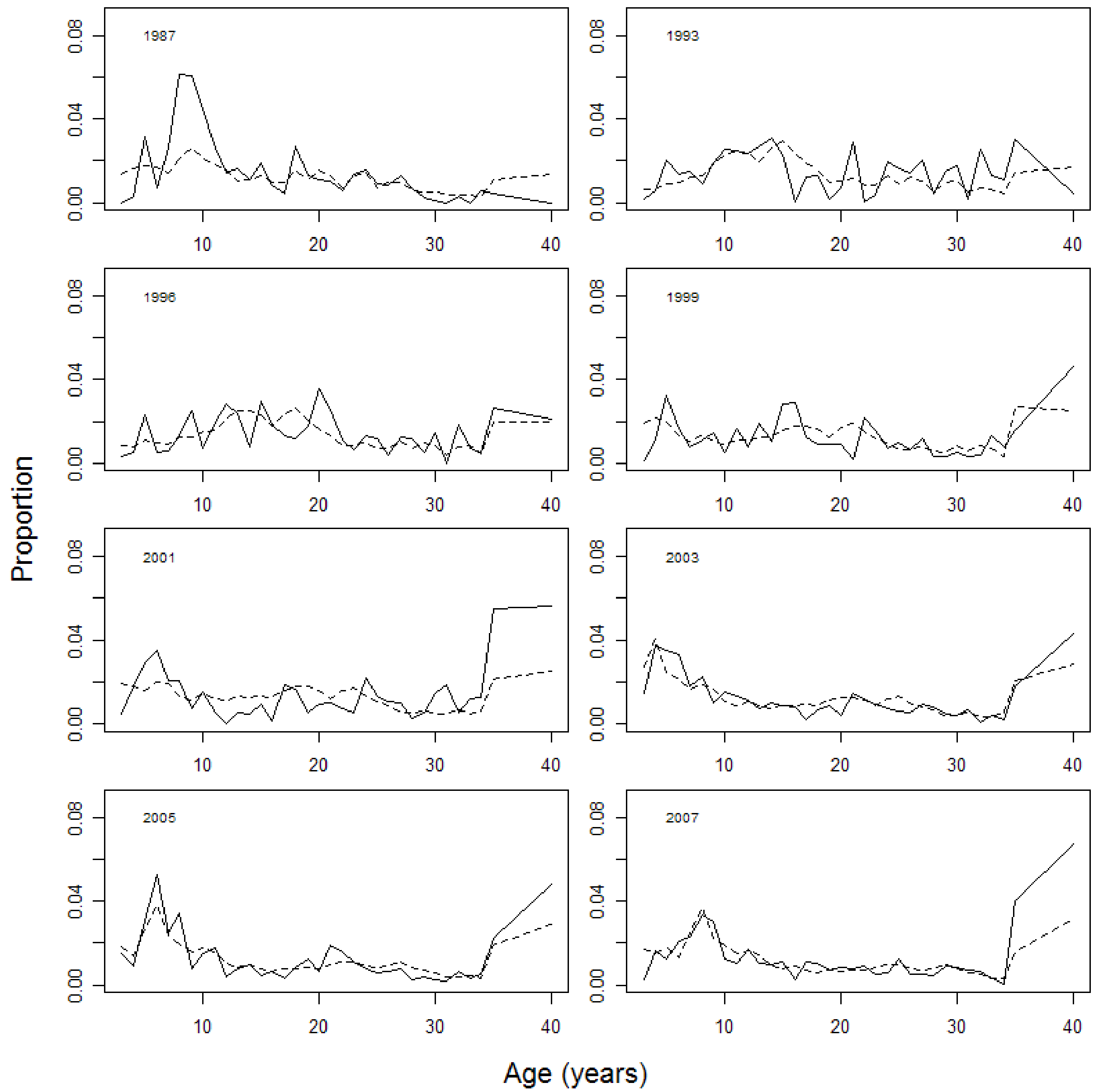


Figure 5.15a. Preferred (base) model fits to the female survey GOA Dover sole age composition data. Dashed lines represent the model estimates, solid lines represent the data.

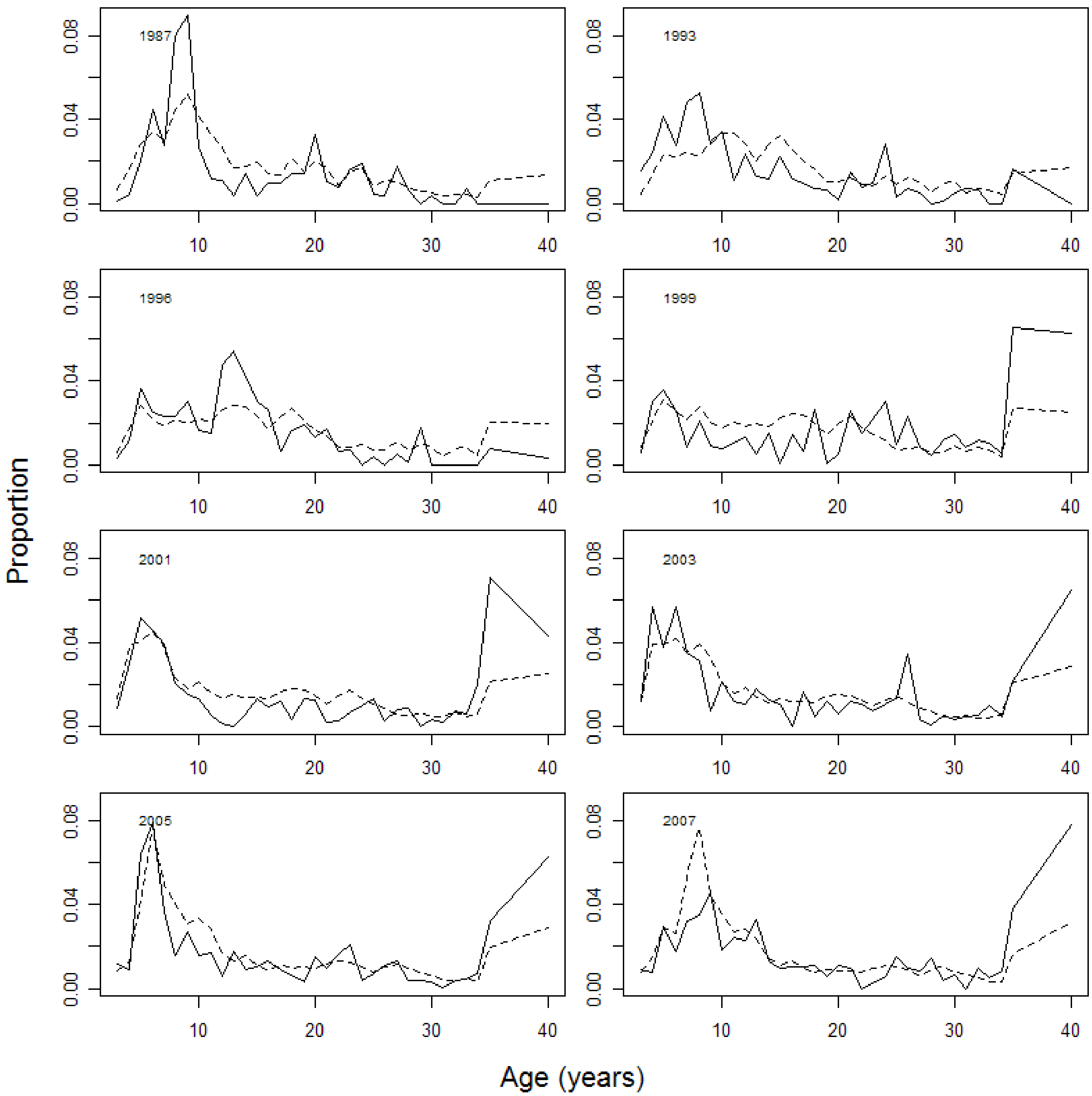


Figure 5.15b. Preferred (base) model fits to the male survey Dover sole age composition data. Dashed lines represent the model estimates, solid lines represent the data.

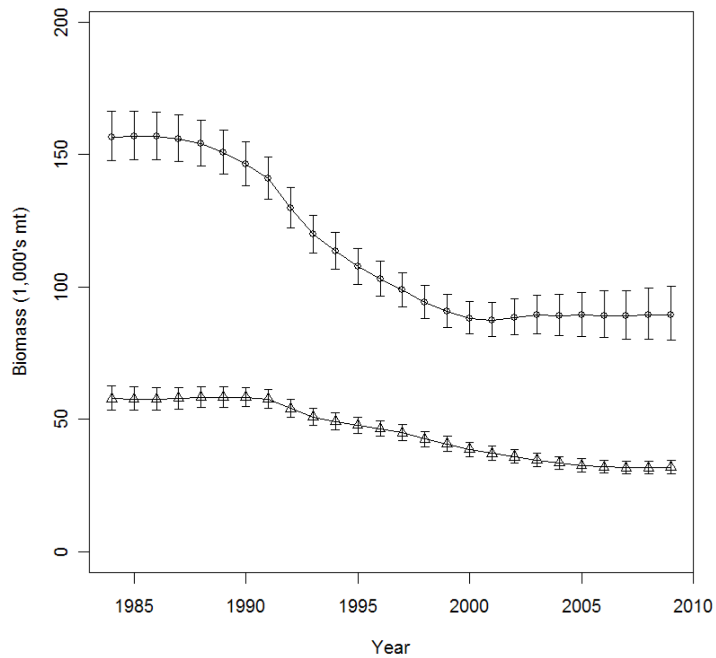


Figure 5.16a. Estimated age 3+ biomass (circles) and female spawning biomass (triangles) for GOA Dover sole from the preferred (base) model. Error bars are approximate lognormal 95% confidence intervals.

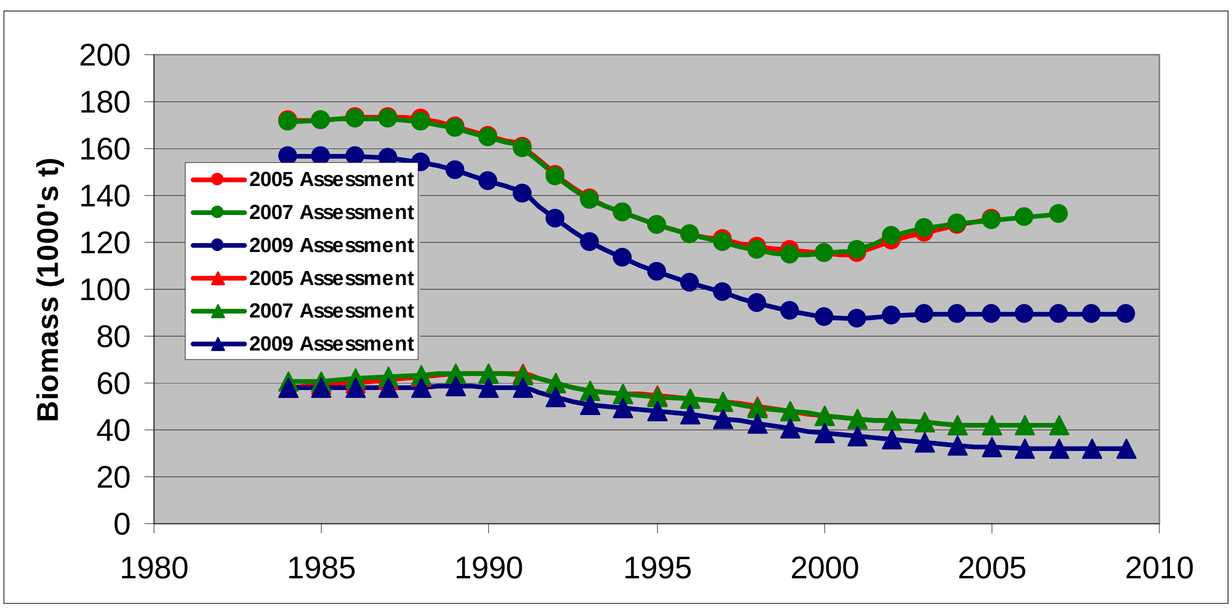


Figure 5.16b. Estimated age 3+ biomass (circles) and female spawning biomass (triangles) for GOA Dover sole for the current and two previous assessments.

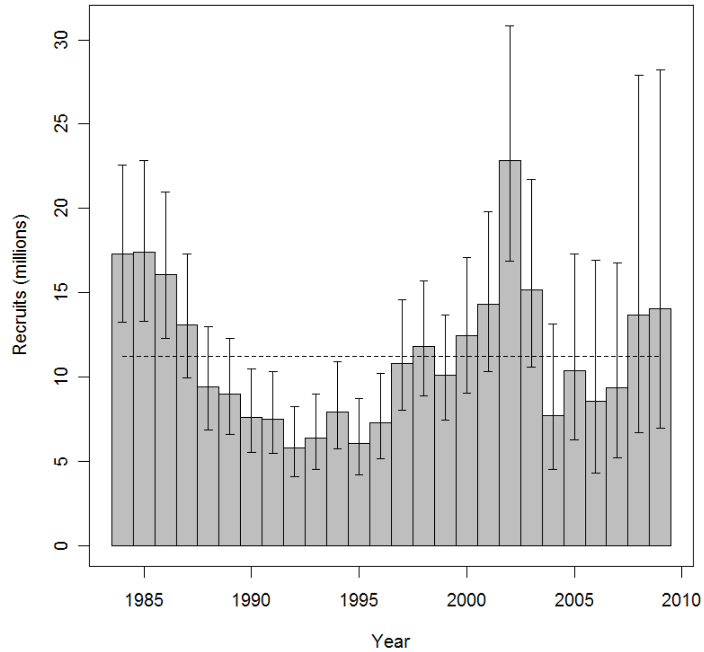


Figure 5.17a. Estimated age 3 recruitments of GOA Dover sole from the preferred (base) model, with approximate 95% lognormal confidence intervals. The horizontal line is mean recruitment (11.0 million individuals).

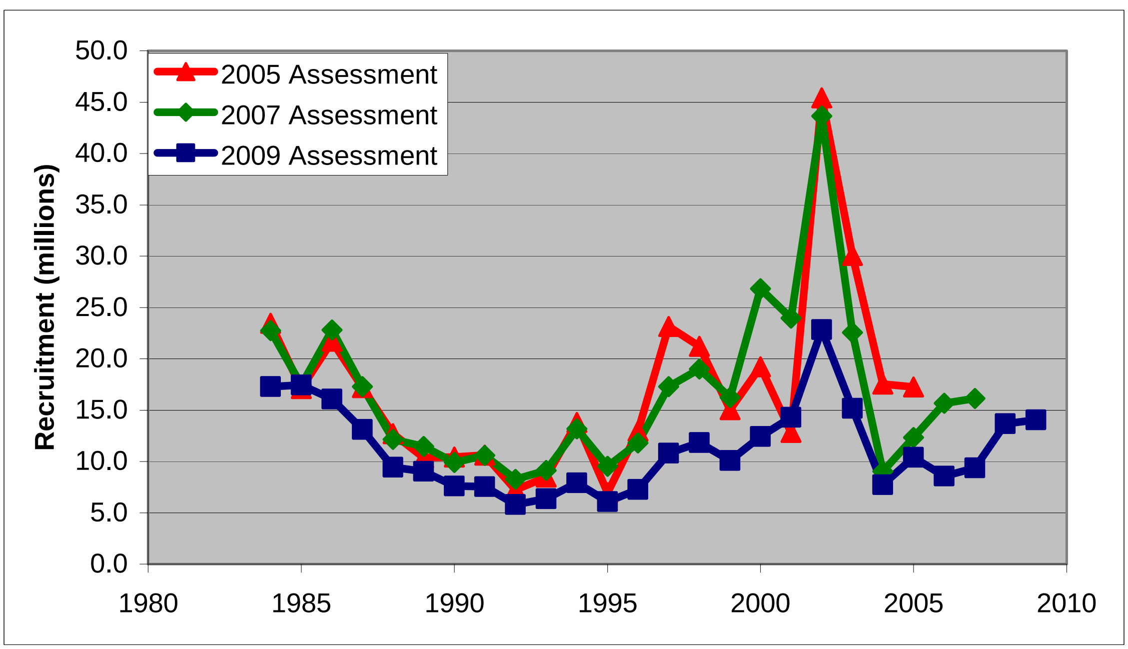


Figure 5.17b. Recruitment estimates for the current and previous two assessments.

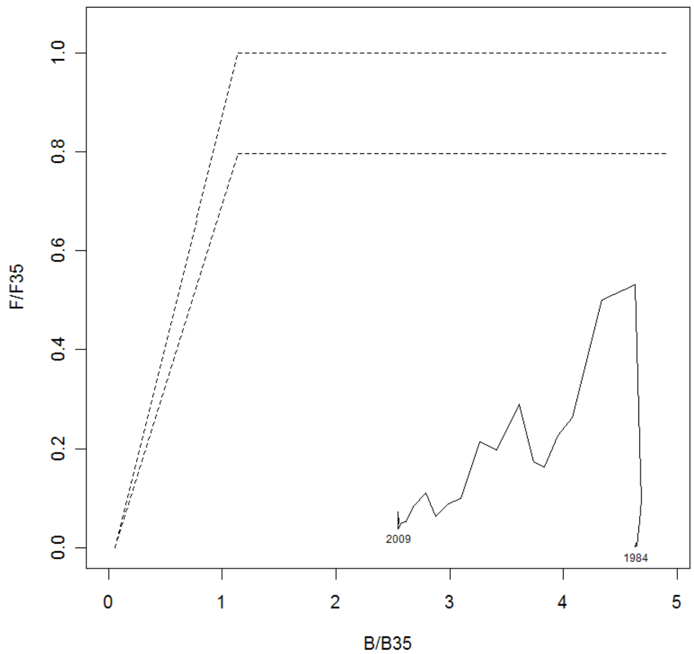


Figure 5.18. Control rule plot of estimated fishing mortality versus estimated female spawning biomass for GOA Dover sole from the preferred (base) model. F_{OFL} = solid line, $F_{max\ ABC}$ = dashed line.

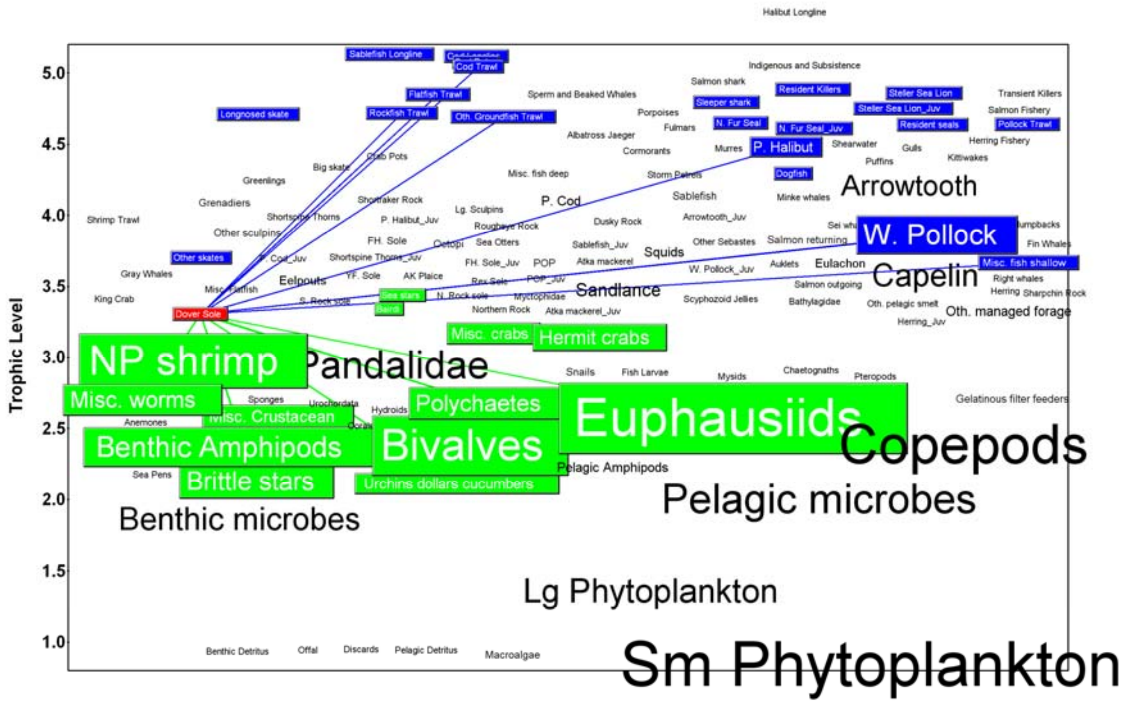


Figure 5.19. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., 2007) highlighting Dover sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

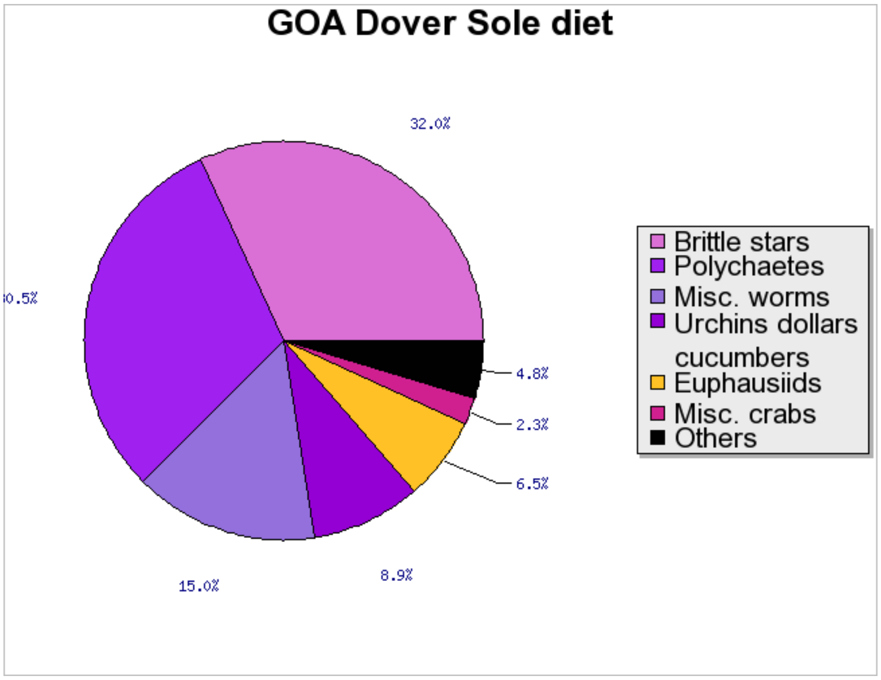


Figure 5.20. Diet composition for Gulf of Alaska Dover sole from the GOA ecosystem model (Aydin et al., 2007).

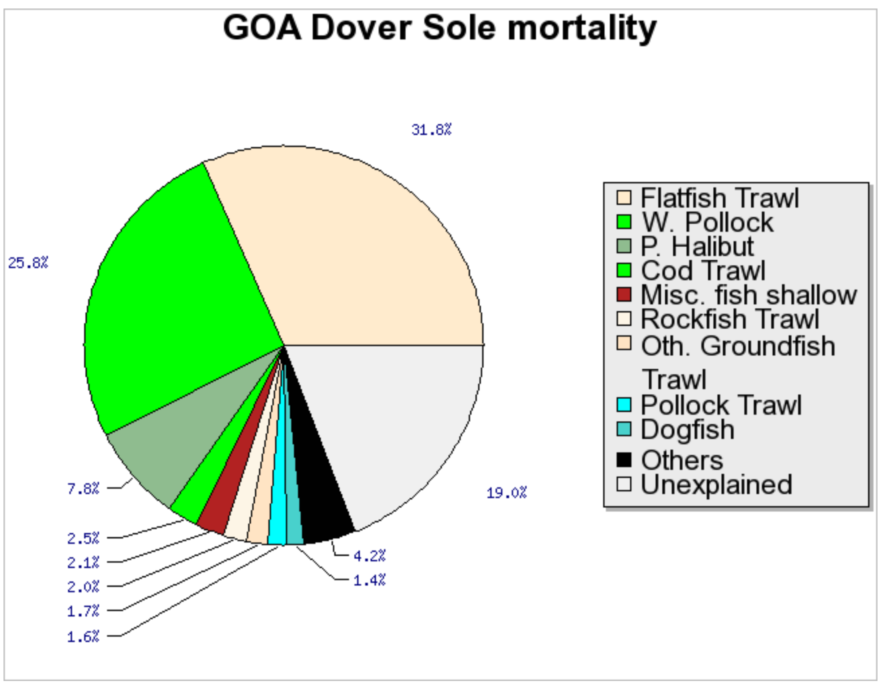


Figure 5.21. Decomposition of natural mortality for Gulf of Alaska Dover sole from the GOA ecosystem model (Aydin et al., 2007).

Appendix A.
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 (38).
L	number of length classes (28).
T_{min}	model start year (1984).
T_{max}	assessment year (2009).
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
$M_x = 0.085$	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 accepted model. A total of 103 parameters were estimated in the preferred model.

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	$T_{\min} - A + 1 \le t \le T_{\max}$	63	log-scale recruitment deviation in year *t*.
$\ln(f_0)$	NA	1	natural log of the geometric mean value of fishing mortality.
ε_t	$T_{\min} \le t \le T_{\max}$	26	log-scale deviations in fishing mortality rate in year *t*.
$r^F{}_2$	NA	not estimated	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	not estimated	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.

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